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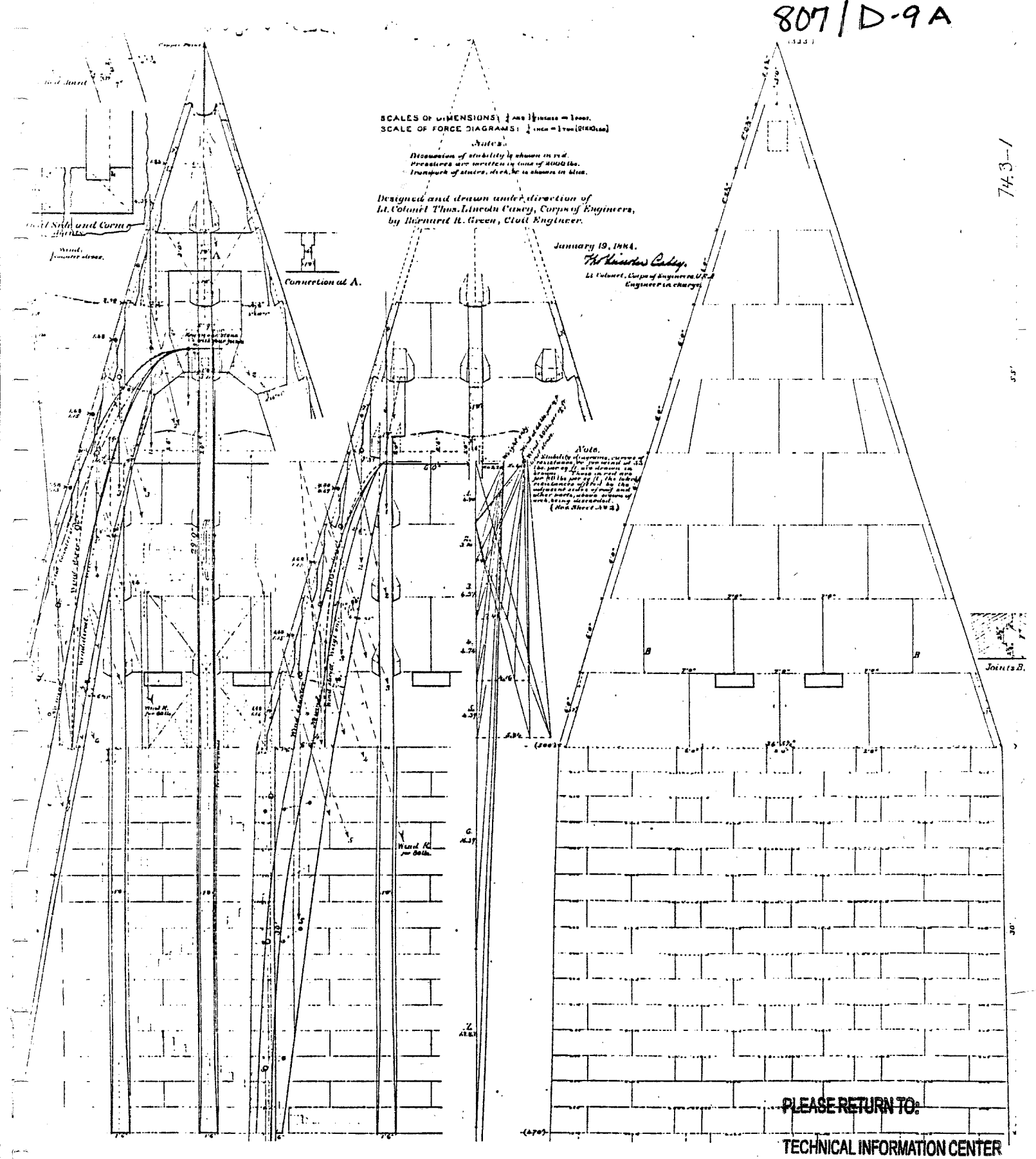

EVALUATION OF THE WASHINGTON MONUMENT

OEHRLEIN & ASSOCIATES ARCHITECTS

EVALUATION OF

THE WASHINGTON MONUMENT

WASHINGTON, DC

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I. INTRODUCTION

I. INTRODUCTION - SCOPE AND PURPOSE OF STUDY

The Washington Monument is the tallest and most visible monument in Washington, DC. It is a marble-faced obelisk 555'-5 1/8" tall, marking the center of the capital city. Its importance as a memorial, as a symbol of the City of Washington and as a feat of engineering is unsurpassed.

The purpose of this study is to provide a general evaluation of the condition of the Washington Monument and to make recommendations for conservation of the building fabric. While many reports have been made in recent years focusing on specific aspects of the Monument, an overall assessment of its condition is needed. This study will provide an understanding of the current condition of the Monument and will serve as a guide for further work and study.

The scope of work for this study requires that attention be paid to specific known problem areas. These areas include water infiltration problems in the Monument, structural evaluation of underground service areas, identification and recommendations for abatement of asbestos-containing materials and lead-based paint, the evaluation of the condition of stone, mortar, windows and sealants, and an evaluation of the settlement of the Monument. Topics not included in the scope of work are the site, the electrical system, the elevator, and finishes in the lobby and observation areas.

This study includes a review of past studies of the Monument, a review of work performed on the Monument, and a description of the construction of the Monument. The interior and exterior condition of the Monument was surveyed and a year-long program of monitoring the interior environmental conditions was conducted. Recommendations for conservation and maintenance were based on the results. Recommendations include future studies, future monitoring and a prioritized outline of work which should take place.

The study was prepared by David W. Amundson under the direction of Mary L. Oehrlein.

II. EXECUTIVE SUMMARY

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The Washington Monument has a number of problems which threaten its integrity and stability. The most urgent problems require immediate attention. The biggest of these are the water which leaks into the Monument and the cracks which have formed in the stone at the upper levels. The leaking water has caused many additional problems of building fabric deterioration which will require repair after the leaks have been stopped. There are also many less urgent problems which should eventually receive attention.

The most immediate problem is the great amount of water which leaks into the Monument. This water leaks in through the walls of the pyramidion and the shaft, by way of the joints and cracks in the masonry and openings in the walls of the pyramidion. This water has caused, and continues to cause, damage to the interior iron and steel frame, to the structural stone and to the memorial stones. All the masonry joints above the 450' level and all the cracks in the stone should be sealed with a double layer of backer rod and sealant. All the masonry joints below the 450' level should be pointed. Aircraft warning lights and observation windows should be sealed. When water does leak into the Monument, it should be mopped up immediately.

Damage caused by leaking water includes corroded iron and steel framing and deteriorated mortar joints on the interior of the Monument. Iron cramps and frames holding memorial stones have corroded and are causing damage to stone. These areas should be repaired once the leaks have been stopped. The interior walls of the Monument should be steam cleaned.

Chipped and spalled stones on the exterior of the Monument at the lower levels should be patched when the joints are being pointed. Existing mortar patches should be removed and stains on the stone should be cleaned. Cleaning of the exterior stone should occur only when necessary and should be done with a low-pressure steam cleaner.

Cracks have formed which go all the way through the stone at the upper levels of the Monument on the east and west elevations. These cracks formed recently but it is not known if they are continuing to grow. These cracks should be monitored, using linear displacement transducers on the interior and the exterior, along with instruments to measure stone temperature, wind velocity, building sway and other factors which might be the cause of the cracks. This monitoring should be done for a minimum of five years. Other cracks should be monitored visually.

Asbestos-containing materials and lead-based paint have been identified in locations throughout the Monument and in the underground service areas. Deteriorated asbestos-containing materials should be abated and asbestos-containing materials in good condition which are left in place should be

monitored and maintained. Any construction activity or paint removal should be preceded by a thorough survey of lead-based paint in the work area.

The heating, ventilating and air conditioning system in the Monument is effective in maintaining even temperatures in the Monument, although temperatures are often high for comfort levels during the summer months. Relative humidity levels in the Monument vary widely, however, and are often at 100%. The high relative humidity results in condensation on the stone and metal in the Monument. Shutdowns of the HVAC system occur frequently, causing even more severe conditions to occur. A comprehensive evaluation of the HVAC system should be conducted, and the system should be repaired and regularly maintained to prevent shutdowns and to ensure effective and efficient operation.

Deteriorated areas of the underground service areas to the west of the Monument should be repaired. The waterproofing on the roof and walls of the guard room has failed and should be replaced. Concrete beams over the areaway venting the mechanical room are badly deteriorated and should be repaired. Cracks in the concrete and deteriorating stucco at the stair areaway are not structural problems but should also be repaired.

The 1992 settlement survey indicates that the Monument is continuing to settle at a slow, even and predictable rate. This survey adds to the baseline of data on the settlement of the Monument which began in 1879. The Monument settlement should continue to be surveyed on a periodic basis.

Maintenance procedures at the Monument are haphazard and ineffective. Harsh cleaning chemicals and sloppy painting are causing damage. Maintenance should be directed and supervised so that it is effective in cleaning and painting where it is needed, and so that no damage is done in the process.

Information concerning the Monument is widely dispersed and much of it has been lost or destroyed. A central file should be established and managed to ensure that information is preserved and available to those working on the Monument.

III. CHRONOLOGY OF WORK AND REPORTS

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1836	August 10 - The Washington National Monument Society (WNMS) announces a design competition for a monument to George Washington, to be built in the City of Washington.[1] The winning design by architect Robert Mills includes a 100' high, 250' diameter colonnaded pantheon surrounding a 600' high obelisk.[2]
1848	April 11 - The WNMS begins construction on the obelisk part of Mills' design. The WNMS building committee is appointed to supervise the construction, with guidance from Mills.
	Spring - Excavation is begun for the obelisk foundation. The foundation of Potomac Valley blue gneiss is laid.
	July 4 - The cornerstone of the obelisk is laid.
	September - The foundation is completed to ground level (0' level). Construction of the shaft begins.
1854	The shaft is completed to the 156' level. The WNMS exhausts funds and construction is halted.
1859	Army Engineer Joseph C. Ives studies the Monument foundation and reports no signs of settling or insecurity.[3]
1860-1872	No construction activity takes place due to the lack of funds and the Civil War.
1873	Army Chief of Engineers William Louis Marshall studies the foundation and concurs with Ives' 1859 report that the foundation is stable.[4]
1874	April 20 - Marshall again studies the foundation, and reports that the foundation is secure, but that soil conditions will only support the weight of a 400' high obelisk.[5]
	May 1 - Congressional select committee on the Monument recommends a 437' high obelisk with a plaza in place of Mills' pantheon base.[6]

1874 August 7 - Army Board of Engineers for Fortifications evaluates the foundation, and reports that soils could not bear the load of even a 400' high obelisk.[7]

1876 August 2 - Congress appropriates $200,000 to complete construction of the Monument.

September 12 - The Joint Commission on the Construction of the Washington National Monument (JCCWNM) is organized to oversee construction.

November 22 - Ownership of the unfinished obelisk, the land and all materials, machinery and temporary structures owned by the WNMS is transferred to the U.S. Government.

1877 April 10 - The Corps of Engineers evaluates the foundation and reports that it is inadequate for the planned 437' high obelisk and that the soils have already compressed 8" to 9". They also report cracked, chipped and spalled marble blocks on the exterior of the shaft from poorly laid stone.[8]

October - The JCCWNM recommends to Congress that the foundation be strengthened.[9]

1878 June 14 - Congress appropriates $36,000 to strengthen the foundation.

Corps of Engineers Lieutenant Colonel Thomas Lincoln Casey is commissioned to supervise the completion of the Monument.

September 25 - Casey's plans to underpin and extend the surface of the base of the foundation and preliminary plans for completing the obelisk are accepted by the JCCWNM. Casey's plans call for a pyramidal roof of iron and glass.[10]

October - Casey is authorized by the JCCWNM to begin work on the underpinning of the foundation. Casey begins to organize materials, equipment and workers to restart construction.

1879 End of January - Work begins on underpinning the foundation.

February - U.S. Ambassador to Italy George Perkins Marsh recommends new proportions for the obelisk, based on Egyptian models. Casey follows Marsh's recommendations and redesigns the Monument to be monolithic in appearance and to have an acute point on the pyramidion.

February- Survey markers are installed at the four corners of the Monument, at 8 locations 23' out from the face of the Monument and at the top of an obelisk 121' south of the Monument, to monitor the Monument's settlement.

Mid-year - Work begins on the iron frame inside the Monument to support the stairs and the elevator.

1880 May - The foundation work is completed.

July - A new steam elevator to the 150' level is completed and approved. Work begins to remove the top 6' of the existing shaft. Weathered stone is taken off down to the 150' level.

August 7 - The top of the existing shaft is consolidated, the "second cornerstone" is laid at the 150' level and construction of the shaft resumes.

1884 August 9 - The final stone of the shaft is laid at the 500' level. Work begins on the pyramidion, redesigned to Marsh's proportions. It is to be built of marble to match the shaft.

December 6 - Casey sets the marble capstone and aluminum apex at the peak of the pyramidion. At completion it is the tallest building in the world.

December 18 - The iron framework is completed to the 517' level and the elevator can now go to the 500' landing. Casey reports condensation problems causing deterioration of stone below the 150' level.[11]

1885 January - Lightning protection system is installed.

February 21 - President Chester Arthur dedicates the Monument.

1885	December - Architraves are removed from both doorways, the west doorway is closed with a thin marble wall, the east doorway is reduced to an 8' high opening, and a pair of marble doors are installed.
1886	April - Metal stairs and handrails are completed to the 500' landing. Visitors are permitted to climb the stairs.
1887	January - Electric lighting is completed, illuminating the interior of the shaft. The lights are powered by a dynamo in the engine house south of the Monument.
	March - A contract is awarded to fill the lake to the north of the Monument, to pave the plaza around the base, and to slope the grade out for 350' to 450' from the base of the Monument.
1888	October 2 - The JCCWNM is dissolved and the Corps of Engineers is given responsibility for the Monument.
1889	The Eiffel Tower is completed in Paris, surpassing the Washington Monument as the world's tallest building. The Monument remains as the world's tallest load-bearing masonry structure.
1901	An electric elevator is installed, replacing the steam elevator.
1920's	Hinged iron bars are installed at the windows and diverter flashing is installed over the windows.
1926	June - A new electric elevator is installed.
1933	Congressional advisory committee issues a report on the soil conditions and the impact of constructing proposed terraces west of the Monument. The committee concludes that the existing foundation is stable, but that the proposed construction is a threat to the stability of the Monument.[12]
	August 10 - The National Park Service assumes control of the Monument.
1934	October - "Survey of Condition of Stones in Washington Monument." Drawings of the exterior elevations call for the replacement of 166 stones, cutting and pointing cracks at 476 stones, and placing dutchmen at 35 stones.[13]

1934	"Report on Repairs to Washington Monument." This WPA project reports on the problems which are apparent in the Masonry. The biggest problems are the spalling of the marble, especially below the 150' level, leaking masonry joints, generally dirty masonry and condensation on the interior walls. They recommend replacing spalled stone, especially below the 50' level, repointing the joints to make it waterproof, washing the entire exterior, and heating the interior to prevent condensation.[14]
1934-35	The lightning protection system is replaced.[15]
1937	Temporary flags on wooden staffs are installed surrounding the Monument.
1940-1941	A new mechanical system is installed, using forced air heated by steam supplied through a tunnel from the Justice Department.[16] The system is completed in February, 1941. The stairs are repaired. Channels supporting landings at the walls and stair carriage angles at the walls are reinforced with brackets bolted to the walls.[17]
1946	A proposal is made to resurface the face of the Monument with a 5" granite veneer.[18]
1957	April 29 - Kluckhuhn, Cobb and McDavid, The Washington Monument: Preliminary Analysis and Report for New Floodlighting and Electrical Services: Evaluation of the heating system notes stratification of heat in the shaft, and humidity problems inside the shaft due to the leakage of water through the walls above the 400' level. The report recommends exterior waterproofing, renovation of the heating system, and the installation of an exterior floodlighting system. December 6 - Kluckhuhn, Cobb and McDavid, Engineering Consultants, et al, The Washington Monument: Preliminary Analysis and Report for Modernization of Elevator and Associated Facilities: This study recommends major renovations to the elevator system and the addition of a new landing at the 490' landing for loading passengers. August 21 - Josephine Allen, NPS archivist, photographs memorial stones in the Monument and inventories their conditions.

1958 February 11 - Kluckhuhn, Cobb and McDavid, The Washington Monument: Addendum to Preliminary Analysis and Report for Modernization of Elevator and Associated Facilities: This addendum includes a cost estimate and minor revisions to the 1957 report.

Aircraft warning lights are installed, two on each side of the pyramidion, at the 516' level. A special platform is constructed on the outside of the pyramidion to support the workers cutting the 14" diameter holes and installing the frames and glazing.[19]

1959 A new elevator is installed, following the recommendations in the 1957 report. A new landing for the elevator at the 490' landing is constructed. New stairs are constructed in the northeast and southeast corners between the 490' landing and 500' landing, and on the south side between the 490' landing and 480' landing. New floodlights are installed to illuminate the exterior of the Monument.

Temporary wooden flagpoles are removed and 50 aluminum flagpoles 24' high are constructed in a circular colonnade surrounding the Monument.

1959 National Bureau of Standards, Report of Acceptance Test, Washington Monument Elevator: Description of the new elevator and the evaluation of its inspection and testing.

1961 Iron bars are removed from over the windows and the 8 windows are glazed with safety glass.

1964 New rigging designed and built which hangs work platforms on each face of the Monument from 1" diameter cables suspended at the 500' level.[20]

1964 All exterior stonework is cleaned, raked and pointed, expansion joints are inserted, stone is repaired and replaced, and interior metal is cleaned and repaired.[21]

1971 June - Climbing the stairs to the top of the Monument is no longer permitted, walk-down tours are conducted on a limited basis.

1973

Robinson Engineering, Washington Monument: Interior Structural & Mechanical Analysis: This report deals with a wide range of issues regarding the Monument. The condition of the metal structure supporting the stairs and elevator is surveyed landing by landing, and the extensive corrosion of the structure is described. Recommendations are made for repair, cleaning and repainting the metal structure and for refinishing the surfaces of the stairs and landings. The heating system is described and evaluated, and renovations to the system are recommended to alleviate problems of temperature stratification and condensation. Outline specifications recommend a new electrical system, sandblast cleaning and coating with a silicone sealer for all the interior masonry except the memorial stones, cleaning but no repair to the memorial stones, and stopping the abrasive wheel cleaning of masonry which they observed at the upper levels of the Monument. Cost estimates are provided for all recommendations.

September 20 - Hartman-Cox Architects, Visitor Facility for the Washington Monument: Comprehensive Design Program & Engineering Feasibility Report: This feasibility and design study proposes an underground visitor facility on the Monument grounds and a comprehensive plan for the area around the Monument.

Mueser Rutledge Wentworth & Johnston, Subsurface Investigation and Foundation Study for Interpretive Facility at the Washington Monument: This engineering study, in support of the Hartman-Cox report, investigates existing and historic conditions of the Monument foundation and bearing soils, and concludes that an underground visitor facility could be constructed following certain restrictions.

1974

Robinson Engineering, Drawings for "Washington Monument: Interior Structural & Mechanical Improvements": Work described in construction drawings includes new windows at the observation level, cleaning of all interior stone, pointing of interior masonry joints from the 470' level to the 500' level, pointing of exterior joints from the 470' level to apex, complete renovation of the HVAC system, installation of a new ramp at the entry (eliminating the entry step), and repairs to the stairs and landings. Repairs to the stairs and landings include replacement of some metal framing members, replacement of some landing platforms,

resurfacing of all landings and steps, and cleaning and repainting of all existing metal framing.[22]

1975

Rigid clear plastic panels are mounted to the surface of the interior walls to protect the stone from visitors' graffiti at the 500' and 490' landings.[23]

Interior stone shutters are removed from the observation windows.[24]

Exterior masonry joints are repointed from the 470' level to the capstone and joints every 20' are caulked with polysulfide sealant.[25]

1976-1977

Exterior masonry joints are repointed from the 0' level to the 470' level, and joints every 20' are caulked with polysulfide sealant.[26]

1978-1979

Memorial stones in the Monument are cleaned and repaired by Constantine Seferlis. 192 stones are cleaned and 17 stones are scheduled for restoration.[27]

1980

Architects Group Practice, Environmental Assessment: Improvements to the Washington Monument, 500 Foot Level: This study investigates design options for providing accessibility to the observation windows by wheelchair-bound visitors. The report favors enlarging the windows to provide a favorable viewing angle from a wheelchair.

Donald C. Pfanz (NPS), prepares National Register of Historic Places Inventory Nomination Form, Documentation of Existing National Register Property.

1981

September - National Capital Parks-Central, Development Concept Plan and Alternatives: Washington Monument Grounds: Design study proposes redesign of the plaza around the Monument with low walls and trees, the removal of the Memorial Lodge, and a reconfiguration of the paths and roads leading to and around the Monument.

1984

Mara Koeppel, Park Technician for Mall Operations, letter to Heather Hite, National Capital Parks, Central: Dehumidifiers and fans are installed at the observation level, and they prove to be effective in moderating the heat.

1984

Mueser, Rutledge, Johnston & DeSimone. Settlement Analysis for Washington Monument Grounds Improvement: This report concludes that the settlement of the Monument is within allowable and expected limits, and that planned earthwork in the nearby vicinity will not disturb the stability of the Monument.

1985

George Sexton Associates, et al, Proposed Lighting Design: Study for exterior lighting design.[28]

NPS Job Order Requests specify graffiti removal using poultice at the 500' level, northwest corner and at the exterior, southwest corner.

1989

National Park Service, Denver Service Center, Development Concept Plan, Washington Monument Grounds: This revision to the 1981 design study proposes a design for the Monument plaza without trees, the restoration of the Memorial Lodge, and other changes to the surrounding areas.

1991

April - Notter, Finegold + Alexander, Inc., Washington Monument: Proposed Renovation of Entry Level Lobby: This design study proposes the restoration of the high ceilings in the lobby, new bronze door surrounds at the elevator, and the restoration of damaged and missing historic fabric.

1992

August - Four fans are installed above the 500' landing to circulate air at the observation level.

Notes

1. Resolution of 6 July 1836 by the Board of Managers, Washington National Monument Society, Records of the Washington National Monument Society, Records of the Office of Public Buildings and Grounds, Record Group 42, National Archives (hereafter cited as RG 42, NA), cited in Louis Torres, "To The Immortal Name and Memory of George Washington": The United States Army Corps of Engineers and the Construction of the Washington Monument (Washington, DC: US Government Printing Office), 1985, Chapter 2, Note 10, This is the basic source for the chronology of general historic events.

2. Torres, p. 11.

3. Extract of a report of Lt. J.C. Ivs, 10 August 1859, H. Rept. 48, pp. 3-4, cited in Torres, Chapter 3, Note 12.

4. Lt. Marshall's Report, 19 February 1873, Foundation of the Washington National Monument (Washington: The Joint Commission, 1877), p. 4; also printed in H. Rept. 79 (hereafter referred to as Foundation), cited in Torres, Chapter 4, Note 5.

5. Report of Lt. Marshall to Gen. Humphreys, 10 April 1874, H. Rept. 485, cited in Torres, Chapter 4, Note 10.

6. H. Rept. 485; Speech of Hon. John B. Storm, 4 June 1874, in the House of Representatives, Washington National Monument: Shall the Unfinished Obelisk Stand a Monument of National Disgrace and National Dishonor (Washington: Government Printing Office, 1874), pp. 14-15, cited in Torres, Chapter 4, Note 11.

7. Board of Engineers to Humphreys, 7 August 1874, Foundation, pp. 22-24, cited in Torres, Chapter 4, Note 16.

8. Report of the Board of Engineers, 10 April 1877, Foundation, pp. 26-38, cited in Torres, Chapter 4, Note 25.

9. Duane and Gillmore to JCWNM, 17 October 77, H. Exec. Doc. 1, cited in Torres, Chapter 4, Note 34.

10. National Archives and Records Service, records of the Office of Public Buildings and Grounds, records of the Washington National Monument Society, 1833- 1951, Record Group 42 and 79. These Record Groups contain operational reports, correspondence, contracts and drawings concerning the construction of the Monument. Drawings include plans, sections, elevations, working drawings and other documentation for the design and construction of the Monument.

11. Casey to Newton, 8 April 1885, Letters Sent, Vol. IV, RG 42, NA, cited in Torres, Chapter 6, Note 15.

12. "Improvements of the Washington Monument Grounds," U.S. Congress, House, H. Doc. 528, 72nd Cong., 2d sess., 1933, cited in Torres, Chapter 7, Note 57.

13. Drawing from NCP 74.2-212, RG 79, NA, Cartographic Branch.

14. Work Progress Administration, Work on Repairs to Washington Monument", US Department of the Interior, Office of National Parks, Buildings and Reservations, Work Progress Administration Federal Project 365, March 7, 1934.

15. Drawings from NCP 74.23-25, RG 79, NA, Cartographic Branch.

16. NPS drawings 80078; 74.25.1 through 74.25.5.

17. See Robinson Engineering, Washington Monument: Interior Structural & Mechanical Analysis, 1973 for description.

18. "Sketch showing method of resurfacing the Washington Monument...", (1946: NPS drawing file number 807/800 85).

19. Newspaper clipping in looseleaf binder titled "Trivia and Clippings on the Washington Monument", 1927-1959, located at the Survey Lodge on the Monument grounds.

20. Drawing NCR 74-175.

21. Specifications available at National Park Service, National Capital Region.

22. NPS Drawing 807/41,0001, on microfilm at National Park Service, Denver Service Center, Falls Church, VA. Construction documents including as-builts.

23. Donald C. Pfanz, National Register of Historic Places Nomination Form for The Washington Monument, December 2, 1980.

24. Ibid.

25. "Masonry Pointing and Repair, Washington Monument Exterior, Washington, DC," IFB-3-6-125, National Park Service Specifications.

26. "Masonry Pointing and Repair, Washington Monument Exterior, Washington, DC," IFB-3-6-125, National Park Service Specifications.

27. National Park Service, National Capital Region, "Terms of Agreement Regarding Cleaning and Repair of Commemorative Stones in the Washington Monument," May 1978, and attachments.

28. On microfilm at National Park Service, Denver Service Center, Falls Church, VA.

IV. DESCRIPTION OF THE CONSTRUCTION

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General

The Washington Monument is the world's tallest load-bearing masonry structure. It stands 555'-5 1/8" tall above ground level and weighs an estimated 81,120 tons[1]. The masonry structure of the Monument is made up of three parts; the foundation, the shaft and the pyramidion. Inside the shaft an iron and steel frame supports the stairs, landings and elevator shaft. The interior walls of the shaft have 193 memorial stones mounted into the walls. A set of concrete stairs to the west of the Monument leads to an underground service area. The underground service area contains a mechanical room and a locker room and rest room for the Monument staff.

Foundation

The original excavation and construction of the foundation took place in 1848 (see diagram of the completed foundation - Figure 1). The original foundation was made up of blocks of blue gneiss stone, quarried in the Potomac Valley, dovetailed together and bonded with a mortar of hydraulic cement, stone, lime and sand. The Monument architect Robert Mills called for the foundation stones to be a minimum of 4' square and 9"-12" thick. The 80' by 80' base of the original foundation stepped in over its 23'-4" height to support the 55'-1 1/2" square obelisk shaft. This foundation supported the construction of the shaft to the 156' level, where construction stopped in 1854.

Before work resumed on the shaft in 1880 extensive underpinning and buttressing of the foundation was completed. Lieutenant Colonel Thomas Lincoln Casey of the Army Corps of Engineers was given control of the Monument project, and he began by estimating the weight of the planned obelisk and evaluating the ability of the foundation to carry that weight. He concluded that the foundation as it existed was not adequate to support the load of the planned obelisk, and he observed that the shaft was already leaning 1 3/4" to the north. Work began in January, 1879 to enlarge and strengthen the original foundation. Working 4' wide sections at a time, existing masonry and soil were excavated, concrete was placed underneath the original foundation and concrete buttresses were built up on the sides. The 1 3/4" lean was eliminated by careful redistribution of the loads. The new concrete foundation added an additional 13'-6" to the original 23'-4" depth of the foundation, and broadened the footprint of the foundation from an 80' square to a 126'-5 1/2" square. When completed, the bottom of the foundation was at the high groundwater level, resting on a stratum of silty sand and gravel. The water table in the vicinity has lowered since that time, largely as a result of construction activity in the late 1960's and the 1970's.

Foundation (cont'd)

Today the bottom of the foundation is 10'-15' above the high groundwater level.[2]

Shaft

The shaft of the Monument is a load-bearing masonry structure rising 500'-5 1/8" from the ground (0' level) to the base of the pyramidion (see section of the shaft and pyramidion - Figure 2). The exterior walls of the shaft are battered at .247" per foot and are made up of dressed marble blocks in 2' high courses. The interior walls rise vertically to the 150' level, where they slope out to the 160' level and then continue vertically to the 500' level. Pockets in the interior walls carry metal beams which support the floor, stair and landing framing system.

At the bottom the shaft is 55'-1 1/2" square, with 15' thick walls and a 25'-1" square space on the inside. The exterior face of the lower part of the shaft is ashlar cut and coursed marble, laid in a random pattern with headers every 2 or 3 stretchers. The marble at this lower part of the shaft is a white crystalline metalimestone from Baltimore County, Maryland known as "Texas" marble[3] The interior face of the shaft is constructed of random blocks of cut gneiss. Between the two faces is stone rubble fill.

The bottom section of the obelisk shaft was completed to the 156' level by 1854. Later work removed the top 6' before restarting construction. The first phase of construction now makes up the bottom 150' of the shaft. The distinction between the old and the new construction is clearly visible on the exterior. The marble above the 150' level is distinctly darker than the marble below, and in addition to being darker, the first 6 courses above the 150' level contains dark brown streaks.

Although the change in the color of the marble on the exterior at the 150' level of the Monument is clearly visible, it is unclear which sources were used for the different levels of construction above this level. The histories of the Monument agree that "Texas" marble was used for all of the exterior below 150', and that only Cockeysville marble was used above the 176' level. While the histories agree that marble from quarries in Sheffield, Massachusetts, Lee, Massachusetts and Cockeysville, Maryland were used after resuming construction at the 150' level, they disagree about which marble was used where between the 150' level and the 176' level.[4]

When construction was resumed in 1880 and the top 6' of the existing shaft was removed, the masonry was consolidated with hydraulic cement concrete at the 150' level (see plan of masonry at 150' level - Figure 3). The new construction from the 150' level to the 160' level makes a transition to

Shaft (cont'd)

thinner walls and a wider interior space in the shaft. The size of the interior space widens with sloping walls, from 25'-1" to 31'-5 1/2" in the course of this 10' rise in height. Maine ashlar granite makes up the bulk of the wall's mass in this part of the Monument, with ashlar marble alternating headers and stretchers on the exterior, and a 4" granite veneer facing the interior (see Figure 4).

Between the 160' level to the 216' level the exterior of the shaft was constructed with coursed ashlar marble, alternating headers and stretchers, and coursed Maine granite at the interior. The walls at these levels are 2 to 4 stones thick (see Figures 5 and 6 for plans at the 160' level and the 162' level). From the 216' level to the 452' level the same materials are used, but the marble headers extend through the wall to the interior face (see Figures 7 and 8 for plans at the 262' and 264' levels). Galvanized iron cramps are used to anchor the stone between the 440' level and the 452' level[5].

Between the 452' level and the top of the shaft at the 500' level the walls are constructed of a solid single thickness of ashlar marble (see Figure 9 for plan at 498' level). Above the 470' level the stones have tenons mortised into the course below. At the 500' level of the shaft, at the top where it is thinnest, the wall is 1'-6" thick (see plan at the 500' level -Figure 10).

Between the 470' level and the 500' level twelve stone ribs which support the pyramidion project from each of the interior walls (see section on the pyramidion, below, for a complete description of these ribs). Every second course of these ribs penetrates through the wall to the exterior. These stones are visible on each elevation of the exterior as three vertical rows of headers.

The original construction of the Monument included Egyptian-style frames and pediments at 18'-6" high doorways on both the the east and west faces of the Monument. In December of 1885 frames and pediments on both doors of the Monument were removed. The west doorway was closed off with a thin marble wall and the opening to the east doorway was lowered from the original 16'-8" height to 8' by filling in the opening with marble. Stone doors of matching marble were added to the east doorway so that when they were closed the Monument would appear monolithic. These doors are now fixed in an open position and are embedded in the paving which was added when the ramp was built at the entry in 1976. The odd coursing of the stone up to the 22' level at the middle of the east and west walls of the Monument are the result of the removal of the frames and pediments and the closing of these openings (see Photo 1).

Pyramidion

The pyramidion rises 55'-0" from the top of the shaft walls to the apex of the Monument (see diagram of pyramidion - Figure 11). The structure of the pyramidion is entirely of stone and weighs an estimated 300 tons.[6] It is made up of twelve ribs which rise from the walls of the shaft, 7" thick stone walls which rest on the ribs, and a capstone.

The twelve ribs project in and up from the walls of the shaft, springing from the 470' level. Two pairs of center ribs slope inward forming arches, connected at their crossing with a cross-shaped keystone approximately 30' above the 500' level landing. Two additional courses of stone continue above the crossing of the four center ribs.

Each of the 4 center ribs is flanked by 2 side ribs. These eight side ribs also slope inward, and are connected together by a frame of stone lintels, approximately 23' above the 500' level observation landing. One additional course of stone continues above the frame connecting the side ribs.

The sloped walls of the pyramidion are constructed of 262 white marble stones, 7" thick. These stones which make up the walls of the pyramidion are laid in 4' high courses. The bottom edge of the bottom course of the pyramidion wall is rabbeted into a slot at the top of the shaft at the 500' level, and the tops of the stones rest against the ribs. Subsequent courses of wall stones lay on the ribs, overlapping and securing the top of the course below. The stones of the ribs have pointed corners which form a sawtooth pattern. These sawtooth points key into projections in the wall stones (see pyramidion joint details - Figure 12).

The joints at the hips of the pyramidion are rabbeted, with the joints exposed on alternating sides. Vertical joints on the faces of the walls are tongue and groove, either square or triangular. Horizontal joints between wall slabs are rabbeted, with the inside half of the joints perpendicular to the slope of the wall and the outside half of the joints parallel to the ground plane. The top course of the pyramidion wall is made up of one marble slab on each face, with the bottom edges lapped over the top edge of the course below on all four sides. The joints between the stones in the pyramidion do not provide a lot of depth to keep out water, as can be seen in Figure 12. At the joint where two wall stones and the point of a rib stone intersect (indicated "General Connection of Covering with Voussoirs" in Figure 12), there is only a 3 1/2" deep horizontal joint to keep out the water.

The capstone is a single pyramidal block of marble 5'-2" high, and weighing 3300 pounds (Figure 11 shows the capstone as built). The top edge of the wall slabs below are rabbeted into the bottom of the capstone. At the apex of the capstone is a pyramidal block of solid aluminum 8 7/8" high.

Pyramidion (cont'd)

The eight windows in the pyramidion were originally unglazed. During the 1920's hinged iron bars covered the openings to prevent suicide leaps, and diverter flashing was installed over the openings to keep water from running in. Stone shutters, installed soon after the Monument was completed, closed flush with the pyramidion wall to create a monolithic appearance. In 1961 the iron bars were removed and glass windows were installed. In 1974 they were replaced with aluminum framed windows with lockable top hinges and glazed with 3/4" bullet-resistant glass. The tops of the windows project from the faces of the pyramidion 7 1/4". Each of the windows on the north, south and west are 3'-0" wide by 1'-6" high, and the two windows on the east are 3'-0" wide by 2'-0" high. The stone shutters were removed in 1975.

In 1958 two 14" diameter round openings were cut into each wall of the pyramidion at the 516' level for aircraft warning lights. A special steel work platform was built to do this work. It was attached to the iron columns of the elevator shaft and projected out the window openings. The aircraft warning lights are made up of frames which are sealed into the round openings and glazed with safety glass which is flush with the outside wall of the pyramidion. Lights are mounted on the interior of the pyramidion which flash out the openings.

Iron and Steel Stairs, Landings and Elevator Shaft

The iron framework supporting the stairs, landings and elevator shaft was built beginning in 1879, while the underpinning of the foundation was taking place. The iron frame supported the construction elevator, and continued to rise above the masonry shaft as the stones were laid. Repairs to the framing system in 1940, 1959 and 1974 mixed in steel members with the original wrought iron of the framing system.[7]

Eight iron "Phoenix" columns form two squares inside the masonry shaft, with the inner square supporting the elevator, and the outer square supporting the stairs and the landings (See typical framing plans - Figures 13 and 14). Nine inch deep "I" beams span between the columns and between pockets in the stone walls of the shaft and the columns, supporting the stairs and landings and bracing the iron columns. Nine inch channels run against the interior walls and rest in pockets in the corners of the masonry, supporting the edges of the landings against the walls. Smaller framing members span between the beams and channels to support the landing decks.

Iron and Steel Stairs, Landings and Elevator Shaft (cont'd)

The numbering system for the landings below the 500' level is based on the height of the course on which the framing for the landing is resting. The bottom of the framing is resting at the designated level and the top of the landing is about 11" higher. For example, the framing for the 260' level landing is resting on the course of stone with its top at the 260' level and the top of the landing is at the 260'-11" level.

In 1940 clip angles were added below the channels of the stair stringers and below the channels supporting the landings. In 1959 the construction of a new elevator prompted a reconfiguration of the stairs and landings at the 490' and 500' level to make loading and unloading the elevator easier. These changes included adding new framing to enlarge the landing at the 490' level, adding new stairs in the northeast and southeast corners between the 500' landing and the 490' landing, and adding a new stair between the 490' landing and the 480' landing. All of this work was framed in steel.

Extensive work was done on the interior frame during 1974 renovations to the Monument interior. Parts of the frame were repaired or replaced with steel, and all the metal was sandblasted and repainted. A synthetic terrazzo floor surface of resin and aggregate was installed on all the stairs and landings and abrasive nosings were installed at all the stairs.

Memorial Stones

193 memorial stones were mounted into the face of the interior walls of the Monument beginning in 1849 and continuing until recent years. The lowest is at the 30' landing and, except for the State of Alaska stone installed at the 455' level in 1982, all the memorial stones are below the 400' level. With the exception of the Building Committee stone on the south wall at the 80' level, all of the stones are on either the east or the west walls of the Monument above the landings.

Efforts were made to restrict the size of memorial stones to two feet high by six feet wide and six inches thick, but the restrictions were not enforced and the stones range widely in size. In 1878 standards were established for the method of attachment of the memorial stones to the walls, using bronze expansion bolts and ornamental nuts. These standards were also disregarded, and the memorial stones were typically attached with iron wedges and cramps, lead spacers and cement mortar (see Figure 15).

Lightning Protection

The original lightning protection system was installed soon after the Monument was topped out. The system was replaced in 1935 with a series of rods mounted to the apex and attached to cables which ran down the hips of the pyramidion (see Figure 16). A metal rod runs from the aluminum apex through the capstone and grounds the system with cable to the iron columns of the elevator shaft.

Underground Service Area

Directly to the west of the Monument is a set of exterior stairs leading down to an underground service area (see plan, Figure 17). This area is not visited by the public. The underground service area was originally built as an engine room for the original steam elevator. It is not known when it was converted for use as a mechanical room and guard room, but it can be assumed that a mechanical room was in this location by the time the steam heat system was installed in 1940.

The stairs and the walls on the sides of the stairs are concrete, and the walls at the landing at the bottom of the stairs are brick covered with a layer of stucco. A door straight ahead leads to the guard room, containing lockers and a bathroom for the use of Monument personnel. The floor and ceiling of this space is concrete, and the walls are covered with ceramic tile. The ceiling is exposed concrete with fluorescent light fixtures and piping and ductwork below.

The door to the left at the bottom of the stair leads to a mechanical room. This space contains equipment for the HVAC system in the Monument. All the wall, floor and ceiling surfaces in this space are concrete. Metal louvers covering openings to the stairs to the north and openings to an areaway to the south ventilate the mechanical room.

Heating, Ventilating and Air Conditioning System

The heating, ventilating and air conditioning (HVAC) system supplies conditioned air to the Monument from an air handling unit at the 10' level. Coolant is supplied to the air handling unit from refrigerant compressors in the underground service area mechanical room and condensors in an underground vault to the northwest of the Monument. A single 28" diameter duct runs from the air handling unit to above the 500' level, with air outlets at the 131', 211', 251', 291', 331', 371', 411', 431', 451', 461' and 479' levels. Below the 490' level the 28" duct splits into three smaller ducts which supply air to the public areas through two registers at the 490' level and through 12 registers above the 500' level. A 12" by 12" duct

from the air handling unit supplies air to three diffusers in the ceiling above the elevator waiting area at the 0' level. Return air to the air handling unit is through a 12" by 96" manual volume damper at the bottom of the unit, and outside air is brought into the system through an 18" by 66" grille in the ceiling between the entry gate and the entry door. Air exhausts from the Monument through the entry door and through the tunnel between the elevator pit and the underground service area mechanical room.

In cold weather supplemental heat is provided by thermostatically-controlled unit heaters which operate on steam supplied through a high-pressure main from a remote central steam plant. Unit heaters are located at the 170', 210', 250', 330', 400', and 440' levels in the shaft, and a total of 6 are located at the 490' and 500' levels. Both electric and steam duct heaters are also used.

The HVAC system for the guard room in the underground service area is supplied by a separate air handling unit in the underground service area mechanical room. Two supply grilles suply air to the guard room and an exhaust fan in the toilet room removes air from the space.

Four 24" diameter fans were installed above the 500' level in July, 1992 to improve air circulation in the public spaces. These fans were installed on metal frames which are bolted to the stone ribs at the corners and to iron columns at the corners of the elevator enclosure. 24" diameter fans on floor stands are also used to circulate air at the 500' level and at the 0' level in the waiting area for the elevator.

Notes

1. Frank Friedel, George Washington: Man and Monument (Washington, DC: Washington National Monument Association, 1965, reprinted 1988), p. 46.

2. For a detailed description and analysis of the soil conditions at the Monument, see Mueser, Rutledge, Johnston & DeSimone Consulting Engineers, Settlement Analysis for Washington Monument Grounds Improvement, NPS: D18 (NCR-NACC) (XF54), Prepared for National Park Service, National Capital Parks-Central, February 13, 1984.

3. Charles F. Withington, Building Stones of our Nation's Capital (Washington, DC: US Department of the Interior Geological Survey, 1975), p. 4.

4. Torres, p. 63; Society of American Military Engineers, The Washington Monument, second edition (Washington, D.C.: Society of American Military Engineers, 1929), p.16; Withington, p. 15.

5. Torres, p. 78.

6. Ibid., p. 85.

7. See Robinson Engineering, Interior Structural and Mechanical Analysis, 1973 for a detailed description of the iron and steel framing system.

V. EXISTING CONDITIONS

V. *EXISTING CONDITIONS AT THE WASHINGTON MONUMENT*

The following description of the existing conditions at the Washington Monument is based on visual observations and on the interior conditions monitoring program which began in October, 1991.

The scope of work calls for particular attention to be paid to problem areas. The areas which require particular attention include water leaking into the interior of the Monument and the deterioration which it is causing, the masonry, the interior framing system, the memorial stones, the underground service area, interior environmental conditions and the performance of the HVAC system.

The only equipment used to aid direct visual observation of the Monument conditions was a flashlight used to illuminate dark areas of the interior and 10 x 25 binoculars to view the exterior.

The 7-day cycle of changing the recording graphs on the monitoring instruments required a weekly walk-down of the stair hall in the Monument. This meant that the Monument was surveyed on a regular schedule through the year, providing information on the building's conditions during different climatic conditions and during different visitor loads. It also meant that we were able to observe the cycles of maintenance and other activities which took place at the Monument.

The Monument's great height makes it difficult to survey the exterior masonry above the 200' level. Using 10 x 25 binoculars we were able to get a reasonably clear view of the bottom part of the shaft, but it is difficult to make a thorough survey of the masonry of the upper parts of the Monument from the ground. Large cracks in the stone are visible at the upper levels using binoculars, but it is not possible to assess the weathering of the stone or the condition of the joints. Our general assessment of the condition of the Monument was based largely on what was visible in the bottom 200' of the shaft.

Cracks in Stone

Vertical cracks are visible on the Monument on all four exterior elevations and in the interior (see exterior crack survey - Figures 18-21, and interior crack survey, Figures 22-25). These cracks fall into two categories; lower level cracks which are between the 160' level and the 234' level, and upper level cracks which are above the 450' level. The lower cracks are longer and more numerous than those at the upper level, but it is the upper level cracks which are most alarming.

The patterns of the lower level cracks on the east and west elevations are similar. On the east elevation there are three cracks which run vertically near the centerline of the wall. The bottom crack runs from the 168' level

Cracks in Stone (cont'd)

to the 186' level, the middle crack runs from the 186' level to the 198' level, and the top crack runs from the 198' level to the 226' level. In addition to these long cracks, there are additional small cracks at the south corner of the east elevation, between the 214' and 222' levels and between the 284' and 310' levels.

The pattern of the cracks on the lower level of the west elevation is similar, with the cracks mainly along the centerline of the wall. A single crack with two short jogs in it runs from the 158' to the 214' levels. An additional short crack to the north of this crack runs from the 156' to the 180' level.

On both the north and the south elevations the cracks are in a broader area on both sides of the centerline of the wall than on the east and the west, and there are more small cracks. On the north wall the lowest cracks start at the 162' level and the highest reach the 234' level. The long cracks on the north elevation appear as continuous cracks, with jogs along horizontal mortar joints. To the east of the centerline of the north wall the lowest long crack is between the 166' and 190' levels, and it continues directly above, between the 196' and 234' levels. To the west of the centerline a single crack can be followed which has seven jogs in it, from the 162' level to the 228' level.

The south elevation is similar to the north in that the cracks are spread out on the face of the wall, but there are more small cracks and the pattern is less clear. The longest and highest crack is along the centerline of the wall and runs from the 196' level to the 232' level. Other cracks on the south wall range in length from the 2' height of a single stone to 18' long.

All of these cracks at the lower levels appear to be less than a half-inch wide. Specifications for the exterior work in 1964 calls for narrow cracks to be enlarged before filling with sealant or epoxy resin, but it is unclear which cracks were actually widened. None of these cracks penetrates through the wall to the interior (the walls at the 196' to 232' levels range from 7'-0" to 8'-7" thick and are made up of up to four courses of stone). All of the cracks at the lower levels appear to be filled with either sealant, mortar or resin.

An incomplete 1959 survey of the exterior indicates that some of the lower level cracks existed at that time. Unfortunately the survey is too vague to be useful in determining which of the cracks have developed since that time. However, since these cracks all appear to have been filled we can assume that they have existed at least since the last time the Monument was pointed in 1976 and that they are not growing.

The upper level cracks are above the 452' level on the east and west walls, where the walls are made up of a single thickness of stone. These cracks

Cracks in Stone (cont'd)

run vertically through the centers of stones and through the mortar joints, and correspond in length and location on the interior and the exterior of the Monument. On the interior, the width of these cracks is less than 1/16", and no shifting of the stones is apparent.

On the interior of the east elevation the crack passes behind the Alaska memorial stone, running from around the 455' level (the bottom of the crack starts 1'-1 3/4" below the bottom of the Alaska memorial stone), to the 466' level (see Photos 2 and 3). The wall at this level is about 2'-4" thick and the crack is visible on both sides of the wall. This crack is a major path for water leaking into the Monument.

The upper level crack on the west wall is also visible on both the interior and the exterior. It begins at the 450' level, includes the top course of double-width stones, and runs up to the bottom of the center rib at the 470' level (see Photos 4, 5, and 6).

We have found no previous evidence for the existence of these through-the-wall cracks. They are not visible in historic photographs, including photographs taken as recently as 1964. They are not mentioned in any previous studies of the Monument, including the 1973 Robinson Engineering report which performed a detailed survey of the interior of the Monument. These through-the-wall cracks apparently have developed since 1973. Beyond that, when they appeared and how fast they have grown is not known.

James Madison Cutts, Consulting Structural Engineers, has reviewed these upper level cracks as a part of this report (see Appendix A). Their conclusion is that these cracks are likely caused by thermal forces resulting from differential heating of the walls of the Monument.

The cracks in the stone of the Monument, particularly the upper level through-the wall cracks, are a serious concern. The cracks are an indication of structural failure of the load-bearing masonry wall. It is not clear why the cracks have formed and it is not known if they are still developing. In addition, the cracks are a major path for water leaking into the Monument. More needs to be known about the cause of the cracks and whether they are continuing to grow.

Exterior Stone Weathering and Patching

The masonry on the exterior of the Monument has undergone numerous repairs. Many layers of patching, pointing and stone replacement have been added to the Monument over the years (see Photos 8, 9, 10 and 11). Patching and replacement of the exterior stone was done in 1934 and again in 1964. There probably have been other repairs done to the Monument at other times, especially at the easily accessible and highly visible bottom of the shaft, but these are undocumented.

The bottom four courses of the shaft are faced in a lighter color marble than the rest of the Monument. The lighter color may be the result of regular cleaning of the base of the shaft, or it may be the result of using a lighter color stone. On the west elevation, these four courses of stone have chamfered edges. Again, it is unclear when this was done.

The exterior has large mortar patches of different colors and textures. The largest mortar patch is approximately 3' by 5', near the ground on the south elevation. On the north side the largest patches are between the 8' and 14' levels, and are a dark, sandy mortar. Some mortar has chipped off the surface, but this is usually a second layer of mortar which has come off an earlier mortar patch.

A lot of damage has occurred to the edges of stone at the joints, probably as a result of past repointing efforts or the use of extremely hard mortar. There are chips on the edges of the stone at virtually all of the horizontal joints, and the chipping is particularly severe between the 60' level and the 150' level. The chipped edges of the stone have been repaired, typically using the same mortar which is used in the joints between the stones. The mortar at the joint was tooled with a concave finish, and the mortar was then spread out as far as necessary to cover the chipped edges of the stone.

The worst weathering of the marble can be seen at the four corners near the ground (see Photos 9, 10, and 11). The corners have been repaired with dutchmans and mortar patches. Areas which have not been repaired are still deteriorating. Continuing deterioration at the corners includes chips and cracks at the corners and at the joints. There are vertical cracks in the corner stones, typically 3" to 4" in from the corners, particularly at the northeast and southwest corners. Some of these cracks appear as though they may result in detachment of parts of the stone. Closer investigation of these conditions is needed.

Dutchman repairs are typically made of blocks of marble 4" to 6" thick which vary in length. Most of them probably date from the 1964 exterior repair work on the Monument. The stone used for the dutchman repairs is lighter in color and has a finer grain than the adjacent marble. The stone used in these repairs shows little weathering.

Exterior Stone Weathering and Patching (cont'd)

On the southwest corner there are dutchman repairs from the 0' level to the 20' level, and the stones are badly chipped and cracked above the repairs to the 32' level. Many of the chips and cracks have been filled with mortar. Additional stones have been replaced on the east face near the southwest corner at the bottom 3 courses. On the southeast corner there are dutchman repairs from the 0' level to the 12' level, and the stones are badly chipped at the corner, but not cracked, to the 26' level. On the northeast corner there are dutchman repairs from the 0' level to the 6' level and from the 14' level to the 16' level. Many of the stones in the northeast corner above the 24' level have vertical crack 4" to 8" from the corner. If these cracks go all the way through the stone they could lead to detachment of large pieces of the stone. On the northwest corner there are dutchman repairs from the 0' level to the 8' level, with the stone above in relatively good condition.

With a few exceptions the weathering of the exterior stone has been fairly even. In general, the stone has a rough surface, with no visible tool marks. The worst weathering has occurred at the corners, as discussed above. Veins in the stone have weathered worse than the unveined surfaces, and surface cracks have developed at the veins in many areas, especially on the north and east elevations. Some of these cracks have been filled with mortar. The bottom and second courses of stone at the north jamb of the entry are sugaring at the corner, and there is some sugaring at the corner of the third course on the south jamb.

Annually the exterior walls and the area around the Monument are pressure washed from the ground. Pressure washing of the basement of monument was observed during a site visit on February 11, 1992.

Water Infiltration

The Monument has a severe problem of water leaking through the joints and cracks in the walls. The worst problems are at the upper levels where the walls are thinnest, but water has been observed to have dripped down as low as the 70' level. Water penetrates the walls, seeps along cavities inside the walls, and runs into the interior of the Monument for several days after a rain. Water coming out of the masonry then flows down the face of the walls, forming puddles on the stairs and landings and raising humidity levels to 100%. The resulting high humidity causes water to condense on stone and metal. Many of the current problems in the Monument are directly or indirectly caused by this water infiltration problem.

The primary path for water entering the Monument is through the joints in the masonry. Rain driven against the walls flows into and through the joints of the stone walls of the pyramidion and through the joints of the walls of

Water Infiltration (cont'd)

the shaft. Major leaks through mortar joints are throughout the pyramidion and in the shaft above the 440' level where the walls are thinnest. Smaller leaks occur at the joints as low as the 160' level. The water which has run out of the joints can be seen even when dry by the stains and deposits of calcium carbonate which have built up below the joints (see Photos 12 and 13). There may be some water which passes through the stone, but it is a small amount and is not discernible against the large amount of water which passes through the joints.

In addition to the water which leaks through the mortar joints is the water which leaks through the cracks in the stone. The upper level cracks provide a direct route for water to move through the walls. The crack between the 455' level and the 466' level on the east elevation is a particular problem. Water which puddles on the 450' level landing below this crack makes it the wettest spot in the Monument. A thick buildup of calcium carbonate is forming along this crack as a result of the large volume of water which moves through it.

The eight holes in the walls of the pyramidion for the aircraft warning lights are another direct path for water infiltration. On these windows, metal frames hold panes of glass flush with the face of the pyramidion wall (see Photo 14). The seals around these holes in the masonry have failed, and large amounts of water flow into the interior through these openings and down the walls to the floor of the 500' level.

Water leaking through the walls leaches minerals from the stone and deposits calcium carbonate on the walls (see Photo 12). These deposits are building up below masonry joints on the interior walls between the 500' and the 160' level and on the exterior. As well as being unsightly stains, these deposits indicate deterioration of the internal stone and mortar as a result of the water infiltration.

Damage may be occurring within the walls from the leaks which will not be visible until the damage is severe. This damage may include the corrosion of metal cramps which anchor the stones together between the 440' and 452' levels, deterioration of mortar, and stone deterioration from freeze/thaw cycles.

Exterior Pointing

The Monument was completely repointed in 1934 and 1964. It was repointed from the 470' level to the capstone in 1975 and from the 0' level to the 470' level in 1976. As described in the section above, joints are tooled with a concave finish, and the mortar in the joints was used to cover the chipped edges of the stone by spreading it out over the damaged edges. At the lower levels, where many undocumented repairs can be seen, the mortar is made of a variety of aggregates and textures.

Sealant was installed in 1975 and 1976 on the exterior of the Monument at the 8' level and at the joints every 20' above it. The sealant joint at the 8' level is the only one that can be seen clearly from the ground. The sealant has shrunk and pulled away from both edges of the joint. The sealant does not cover the chips at the edges of the stone, so the chips are typically left bare at the sealant joints. Only the largest of the chips at the sealant joints are filled with mortar. The sealant joints have collected dirt and are visible as dark horizontal lines on the face of the Monument.

Stains on Exterior Stone

Red and reddish-yellow stains can be seen on the exterior face of the Monument on all four sides. They are most visible from the 0' level to the 30' level, and they are concentrated at the corners and around joints and chips in the stone. It is likely that these stains are organic and are leading to deterioration of the stone.

White stains can be seen on the stone below the bottom edge of some of the vertical cracks in the stone. These appear to be from water entering the cracks, running down inside the wall and leaching calcium carbonate from the stone. When the water returns to the surface of the Monument, the minerals are deposited on the stone, leaving the white stains.

Interior Pointing

On the interior of the Monument the masonry joints above the 150' level are typically of a very hard cement mortar. The joints are finished with a flat profile flush with the face of the stone. The exceptions to this are some areas which have been repointed, and the joints around memorial stones. Many of the repointed areas have mortar which has been roughly applied, with the mortar built up beyond the face of the stone. The joints above the 452' level, where the walls are a single stone thick, are typically 1/4" wide. The joints from the 452' level to the 150' level are typically 3/8" wide. There are some areas, particularly above the 450' level, where the mortar is cracked, where the mortar has separated from the stone, and where the joints

Interior Pointing (cont'd)

are open. Some joints have built-up deposits of calcium carbonate. These problems amount to less than 30% of the joints above the 450' level, and to less than 20% of the joints between the 450' level and the 150' level.

Below the 150' level the joints on the interior vary in size, finish and material. The joints vary in width from 1/8" to 1/2". The joints are made up of either a very soft, crumbling mortar of a very light color or a very hard cement mortar which is dark gray. The soft mortar is crumbling into dust, leaving many large voids in the joints and small piles of mortar dust on the stairs and landings. The hard mortar is roughly finish, and in places it has been smeared over the face of the adjacent stone.

Interior Stains and Deterioration of Stone

Water infiltrating the Monument is causing stains on the surface of the interior stone. Water running down the walls of the pyramidion leaves dark streaks on the stone, water leaking from the mortar joints builds up deposits of calcium carbonate on the walls, and corroding metal causes streaks of rust below the stairs and landings. The stone of the walls is generally covered with a layer of grit and dirt.

Four stones at the 204' level and five stones at the 184' level are flaking over their entire surface. Flaking of this severity is not taking place anywhere else in the Monument. It is not clear if the flaking in these areas is happening because of inferior stone used in these locations or if a particular problem with water or some other condition is causing it. The flaking was described in the 1973 report on interior conditions of the Monument by Robinson Engineering.[1]

In addition to the through-the wall cracks discussed above, there are also many small cracks which can be seen on the interior. Most of these are cracks in individual stones. One crack runs between the 472' and 478' levels on the east elevation between the middle and the south ribs. Although the wall is only a single stone 2'-1" thick at this point the crack is not visible from the ground on the exterior.

On the west wall above the 480' level the south side rib has a 2' high piece of stone which has cracked. The cracked piece is completely loose from the rib, so there is no longer any stress on the loose part of the stone (see Photo 7). This crack is discussed and shown in a photograph in the 1973 Robinson Engineering report. It appears as though it has changed little since that time.

Memorial Stones

The memorial stones which are set into the interior walls of the Monument underwent cleaning and restoration in 1978 and 1979. All the stones were cleaned, and 18 stones were restored by sculptor Constantine Seferlis. In the restoration work parts of the carvings which had been broken off by vandals were replaced. This was done by either attaching matching stone with resin adhesive or by building up a resin patch. The stone or resin patch was then carved to replicate the missing piece, as known by historic photographs or by speculation. The restoration work varies in quality and in most cases the resin is yellowing. Four memorial stones have broken pieces which are unrepaired.

Metal cramps and metal frames surrounding the memorial stones are corroding and causing damage to the stones. The expanding metal frames and cramps have caused cracks and spalls in 22 memorial stones and in surrounding wall stone. Streaks from corroded iron stain the faces of some stones. Corroding metal around the frames of the stones is seen on 41 of the 193 memorial stones, all but one of them above the 150' level. In some cases, such as the Kentucky I.O.O.F. memorial stone at the 230' level, damage to the stone is visible in the 1957 photograph and does not appear to have worsened. In other cases, however, such as the "Two Disciples of Daguerre" memorial stone at the 280' level, the damage is not severe in the 1957 photograph, worsens in the 1973 photograph and is even more severe today (see Photo 15).[2]

The joints between many of the memorial stones and the building stone have been pointed with a hard portland cement mortar. The joints are typically uneven and roughly finished. The mortar in these joints probably covers many additional corroding metal frames and cramps.

The memorial stones themselves are deteriorating from the direct effect of water which is leaking into the Monument. Mineral deposits leaching from marble and granite are building up on the faces of some stones, and general deterioration and loss of detail can be seen in 4 others. Comparison between the present condition of the memorial stones and the memorial stones as they appear in the 1957 and 1973 photographs reveals the many repairs which were done to them in 1978-79, but it also shows that many of them are continuing to deteriorate.

Iron and Steel

The survey of the condition of the iron and steel framing in the Monument was done visually from the landings and stairs, using a flashlight to illuminate dark areas. Chipping or probing of corroded areas was not

attempted, and staging or ladders were not used to gain access to remote areas.

Repair work to the metal framework in the Monument was carried out in 1940, 1959 and 1973. The 1940 work reinforced the connection between the stair stringer and the stone wall with the addition of bolts into the wall under the stringer. In 1959 a new landing was installed at the 490' level for boarding the elevator, a second stair was built between the 500' level and the 490' level, and clip angles were bolted to the stone wall to support the channels under the landings. Extensive repairs to the iron and steel framing took place in 1973. Corroded metal members were replaced, including some of the members installed in 1959, and all of the iron and steel was cleaned and painted. All of the floor plates were replaced and the landings and stairs were resurfaced. Abrasive nosings were installed at all the stairs.[3]

Corrosion of the structural metal is prevalent in the Monument. This is especially evident at the framing where the metal comes in direct contact with water leaking into the Monument. Even steel members which replaced corroded iron members in previous repairs have begun to corrode. As long as the water infiltration problem exists, the corrosion will continue. The corrosion appears to be mostly on the surface of the metal at this time. If allowed to continue, it could require replacement of the members or lead to structural failure. The corrosion is also causing staining on the stone walls on the interior of the Monument and there is the possibility that corrosion of bolts which are fastened into the stone will cause damage to the stone.

The most severe corrosion is at channels and angles which are set against the stone walls supporting the landings and the stairs, and at the angles which sit on top of the floor against the stone walls (see Photos 16 and 17). These members are in direct contact with water leaking into the Monument. It is not possible to see the face of the channels against the walls, but the corrosion which is spreading around the edges of the channels indicates that the faces are also corroding.

In addition, the four iron "Phoenix" columns which support the landings and the stairs have blistered paint indicating corrosion, typically for about 6" above the landings. Clip angles which were bolted to the stone walls in 1959 to support the channels under the landings all have surface corrosion. Welds connecting replacement steel, clip angles and bracing typically have some corrosion developing, and there are also other random spots of corrosion at other locations, evident by blistered paint and ferrous colored streaks. Other ferrous metals which are corroded include four conduits which penetrate the landings at the northeast corner and the metal plate which holds them are corroding at the landings throughout the Monument (see Photo 16). The steel gate at the entry has spots of light corrosion.

Hazardous Materials

Dewberry & Davis conducted a survey of the Monument for the existence of asbestos-containing materials and lead-based paint in December, 1991. The survey inspected the full height of the Monument, equipment space above the elevator, and the underground service areas. The complete report by Dewberry & Davis is included in Appendix B.

Within the Monument asbestos-containing materials (ACMs) were detected in vinyl floor tile, pipe joint insulation, and transite board. In the underground service areas ACMs were identified in vinyl floor tile, pipe and joint insulation and tank insulation. The ACMs in the underground service area mechanical room are severely deteriorated and pose an immediate health hazard. ACMs in the guard room are also deteriorated and are also a health hazard.

Lead-based paint (LBP) in concentrations that exceed the HUD recommended abatement threshold limit of 0.5% by weight was identified on the handrail at the 0' level, the stair stringers at the 10' and 470' levels, the stair support columns at the 0' level, the stair stringers at the 10' and 470' levels, the stair support columns at the 10' and 100' levels, at a pipe at the 40' level, and at the ceiling of the underground service area mechanical room. The LBP survey was limited in scope, and only presents a general characterization of the presence of LBPs in the Monument.

Temperature and Humidity Monitoring

Ten mini-drum hygrothermographs (Cole-Palmer model 8369-50) were installed in the Monument on 11/5/91. They were placed on the floors of the landings in the corners at the following locations: 480' landing NW; 450' landing SE; 400' landing NW; 350' landing SE; 300' landing NW; 250' landing SE; 200' landing NW; 130' landing SE; 80' landing NW; and 10' landing NW. The instruments measured air temperature and relative humidity on a continuous basis, recording the readings on 7-day charts. In addition to these ten instruments, there is an additional instrument installed by NPS at the 490' level on a bracket on the wall across from the bookstore. We were able to obtain copies of some of the charts from this instrument but it has not been maintained and it is no longer operating.

Each week, when the instruments were maintained, spot readings were taken near the hygrothermographs of air temperature, stone and mortar surface temperature, metal surface temperature (taken on the iron column nearest the hygrothermograph) and stone surface moisture. Spot temperature measurements were taken with a hand-held digital thermometer with air and surface probe (Supco model 3T189). Stone surface moisture measurements

Temperature and Humidity Monitoring (cont'd)

were taken with a hand-held two-pin electrode dampness meter (Protimeter Minor IV or Mini III).

To correlate the conditions in the Monument with outside weather conditions, National Oceanic and Atmospheric Administration monthly summaries of local climatological data were used.

A review of the collected data indicates that the air temperature in the Monument is relatively stable while there is broad fluctuation in the humidity levels in the Monument (see hygrothermograph charts, weekly monitoring forms and NOAA Monthly Summaries of Local Climatological Data, Appendix D).

From October to May the air temperature in the interior of the Monument stayed between the extremes of 50 and 75 degrees Fahrenheit. During these months the range of air temperatures from the top to the bottom of the Monument was within 15 degrees. The warmer air temperatures were usually seen at the 480' level and the 10' level, levels which are warmed by their proximity to the heated public spaces. During these months the surface temperature of the stone at the different levels varied by as much as 20 degrees, with the colder temperatures at the top where the stone is thinnest. The temperature of the stone was at times as much as 10 degrees colder than the air temperature.

During June, July and August the air temperature on the interior of the Monument was consistently between 75 and 85 degrees. Although these temperatures were consistent, this is high for visitor comfort. The range of air temperatures through the height of the Monument on a given day during these months was often very small, usually within 5 degrees.

While temperature levels are typically within a narrow range in the Monument, the relative humidity levels vary widely. Relative humidity levels vary with the humidity levels on the exterior and with the amount of rainwater which has leaked into the building. When the relative humidity levels vary inside the Monument as a result of changes in the humidity levels outside, the changes occur throughout the height of the Monument, while the temperature remains constant. During weeks with changing humidity levels outside but no precipitation, the variations in the relative humidity levels inside the Monument follow similar patterns at all the levels.

The charts for the week of 4/28/92 to 5/5/92, a week with no precipitation, show an example of this pattern. During that week the relative humidity increased at all the levels, reaching as high as 90% on 5/3/92. Later that day the relative humidity dropped at all the levels, to a low of 40%. This drop corresponds to a drop in the average dew point outside on that same day. While the relative humidity was making these wide swings, the range

of temperatures inside the Monument remained within 5 degrees during this week at all but the 480' level.

High humidity also occurs in the Monument as a result of rainwater leaking into the Monument. Leaking water runs down the walls, collects on the steps and the landings, and evaporates into the air. The relative humidity at these times is as high as 100%, regardless of the humidity levels on the exterior.

The hygrothermograph charts from the week of 5/5/92 to 5/12/92 show a typical pattern in the humidity levels which results from leaking rainwater. After a period of 12 days with no precipitation, 0.71 inches of rain fell in thunderstorms on 5/8/92. Before raining, the relative humidity level inside the Monument was an average of 40%. At the 480' level the relative humidity level shot up to 100% as the water leaked into the Monument, and then slowly dropped to 60% over the next three days as the upper levels dried out. At the 400' and 450' levels there were sustained relative humidity readings above 80% for the rest of the week. From the 400' level down, where less water leaks directly through the walls and more drips down from above, the relative humidity levels rose slowly, reaching a peak of 85 to 95% three days after the rain.

The high humidity in the Monument causes moisture to condense on the stone and the metal. For condensation to occur, moist air must come in contact with a material which is cooler than the dewpoint of the air. These conditions can be seen on three typical days which had high readings of stone and mortar moisture. Analysis of the monitoring data collected for the days of 12/10/91, 1/14/92 and 4/21/92 show that the conditions necessary for condensation were present (see the summary charts for these days and the psychrometric chart in Appendix D). The summary charts for these days show for each of ten levels the air temperature, the relative humidity, the dewpoint, the stone temperature, the degrees above or below the dewpoint of the stone temperature, and the stone and mortar moisture spot readings. Temperature, humidity and moisture readings were taken from the hygrothermograph charts and from the weekly temperature and moisture monitoring. The relative humidity level used for the summary was the highest relative humidity level from the previous three days. The dewpoint was determined from a psychrometric chart, using the summarized temperatures and relative humidity levels.

The pattern of the data from these four days is clear. The stone temperature was often below the dewpoint, and when those conditions existed there was moisture on the stone and the mortar, indicating that condensation had taken place. In most cases, the further the stone temperature was below the dewpoint the higher the stone and mortar moisture readings were. In a few cases there was moisture on the stone or mortar when the stone temperature

Temperature and Humidity Monitoring (cont'd)

was above the dewpoint, but the moisture could still be from condensation if the stone temperature was lower at some time before the spot reading of stone temperature was taken.

Condensation in the Monument is causing deterioration to the stone and metals. The damage caused by condensation on the stone and metal is visible throughout the Monument. This is not a new problem in the Monument. Deterioration of the stone in the Monument due to condensation was described in a report by Thomas Lincoln Casey, written just after the Monument was completed in 1884. A 1973 report also described severe condensation on the interior walls as one of the reasons for installing a new HVAC system.[4]

During the heating season, the readings from the instrument at the 250' level oscillate tightly several times an hour rather than following a smooth curve. These oscillations in both the temperature and humidity readings are the result of the instrument's proximity to a thermostatically-controlled unit heater. When the unit cycles on the temperature goes up, causing the relative humidity to go down, and when it cycles off the reverse happens. This results in the oscillations on the charts. The regularity and the narrow range of the fluctuations indicate that the thermostatic control is operating effectively.

At the 10' level the hygrothermograph often records jagged variations in the humidity level. These irregularities do not follow any regular pattern, and occur at random intervals at all times of the day and night. It is unclear what causes them, although they may be the result of outside air entering through the door at the level below.

The surface moisture testing of the stone and the mortar shows that the moisture content of the mortar is consistently higher than that of the stone. Because of its higher porosity more water moves through the mortar, and the surface remains wetter than the surface of the stone.

Heating, Ventilating and Air Conditioning System

The HVAC system in the Monument is maintained and operated by the General Services Administration. Monument personnel have no controls for operating the HVAC system. The only part of the climate control system which can be controlled by the Monument staff is the air circulating fans which are at the 500' level and at the 0' level, and dampers on the ducts.

The results of the monitoring program shows that when it is operating, the HVAC system is effective in maintaining even temperatures in the

Heating, Ventilating and Air Conditioning System (cont'd)

Monument (see previous section on Temperature and Humidity Monitoring). A 1957 report on the Monument described "marked stratification of temperature within the shaft."[5] This is no longer a problem. However, the HVAC system is slow and ineffective in reducing high humidity. Although the system does moderate the humidity and eventually takes the humidity out of the air, it cannot remove the large amount of water which comes into the Monument quickly enough to prevent condensation from occurring on the walls and metal.

The HVAC system has been shut down many times for repair work. Since beginning our study of the Monument in October, 1991 we have known of the HVAC system being shut down during the following dates, either by observation or by information from Monument personnel: the week of 1/21/92; 6/7/92-6/23/92; the week of 6/30/92; and the week of 8/4/92. In all these cases the shutdowns were the result of system failure. The shutdowns took up to ten days to repair.

The effectiveness of the HVAC system at controlling the temperature and humidity is apparent when contrasted with the conditions which occur when the system is shut down. On 6/9/92 the HVAC system was in the middle of a shutdown. The temperatures ranged widely in the Monument, from 83.4 degrees at the 480' level to 72.3 degrees at the 10' level. Leaking water had formed puddles on the landings from the 450' level to the 200' level, raising the relative humidity to 100% for most of the previous week. The walls and metal framing at the lower levels were cooler than the upper levels, so they were below the dew point, causing condensation to form on the stone and metal. There was visible condensation on the walls from the 450' level down. Below the 160' level it was particularly severe, where the temperatures of the air and the stone were up to 11 degrees lower than at the 480' level. At these levels water was beading up and running off the surface of the stone and the landings. Throughout the height of the Monument on that day the surface moisture of the stone was extremely high, up to 28%. Extreme conditions such as these did not occur when the system was operating.

A 1973 analysis of the Monument's previous HVAC system stated that "the cool interior surfaces of the Monument are acting as a dehumidifier".[6] This appears still to be taking place at times, although it is not as extreme as it was before the current HVAC system was installed. Although the situation described above is an extreme case resulting from a shutdown of the system, it is not uncommon to have stone moisture readings above 16%, indicating moisture in excess of normal. Moisture readings above 16% were observed in the Monument on 39% of the days that moisture readings were taken. Condensation of moisture on the stone and metal from high humidity in the Monument is the biggest shortcoming of the HVAC system.

Underground Service Areas

Access to the underground service areas is by a stairway to the west of the Monument (see Photo 18). These concrete stairs lead down from ground level to a concrete areaway. The concrete of both the stairs and the areaway is deteriorated. The stairs have been repaired on the top three treads and risers with concrete patches. The walls of the areaway have cracks and stains from leaking water. An iron grate over the areaway is corroded, although still structurally sound. Metal louvers over the openings to the mechanical room to the left are corroded and stains are forming on the wall below. There is a horizontal crack in the wall at the level of the ceiling of the landing below. The wall at the landing at the bottom of the steps is a brick wall covered with a 1" layer of stucco. The stucco is badly deteriorated, and large parts have fallen from the brick wall.

The ceiling, walls and floor of the mechanical room to the left of the stairs are exposed structural concrete. The structural concrete is in mostly sound condition. The exception is in the areaway to the south of the mechanical room, where concrete beams are badly deteriorated (see the letter concerning these beams, Appendix A). The concrete beams have spalled and reinforcing bars are exposed and corroding.

The guard room has a tile-covered floor and walls. The tile appears to be in good condition. Water leaks onto the floor after heavy rains, and when the floor drain is plugged there can be standing water on the floor. These leaks are the result of failed waterproofing under the paving of the terrace and on the walls of the guard room.

The mechanical room contains a large amount of asbestos-containing materials. Much of it is deteriorated. Exposed pipes run across the ceiling of the guard room. These pipes contain pipe joint insulation which also contains deteriorated asbestos (see the section above, "Hazardous Materials").

Settlement Survey

In February, 1879 a bench mark was installed approximately 121' to the south of the Monument (see diagram of the obelisk and bench marks, Figure 26). The bench mark is a 13'-6" tall concrete obelisk on a concrete foundation, set below ground and encased in a brick manhole. Four reference points were set at the four corners of the Monument, and eight additional reference points were set at 23'-4" out from the face of the Monument, all anchored to the Monument foundation. The four reference points at the corners were enclosed in metal pipes with screw-off caps when the paving level was raised. A special wrench which removes the caps was

Settlement Survey (cont'd)

made available by the Falls Church Branch of the Denver Service Center to gain access to the reference points for this survey. A later bench mark which was added at the east doorway of the Monument was removed during construction in 1974.

The obelisk and the four reference points at the corners of the Monument have served to monitor the settlement of the Monument since they were first installed. Using the obelisk as a bench mark at 36.063', the elevations of the reference points at the four corners were established. Subsequent surveys compared the elevations of the four reference points to the 1879 survey and calculated the differences in elevation to be the amount of settlement. These surveys assumed that the elevation of the obelisk remained fixed.

Settlement surveys were performed in 1884 at the completion of the Monument, and on a regular basis after 1926 (see "Chronological History of Settlement Levels" in Appendix C). The results of these surveys indicate that at the conclusion of construction in 1884 the Monument had already settled an average of .346' at the four corners, with the greatest difference between the corners being .031', between the southeast and northwest corners. The total settlement since 1884 has been an average of .158' at the four corners, with the greatest difference being .009' between the southeast and southwest corners. Between 1984 until 1992, the average settlement at the four corners has been .008', ranging from .004' at the southeast corner to .011' at the southwest corner.

As noted before, previous settlement surveys have all measured the settlement of the Monument relative to the obelisk, which has been assumed to be at a fixed elevation of 36.063'. By assuming this elevation to be fixed there is consistency between the surveys, and this allows direct comparisons going back to 1879. However, surveys to bench marks outside the immediate area of the Monument have shown that the elevation of the obelisk is not 36.063' and, more importantly, that the obelisk itself is settling (see "Chronology and Documentation of Obelisk Settlements" in Appendix C). In 1923 the obelisk was resurveyed using outside points of reference and the elevation was established at 36.909'. This higher elevation is due to changes in the survey datum which was used, and may not indicate any actual change in the elevation of the obelisk. Because the datum was changed, it is not possible to determine the amount of settlement of the obelisk before 1923 using the information which is available. However, the known settlement of the obelisk which has been observed since 1923 can and should be added to the settlement of the Monument relative to the obelisk to get a more complete calculation of the total settlement of the Monument.

Settlement Survey (cont'd)

Between 1923 and 1992, the obelisk has settled .127'. Adding this to the total settlement of the Monument raises the average settlement at the four corners since 1884 to .285'. This is still less than 3 1/2" of settlement and does not increase the calculation for differential settlement.

These settlement survey results indicate that the settlement of the Monument is taking place slowly and evenly. The results of the 1992 survey reconfirms the conclusion of the 1984 settlement survey in which Mueser, Rutledge, Johnston & DeSimone wrote, "there is no significant differential settlement or tilting of the Monument and the rate of settlement is small and completely explainable in terms of normal physical phenomena in the underlying soils".[7]

In 1984, the National Geodetic Survey (NGS) set two stainless steel bench marks in the walls of the Monument (see "Description of NGS Bench marks" in Appendix C). The elevations of these points were established using a first order level run which began at Lafayette Square and included the obelisk and the "Zero Milestone" at the Ellipse north of the Monument. When used with the techniques and equipment available to the NGS, these points provide highly accurate bench marks for surveying the settlement of the Monument. To survey differential settlement, however, at least three points must be used to determine movement in both axes, so these points alone cannot be used to determine the tilt of the Monument.

Maintenance Procedures

The landings at the 500' and the 490' levels are regularly mopped after rains to keep them from being slippery and hazardous. Cleaning crews clean the stair hall on a random basis. Wet cleaning with mops, buckets, sponges and cleaners took place at the 480', 470' and 460' landings in January, 1992. On September 14, 1992 a crew went in with mops and buckets to clean the stairs and landings. The four-member cleaning crew spent less than an hour in the Monument and cleaned less than half of the landings. Most of the landings remain uncleaned, leaving muddy stains from the evaporated puddles of water and a gritty layer of dust. Dark spots on the landings which appear to be discarded chewing gum persist throughout the Monument, even where the cleaning crews have mopped.

The cleaning solution used by the cleaning crew was "Deep Six", by Precise Chemical and Equipment Company. This is a butyl-based all-purpose degreaser which comes in a concentrated form. If it is not properly diluted it has the potential to cause damage to stone and metal.

Maintenance Procedures (cont'd)

The exposed faces of stones on the interior have been ground to remove graffiti from the stone, leaving circular markings on the face of the stone. These marks can be seen on ribs at the 500' level and on the faces of marble in locations throughout the upper part of the Monument. The

original surface of the marble, which typically has a vertical grooved texture with visible chisel marks, is now irreparably lost from these stones. In 1973 Robinson Engineering described this grinding of the face of the stone to remove graffiti at the 500' and 490' levels and recommended that it be stopped.[8] It is assumed that it has not been done in recent years.

All painted surfaces at the 490' and 500' landings are repainted annually (observed 2/25/92). The Monument is closed annually for this maintenance.

Miscellaneous painting and other maintenance in the Monument has taken place with little regard for the historic fabric of the Monument. Throughout the shaft there are spatters and spills of paint on the landings, stairs and stone walls of the Monument. On 8/4/92 globs of sealant from HVAC system work were seen dripped onto 5 steps between the 20' landing and the 30' landing. On 10/6/92 spots and streaks on the face of the stone on the wall above the stair between the 220' and 230' levels were first observed. These streaks appear to be from cleaner sprayed from a bottle. At the 450' landing and down the stairs to the 460' landing, walls were scrubbed at chest height only (see Photo 17). At various times trash from maintenance personnel, such as discarded tubes of hand cleaner and tops from cleaning supply containers have been left in the stair hall.

Notes

1. Robinson Engineering, Washington Monument: Interior Structural & Mechanical Analysis, (prepared for the National Park Service, 1973), p. E-3.

2. Photographs in Allen, Josephine D., "Memorial Stone Blocks in the Washington Monument Photographed" (Washington, D.C.: National Park Service, 1957), and Robinson Engineering, "Memorial Tributes in the Washington Monument", (Falls Church, Virginia, 1973). Both of these sources are from the files of the Falls Church Branch of the Denver Service Center.

3. Robinson Engineering, Washington Monument: Interior Structural & Mechanical Analysis (prepared for the National Park Service, 1973).

4. Proceeding of the Joint Commission, 18 December 1884, cited in Torres, p. 92, and Robinson Engineering, "Washington Monument - Interior Structural and Mechanical Analysis", 1973, Section B.

5. Kluckhuhn, Cobb and McDavid, Engineering Consultants, The Washington Monument, Washington, D.C., Preliminary Analysis and Report for New Floodlighting and Electrical Services, report prepared for National Capital Parks, 1957.

6. Robinson Engineering, Washington Monument: Interior Structural and Mechanical Analysis, (prepared for the National Park Service, 1973), p. B-2.

7. Mueser, Rutledge, Johnston & DeSimone, Consulting Engineers, Settlement Analysis for Washington Monument Grounds Improvement, NPS: D18 (NCR-NACC) (XF54), prepared for National Park Service, National Capital Parks, April 29, 1957, page 3.

8. Robinson Engineering, Washington Monument: Interior Structural & Mechanical Analysis (prepared for the National Park Service, 1973), p. E-4.

VI. RECOMMENDATIONS FOR REPAIR AND FURTHER STUDY

VI. *RECOMMENDATIONS FOR REPAIR AND FURTHER STUDY*

Cracks in Stone

There are cracks in the stone walls of the Monument on all four elevations. Between the 160' level and the 234' level there are vertical cracks in all the walls which are visible only on the exterior. These cracks are not new, and they have had sealant installed in them.

Above the 450' level there is a crack on the east wall between the 455' level and the 466' level, and a crack on the west wall between the 450' level and the 470' level. These two cracks are located where the walls are a single stone thick. They are visible on both the exterior and the interior. These cracks have developed recently and it is unknown if they are continuing to grow.

It is strongly recommended that the upper level cracks be closely monitored. This monitoring must be an ongoing, long-term project, not a one-time study. This monitoring should last a minimum of 5 years, and should continue indefinitely if there are indications that the cracks are growing (see letter concerning these cracks from James Madison Cutts, Consulting Structural Engineers in Appendix A).

To monitor changes in the width of the upper level cracks, install linear displacement transducers with sensors on both the interior and the exterior of the Monument (see "Description of Linear Displacement Transducer" in Appendix A for a complete description of this equipment). These highly accurate sensors monitor both transient changes due to temperature and wind as well as long-term changes. Movement as small as .001" can be discerned, with accuracy of 0.5% over an 1/8" travel. Displacement sensors are placed across the crack and are coupled to a data logger where the data is stored. The sensors on the exterior can be coupled to a data logger at the 500' level with cables through the observation windows. Retain the services of a qualified structural engineer to install the instruments, to interpret the data from the monitors and, if necessary, to provide recommendations for stabilization.

There are a number of possible factors which may be the cause of the upper level cracks. These factors should be monitored and correlated with the crack monitoring to determine what is causing the cracks. We recommend that wind velocity, building sway and stone surface temperature on both the interior and exterior be monitored along with the crack monitoring.

The lower level cracks are not as serious as the upper level cracks. These cracks are located where the wall is several stones thick, they do not go all

Cracks in Stone (cont'd)

the way through the wall to the interior, and they have been filled with sealant. The sealant is old and has probably failed, however, so the cracks provide a route for water penetration into the Monument. These cracks should be sealed as described below under "Water Infiltration".

It is vitally important that all the cracks in the walls of the shaft be monitored for changes. The interior and exterior of the Monument should be surveyed annually to monitor the growth of all existing cracks and to watch for the development of new cracks. Record with drawings and photographs the location and extent of each crack and correlate this information with previous surveys. Consult a qualified structural engineer to evaluate the causes of any changes in the cracks.

Exterior Stone Weathering and Patching

There is extensive damage to the marble on the exterior of the Monument. The edges of the stone are chipped throughout the Monument. Large mortar patches have been installed to cover chips and spalls on the lower part of the Monument. Dutchmans have been installed to repair damaged stone at the corners as high as the 20' level. Unrepaired deterioration of the stone can been seen at the jambs of the entry, at the corners and in cracks in stones.

The mortar patches which cover the chips and spalls at the bottom 50 feet of the Monument should be removed when the joints are raked for pointing. These patches should be completely removed and reapplied. They should be patched using a mortar which matches the color of the marble on the Monument. Use an acrylic admixture to improve bonding, adhesion and curing.

Deteriorated stone at corners and other places will probably require repairs. These problems areas should be investigated more closely to determine what repair work should be done. Possible repairs on deteriorated stone may include mortar patches, pinning and epoxying delaminating pieces into place, and dutchman repairs to replace stone where it is severely deteriorated.

If the stone on the exterior of the Monument requires cleaning, clean it using only low-pressure steam. The use of chemical cleaners or high-pressure water washing can cause erosion of the surface of the stone. The annual pressure washing of the Monument at the base should be abandoned.

Water Infiltration and Exterior Pointing

Water leaking into the Monument through the cracks and joints is the most serious problem at the Monument. Rainwater enters through the joints of the pyramidion and the shaft and runs down the interior walls and collects on the stairs and landings. The evaporation of the water creates high humidity in the Monument and condensation on stone and metal. Many of the current problems in the Monument, such as corrosion of the metal framing and deterioration of stone and mortar, are caused by these leaks. The water infiltration problem must be solved before resolution of other moisture related problems is possible.

The primary path of entry for the water is the joints and the cracks in the stone. The leaks are worse higher up the Monument, with the worst problems at the shaft above the 450' level and at the pyramidion. Leaks also occur at the lower levels of the Monument, with small amounts of water leaking into the Monument from the joints as low as the 160' level.

The joints in the pyramidion and the shaft need to be sealed. Where the joints are leaking the worst, at the shaft above the 450' level and the walls of the pyramidion, pointing should be done with a double application of sealant. Open the joints to a depth of 3/4" to 1" using a thin diamond masonry saw blade. Apply backer rod and sealant in two layers, allowing time for curing between applications. Finish the sealant joints by pressing sand into the surface of the sealant so that the sealed joints match the pointed joints below. Because of the difficulty and high cost of gaining access to the joints, no expense should be spared on the quality of the sealant or the quality of the workmanship which is used for this work; use only a top-quality sealant and a qualified installer, and provide detailed inspection of the work.

The joints below the 450' level can be pointed with mortar. Below this level the wall depth is more than a single stone thick and the leaks diminish in severity. Open the joints to a minimum of 1/2" using a thin circular masonry blade and remove the mortar which covers the chips and spalls in the stone. Point with a lime-based mortar, matching the color of the marble on the face of the Monument. Patch the chips and spalls as described under "Exterior Stone Weathering and Patching."

The cracks in the stone above the 450' level on the east and west sides of the Monument provide a direct route for water to enter the Monument. On the inside the width of the cracks is less than 1/16", and if this is also the case on the exterior the cracks will need to be widened before sealing. Thoroughly document the cracks before doing any work by measuring and photographing them in detail. Open the cracks with a circular masonry blade to a width of 1/4" to 3/8", and to a depth of 3/4" to 1". Seal these cracks with a double layer of backer rod and sealant, as described above for the

Water Infiltration and Exterior Pointing (cont'd)

joints. The cracks between the 160' level and the 234' level have been sealed in the past. Remove the sealant in these joints, and apply backer rod and sealant as described for the other cracks.

An alternative method for sealing the cracks may be the injection of the cracks with mortar, grout, polymer modified grout, polymer resin or other materials. To do this, injection ports of a minimum of 1/4" diameter would be drilled, and injection would take place under pressure. Skilled, experienced operators would be required to perform this method. Choice of the method used to seal the cracks would have to be based on careful, close range study of the cracks and determination of the cause of the cracks. A soft sealant may be necessary to accommodate movement in the stone.

The 8 openings for the aircraft warning lights in the pyramidion leak badly and should be made watertight. The round openings are still closed with what appears to be the original frames. We recommend that the frames, glazing and sealant in these openings be replaced to make them watertight.

The 8 observation windows also leak, although not as badly as the aircraft warning lights. The frames and glazing appear to be sound. Replace the sealant around the frames and the sealant at the glazing on both the interior and the exterior to make them watertight.

Until such time as the building can be made watertight, the problems caused by the water leaking into the Monument can be moderated by regular maintenance procedures. When water collects on the stairs and landings it should be mopped up as soon as possible. If this is done the corrosion of the metal framing in the Monument can be minimized and the humidity levels and condensation will be moderated.

The pointing and sealing should be repeated on a 10-15 year cycle. It should be repeated before the sealants fail and water again leaks into the Monument.

It is not recommended that water repellent sealer be applied to the face of the stone. It does not appear that water leaking into the Monument is moving through the stone itself but is moving through the joints between the stones.

Stains on Exterior Stone

Red and reddish-yellow stains can be seen on all four elevations of the Monument. They are most visible from the 0' level to the 30' level. It is likely that these stains are organic and are contributing to the deterioration of the stone.

We recommend that tests be performed on these areas to determine the precise nature of the stains and to determine the best treatment for removing them. Use the mildest cleaner possible which is effective in removing the stains. Use only water from a low-pressure hose to rinse the stone (less than 400 psi, measured at the nozzle).

Interior Pointing

Water leaking into the Monument is causing the deterioration of interior mortar joints. Above the 150' level the mortar is a hard cement-based mortar. There are cracks in the mortar and in some areas the joints are open. Below the 150' level the mortar is very soft and crumbling except in areas where it has been repointed with a hard cement-based mortar. Much of the mortar below the 150' level has deteriorated.

All deteriorated interior mortar joints should be repointed. This includes areas above the 450' landing where joints are open, and areas below the 150' landing where mortar is crumbling or open. Repoint using a lime-based mortar and finish the joints flush with the surface of the stone to match the existing joints. Most of the deterioration of the mortar is caused by water which is leaking into the Monument. Do not repoint the interior until after the leakage problem is solved.

Cleaning Interior Stone

The interior walls are covered with an overall layer of grime. Only after the water infiltration problems have been solved should cleaning of the interior walls be considered. Removal of the stains and grime can be accomplished using steam cleaning. Special care should be taken when cleaning the interior walls to protect the memorial stones from damage. It is not recommended that an attempt be made to remove the stains caused by corroding metals and deposits of calcium carbonates leached from the stone. These would be very difficult to remove and the procedure could damage the stone.

Memorial Stones

Of the 193 memorial stones on the interior of the Monument, 41 are set into the wall with corroding iron cramps or frames. The corroding iron is causing damage to both the memorial stones and the surrounding building stone. Many of the memorial stones were repaired and all were cleaned in 1978-1979. Many of the repairs were done with epoxy resins which are yellowing.

The memorial stones which have corroding iron frames should be reset to prevent additional damage. Remove the mortar and the iron frames and cramps surrounding the memorial stones, reset the stones using bronze or stainless steel cramps, and repoint the masonry joints using a lime-base mortar. Two memorial stones which have fractured as a result of expanding iron cramps should be repaired by reattaching the pieces with non-corrosive pins and epoxy resin.

The yellowing epoxy on repaired stones should eventually be removed. These stones should be repaired using a permanent technique which does not discolor, such as replacing the damaged areas with matching stone.

Although many other memorial stones still have damage from vandals or deterioration, it is not recommended that any additional repairs or cleaning be done to them. Many of the memorial stones are fragile and could be damaged, and additional cleaning or repair work at this time is not necessary.

Iron and Steel

Water leaking into the Monument has caused widespread corrosion of the iron and steel frame supporting the stairs, landings and elevator shaft. In the past, corrosion has led to the replacement and repair of structural members, and if allowed to continue it could require more replacement and repair of iron and steel members in the future. The iron and steel appears to be corroded only on the surface, but it could quickly lead to more serious problems if it is not arrested. Surface corrosion develops quickly into more serious problems which will require expensive structural repairs.

Not all of the corroded metal is easily accessible. Some of the worst corrosion appears on the channels supporting the landings and on the angles which are the stringers for the stairs, both of which are against the stone of the walls. In both cases, the face of the channel or angle against the stone is in contact with water running down the walls and is corroding. The corrosion on these faces is inaccessible for repair without dismantling the framing.

Iron and Steel (cont'd)

Parts of the iron and steel framing which are corroding are the channels supporting the landings, the angles which are the stringers for the stairs, the angles against the walls on top of the landings, and four iron "phoenix" columns above the top of each landing. Non-structural metal which is also corroding includes four conduits in the northeast corner where they penetrate the landings and the metal plate which holds them at each landing, and the metal gate at the entry.

Where deterioration is accessible the metal should be repaired. To repair the metal, remove the corrosion by wire brushing or sandblasting. Prime and paint the metal. The corrosion must be completely removed to effectively stop it from spreading. Care must be taken not to damage any of the stone adjacent to metal. Follow proper procedures for removal and disposal of lead-based paint.

As long as water continues to leak into the Monument the metal corrosion will be a serious problem. Any repair to corroded metal will be quickly undone if there is water and high humidity in the Monument. Even if the water problems are solved it is difficult to completely stop metal corrosion, so it is important to monitor the condition of all of the structural iron and steel. We recommend that baseline survey documentation, including photographs and a computerized survey database of all metals and their locations, be prepared; metals surveyed annually for further corrosion; and any corroded metals be painted, repaired and replaced as needed.

Hazardous Materials

Asbestos-containing materials (ACMs) were found throughout the Monument and in the adjacent underground service areas (see the complete report by Dewberry & Davis in Appendix B). Within the Monument itself, ACMs were detected in vinyl floor tile, pipe joint insulation, and transite board. In the underground service areas ACMs were identified in vinyl floor tile, pipe and joint insulation and tank insulation. The ACMs in the mechanical room are severely deteriorated and pose an immediate health hazard.

Exposed friable ACMs which should be removed were identified in the Monument at the 40' and 60' levels. Damaged edges of transite panels enclosing the elevator motor room should be encapsulated to prevent release of ACMs into the air. Other ACMs within the Monument may remain in place and should be monitored as a part of an operations and maintenance plan, but should be abated if restoration or maintenance work will disturb it.

Hazardous Materials (cont'd)

It is recommended that the underground mechanical room be immediately sealed off and entered only by personnel wearing respirators and protective clothing. The guard room also has ACMs on 8 pipe joints, one of which is damaged and is exposing friable asbestos. Air sampling is recommended in the guard room to determine if asbestos fibers have infiltrated from the adjacent mechanical room.

It is recommended that ACM abatement be carried out in areas which have been identified as having friable asbestos. Prior to abatement, It is recommended that protective equipment be used by any personnel working with or around ACMs. Contract a licensed asbestos abatement project designer to prepare construction documents for the removal of ACMs, and contract a licensed asbestos abatement contractor to do abatement work. Written records should be kept on all actions and personnel affecting ACMs.

If ACMs are allowed to remain they should be protected from damage. Notify the staff, maintenance personnel and contractors about the location of ACMs. Conduct periodic inspections to ensure that ACMs remain intact.

Lead-based paint (LBP) was identified in many locations within the Monument. LBP in concentrations that exceed the HUD recommended abatement threshold limit of 0.5% by weight was identified in the following locations: on the handrail at the 0' level, on the stair stringers at the 10' and 470' levels, on the stair support columns at the 10' and 100' levels, on a pipe at the 40' level, and on the ceiling of the underground mechanical room.

The LBP survey was not comprehensive, but it does indicate that there are high levels of LBP throughout the Monument. Any construction or paint removal work on the Monument should be preceded with a thorough survey for LBP in areas where work is to take place. Properly remove and dispose of LBP in areas which are to have construction or paint removal work.

Heating, Ventilating and Air Conditioning System

The heating, ventilating and air conditioning (HVAC) system is ineffective in moderating the levels of humidity in the Monument, but more effective in maintaining even temperatures. During the cooling season of June through August the interior temperature is consistent and even, although it is high for visitor comfort levels, often reaching 85 degrees. Newly-installed air circulating fans above the 500' level landing attempt to moderate this heat. During the heating season of October through May the temperatures in the Monument are also consistent and even, and appropriate for visitors dressed for the outside. The relative humidity levels in the

Heating, Ventilating and Air Conditioning System (cont'd)

Monument are not consistent, however, and vary with the humidity levels on the outside and with the amount of water which has leaked through the walls. The high humidity is causing condensation to form on the stone and metal surfaces on the interior of the Monument, leading to deterioration of these materials.

The worst extremes in temperature and humidity occur during the frequent shutdowns of the mechanical system. These shutdowns occur often, and last for up to a week before the system is operating again. The operation and maintenance of the system, which is performed by the General Services Administration, appears to occur only in response to system failures.
The ineffectiveness of the HVAC system in moderating the humidity in the Monument is worsened by the water leaking through the walls. Some of the swings in the humidity levels are the result of increases in the exterior humidity, but much of it results from water infiltration. It will be almost impossible to effectively control the humidity in the Monument until the leaks are stopped.

The temperature and humidity levels should continue to be monitored, with instruments at the public areas at the 0', 490' and 500' levels, and in the stair hall at 5 to 10 locations. The HVAC system should be adjusted so that the temperature is maintained between 65 and 75 degrees fahrenheit, and the relative humidity is between 30% and 75%. The temperature range should be within 5 degrees fahrenheit throughout the height of the Monument, and the relative humidity should be within 15 percent.

Moderate relative humidity levels will be difficult to maintain as long as water is leaking through the walls. However, the system should be adjusted so that it reduces the humidity to the greatest extent possible until the leakage problem is solved.

But not all of the humidity problems will be solved by stopping the leakage of water into the Monument. Even when there is not water leaking through the walls there are high humidity levels inside the Monument which correspond to high humidity levels on the outside. The severity of these peaks should be monitored to see if the problem continues after the leaks are stopped. If the monitoring indicates that the humidity levels are still high, then a more effective dehumidification method in the HVAC system will be necessary.

We recommend that there be a comprehensive evaluation of the HVAC system. This evaluation should include a review of the design of the system, a study of the air flow in the Monument, an assessment of the condition and effectiveness of the components which make up the system, and recommendations for modifications and repairs to the system.

Heating, Ventilating and Air Conditioning System (cont'd)

The General Services Administration, which operates and maintains the HVAC system in the Monument, should repair and update system components and make seasonal adjustments on a regular basis to ensure that it operates at maximum effectiveness. The system should be maintained regularly so that there are not the frequent shutdowns which we have seen over the last year.

Underground Service Areas

The underground service area to the west of the Monument is made up of a concrete stairs, an areaway, a mechanical room and a guard room. None of these spaces is visited or seen by the public.

The concrete areaway and the concrete stairs leading down to the underground service area are deteriorated. The stairs have been repaired with concrete patches, but the walls have cracks and stains caused by water leaking down from above. The stucco on the wall at the bottom of the stair has deteriorated, exposing the brick wall. The louvers to the mechanical space are corroded. Concrete beams spanning the areaway on the south side of the mechanical room are severely deteriorated.

In the guard room water leaks through the walls onto the floor after a heavy rain. At times standing water forms on the floor, usually as a result of a clogged floor drain.

The stairs, stucco and louvers should be repaired by patching the concrete, repairing the stucco on the wall and replacing the corroded louvers. None of these are structural problems, however, and these areas are not seen by the public, so repairs are not critical at this time.

The concrete beams over the areaway are structurally unsound and should be repaired. Remove the loose and spalled concrete, sand blast the sound concrete and apply new epoxy concrete. Flash over the tops of the beams and along the tops of the areaway curbs with copper or stainless steel to prevent further deterioration from water (see the letter from James Madison Cutts, Consulting Structural Engineers regarding these beams in Appendix A).

We do not know the type, age or condition of the waterproofing on the roof and walls of the underground service area, but it is clear that it has failed. The paving above the underground service area should be removed and the fill against the walls excavated so that the condition of the waterproofing and the roof and walls enclosing the area can be assessed. The structure should then be repaired and rewaterproofed.

Underground Service Areas (cont'd)

The floor drain in the guard room should be kept clear and functioning at all times to minimize the standing water which forms on the floor.

Both the mechanical space and the guard room have deteriorated asbestos-containing material in them. The deteriorated ACMs must be abated, and precautions must be taken by personnel exposed to them. See the recommendations above, under "Hazardous Materials".

Settlement Survey

The settlement survey conducted in June, 1992 indicates that the Monument continues to settle at a slow and even rate (see Appendix C). The average settlement of the Monument since its completion in 1884 is .285', which is less than 3 1/2", and the maximum differential settlement between the four corners is .031', or about 3/8". Since the last survey was conducted in 1984, the average settlement of the four corners has been .008'.

This survey continues to add to the baseline data on the Monument settlement which began in 1879. Surveys should continue to be conducted on a periodic basis. If any grading, excavation or change in the water table is expected in the nearby area, a qualified geotechnical engineer should be consulted to evaluate the effect of the work on the stability of the Monument. Monitor the settlement of the Monument during and after any work of this type. Otherwise, a survey every 5 to 10 years would be an appropriate period to monitor the Monument's settlement.

In addition to using the conventional bench marks at the four corners of the Monument, future surveys should include the stainless steel bench marks which were installed in the sides of the Monument in 1984 by the National Geodetic Survey (NGS). When used with special electronic survey equipment which is available only to NGS, these bench marks can provide highly accurate elevation surveys. Since there are only two of these markers, however, only overall settlement can be surveyed. The four survey markers under the paving at the corners must still be referenced in order to determine differential settlement.

To ensure high accuracy and provide consistency with past surveys, future settlement surveys should originate and terminate from bench marks at the Mall perimeter, and include the Zero Milestone, the reference points at the four corners of the Monument, the two NGS stainless steel bench marks in the wall of the Monument and the obelisk. A survey using the stainless steel pins must be coordinated with NGS.

Settlement Survey (cont'd)

Do not disturb in any way the two stainless steel bench marks in the sides of the Monument, the four reference points at the corners of the Monument, the obelisk to the south of the Monument or any other survey markers in the area. If any paving, grading or other work which might obscure the markers is planned, protect the existing bench marks and provide a means for future access to them.

Maintenance Procedures

The maintenance procedures in the stairhall of the Monument are haphazard and unsupervised. The stairhall is cleaned on a random basis, and the cleaning often is more damaging than helpful. Random, spotty scrubbing of the interior stone has created unsightly patterns on the walls. The use of harsh chemicals to clean the floors and walls can damage the stone and hasten the corrosion of metals. Spatters from careless painting, spilled sealant from HVAC work and litter from maintenance workers mars the stone, the stairs and the landings.

We recommend that all cleaning and maintenance of the Monument be directed and monitored. Supervise all maintenance work done at the Monument to ensure that no damage occurs to the building. Do not tolerate sloppy or negligent work in the Monument. There should be no random scrubbing of walls, mopping of floors, or pressure cleaning which may damage the Monument. We recommend that cleaning of the stairs and landings be done with a minimum of water and mopped dry. If a thorough cleaning of the floors is done, it would need to be repeated only every few months. Clean the interior walls only as described above, under "Interior Masonry". Do not use grinders or any other abrasive method to clean graffiti from the stone. No paint should be allowed to get on stone or any other unpainted surface.

Information File

Records and information regarding the Monument have been dispersed widely and much has been lost. There were many instances in our research for this report where drawings, photographs, specifications and reports which we knew existed at one time could not be found. The information which we did find was in many different locations and was found only by persistence. Work done on the Monument, studies and reports regarding the Monument, and records of the physical condition of the Monument should be easily accessible and available to NPS staff and contractors who are involved with the Monument.

Information File (cont'd)

We recommend that NPS create a central file to contain all available information on the Monument. Include in this file previous reports on the Monument, data and interpretation from monitoring programs, records of proposed and completed work, maintenance procedures and records, and photographs and drawings. Add to the file copies of all new work and studies which relate to the Monument. Include bibliographic sources or copies of all published and unpublished materials available at the National Archives, the Library of Congress, various NPS sites, and other locations. The file should be a comprehensive collection of all information regarding the Monument, and no information should be allowed to be lost or destroyed.

Maintain an accurate catalog of the information contained in the file. The file can be maintained either by a computer information storage file system or by a conventional system of information management. Make the file available to all NPS personnel and contractors who are involved with the Monument. It is important to have continuity in the management of the Monument, and any time a problem is being investigated all the available information regarding the problem should be readily accessible.

VII. BUDGET ESTIMATES

VII. BUDGET ESTIMATES

The following list and budget pricing of recommended work for the Monument is divided into four categories. Priority "A" work is top priority work. This work should be done immediately. Postponing this work will cause damage to the Monument or will create a hazard to the public or the staff at the Monument.

Priority "B" work is not as urgent as Priority "A" work, but it should be done soon or the problems will eventually cause damage to the Monument. The water leaking into the Monument is causing many of these problems, so it is best to do this work after the leaks are stopped.

Priority "C" work concerns problems in the Monument which are not threatening to cause additional damage.

Priority "D" work is cyclical maintenance or monitoring work. This is ongoing work which should be anticipated in each annual budget and performed on a regular basis.

Priority "A" - Top Priority

Document existing conditions, install, monitor and interpret movement and temperature monitors on cracks above 450' level for a minimum of 5 years	$50,000
Seal 7000 linear feet of joints with double layer of sealant	$140,000
Point 57000 linear feet of joints	$684,000
Repair 1000 s.f. chipped and patched stone	$45,000
Seal 31 linear feet of cracks above 450' level	$465
Seal 470 linear feet of cracks, 160' to 240' level	$7,050
Flash and seal 8 aircraft warning lights, 14" diameter	$800
Flash and seal 8 windows	$1,600
General conditions, swing stage access	$200,000
Abate damaged or friable asbestos-containing material	$26,500

Priority "A" - Top Priority (cont'd)

Survey and abate Lead-Based Paint in construction areas.	Cost Varies
Waterproof ceilings and walls of underground service areas.	$21,000
Evaluate HVAC system	$20,000
TOTAL PRIORITY A, PLUS LEAD PAINT ABATEMENT:	$1,196,415

Priority "B" - High Priority

Remove corrosion, prep, prime and paint metal -angle on landings at wall- 2308 linear feet -channel stair stringer at wall- 912 linear feet -Conduits at 50 landings -6" x 16" plate at 50 landings -Miscellaneous corrosion, typical 6" x 6" at 100 locations -Entry gate - 6' x 8'	$125,000
Reset 41 memorial stones	$82,000
Repair 2 cracked memorial stones	$1,000
Repair concrete at underground service area mechanical room	$7,000
TOTAL PRIORITY B:	$215,000

Priority "C" - Low Priority

Repoint 3900 linear feet of interior masonry joints	$58,500
Clean interior walls (59,000 square feet)	$91,450
Restucco wall at stairs to underground service areas (60 square feet)	$1,500
Replace louvers at mechanical room (2 @ 18" x 18")	$1,000
TOTAL PRIORITY C:	$152,450

Priority "D" - Work to be Performed Cyclically

Asbestos-containing material monitoring and maintenance program (ongoing)	
Survey of cracks in masonry (annual)	
Survey of condition of metal framing (annual)	
Establish and maintain central information file (ongoing)	
Assess, repair and adjust HVAC system (seasonal)	
Settlement Survey (Every 5-10 years)	
TOTAL PRIORITY D ANNUAL BUDGET:	$25,000

VIII. ILLUSTRATIONS

Figures

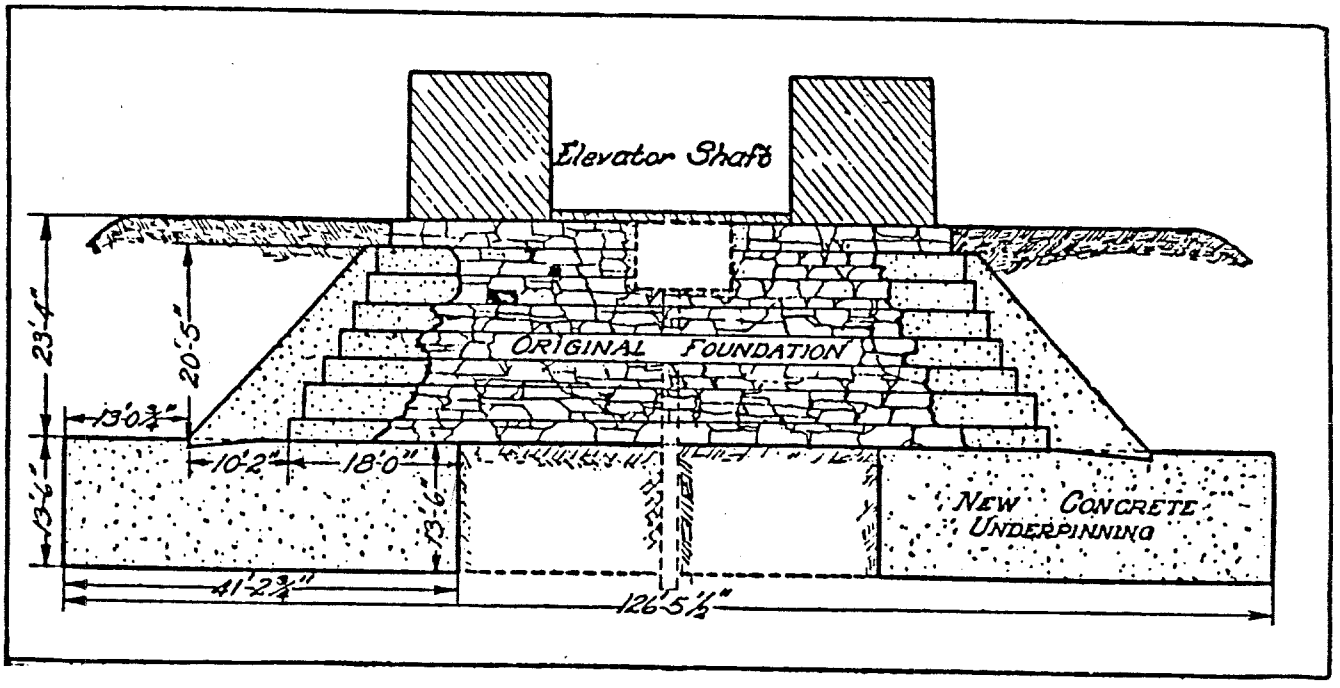

Figure 1. Section of the completed foundation as constructed, showing concrete buttresses and underpinning which were completed in 1880. Scale 1" = 20'. Society of American Military Engineers, The Washington Monument, (Washington, D.C.: Society of American Military Engineers), 1929, p. 17.

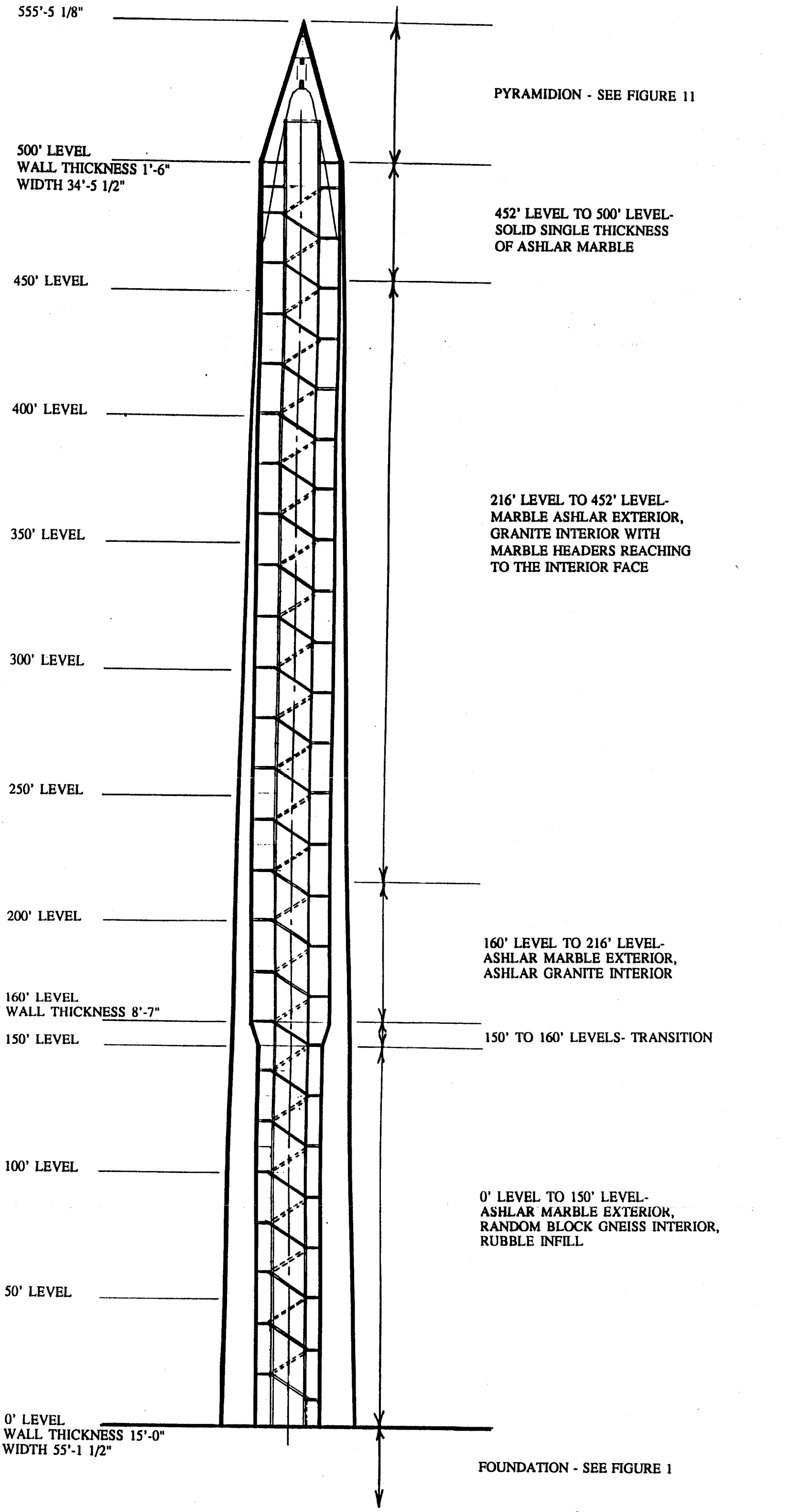

Figure 2. Section of the Washington Monument shaft and pyramidion, indicating the different types of construction. Drawing by Oehrlein & Associates Architects.

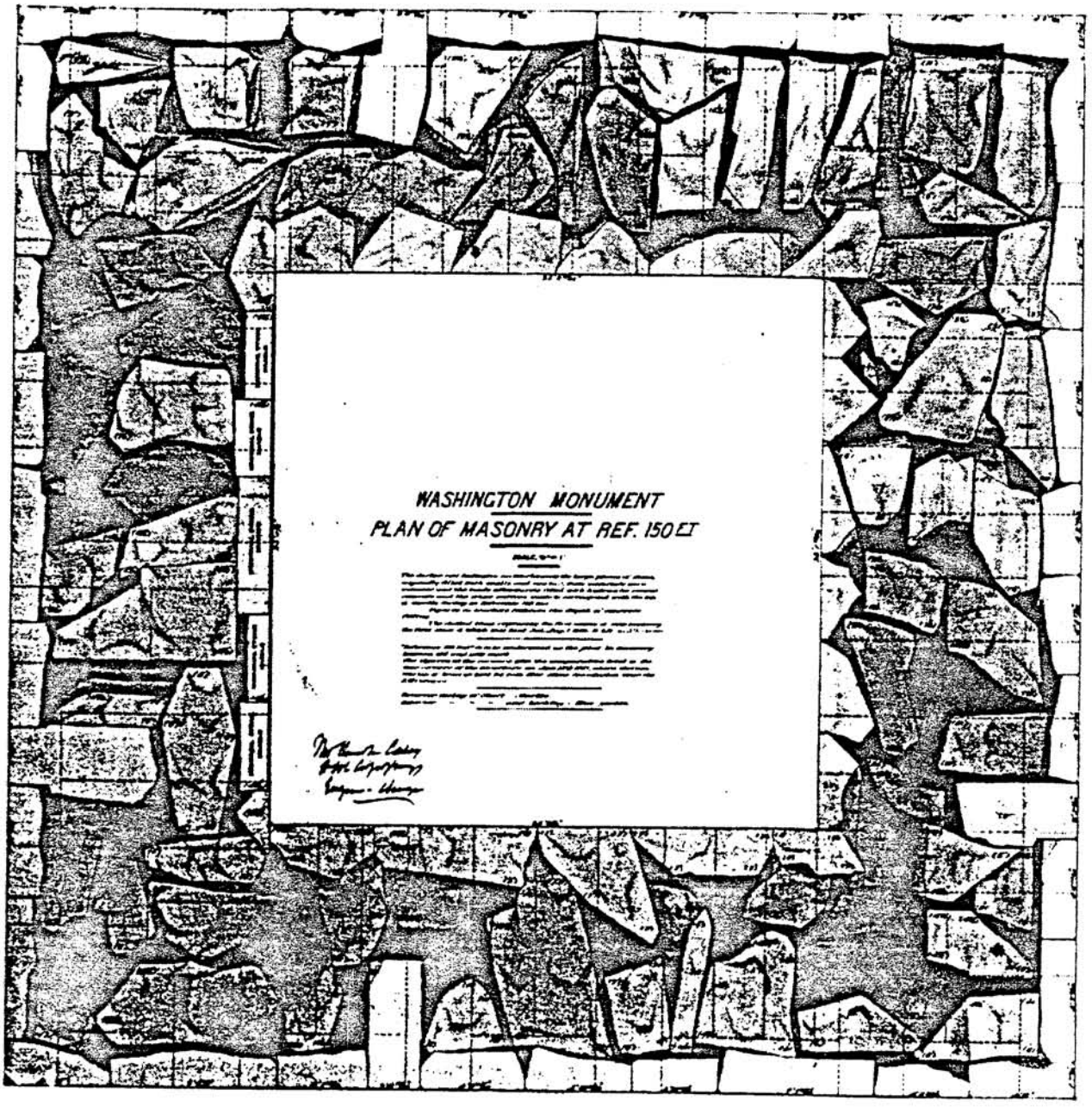

Figure 3. 150' level plan of masonry. The shaft up to this level was completed in the first phase of construction before construction halted in 1854. The old masonry was consolidated at this level and construction continued up from here in 1880. National Archives, Record Group 79, file 74.2-203. Original scale 1/2" = 1'-0", reduced to approximately 1/8" = 1'-0."

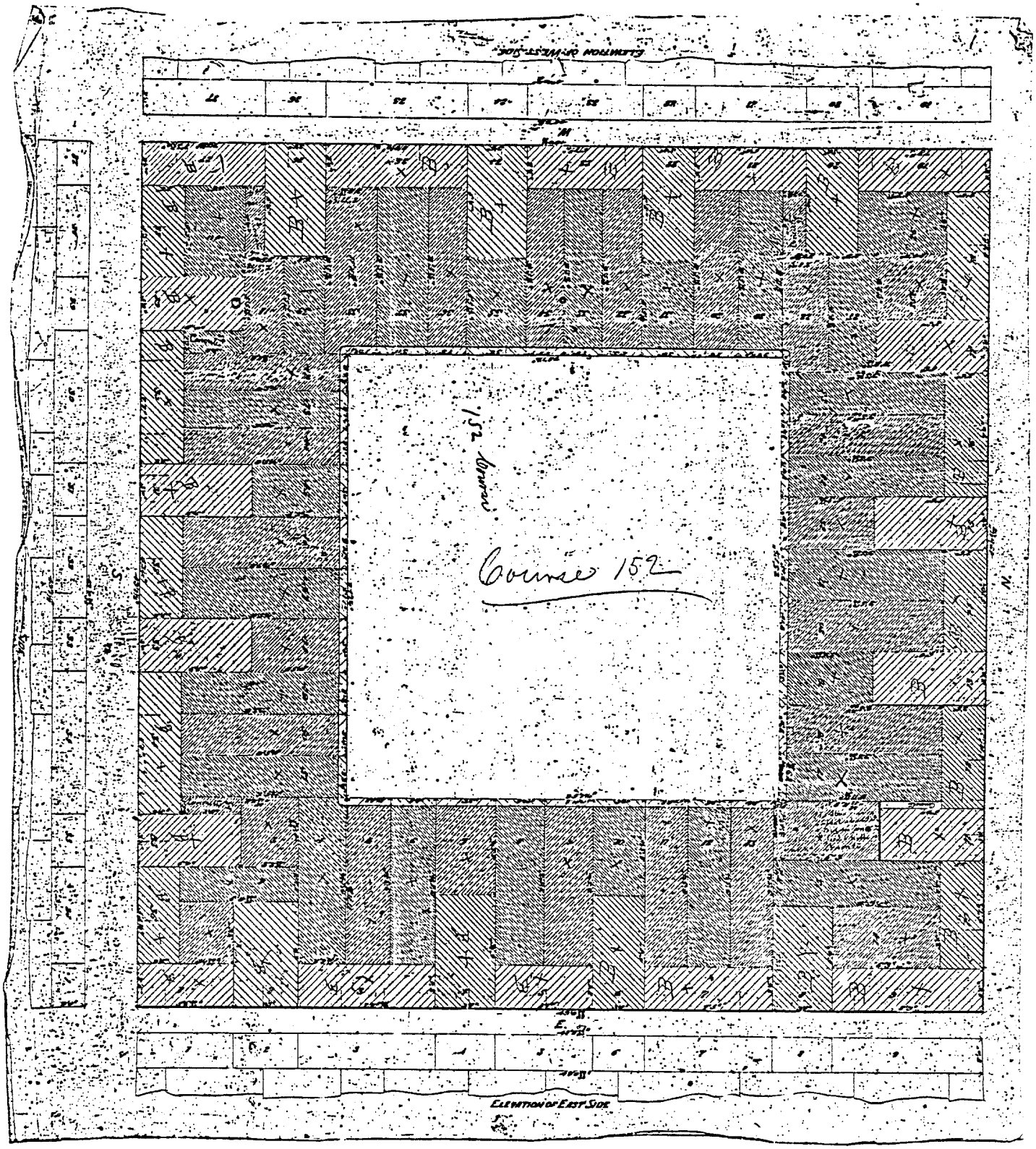

Figure 4. 152' level plan of masonry. Working drawing with dimensions of each stone. Shading patterns indicate marble on the exterior, a granite veneer on the interior and granite blocks between. National Archives, Record Group 79, file 78-8. Original scale 1/2" = 1'-0", reduced to approximately 1/8" = 1'-0."

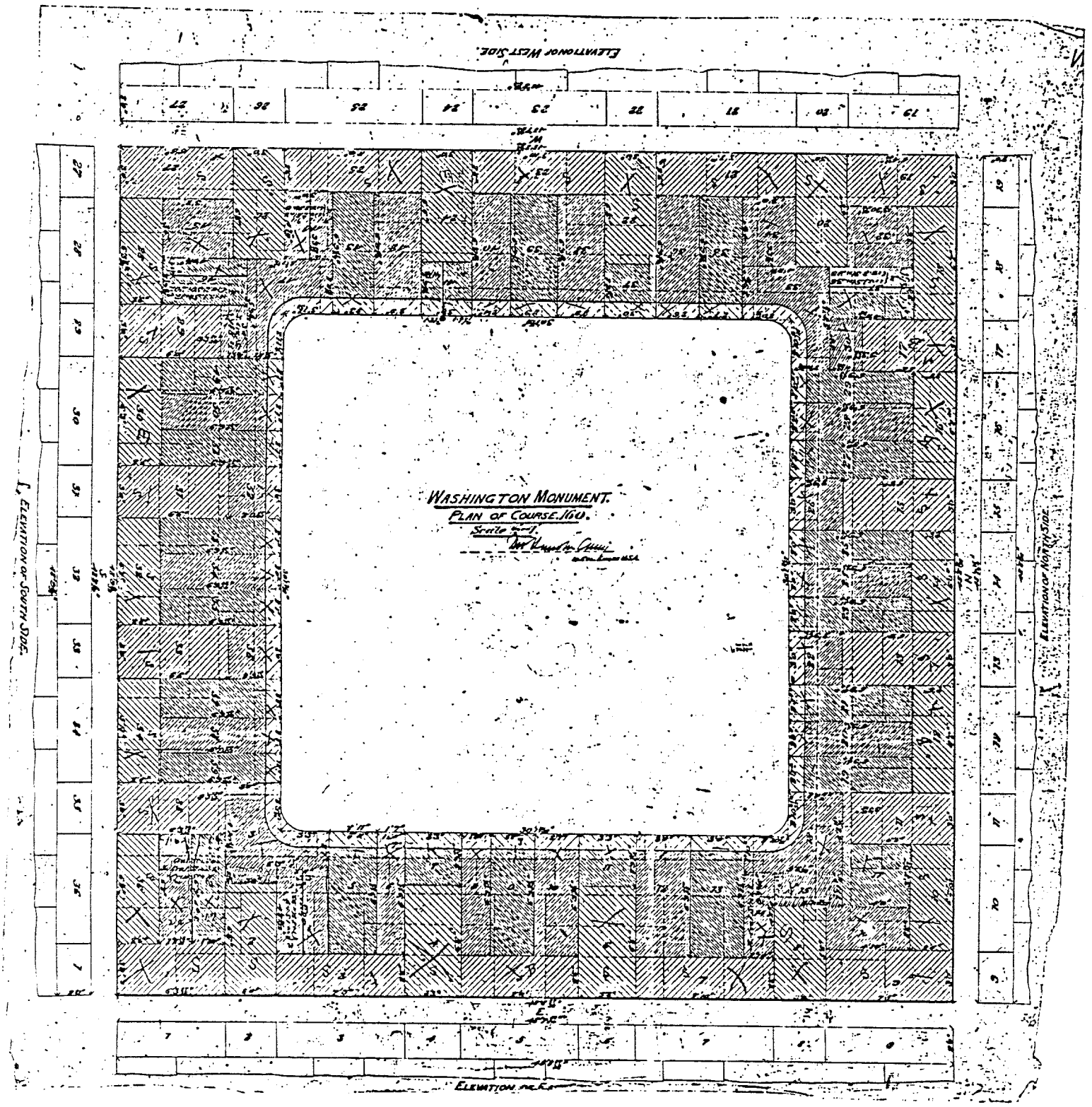

Figure 5. 160' level plan of masonry with 158' level stones dotted in to show the bonding of courses. Shading patterns indicate marble on the exterior, a granite veneer on the interior and granite blocks between. National Archives, Record Group 79, file 74-8. Original scale 1/2" = 1'-0", reduced to approximately 1/8" = 1'-0".

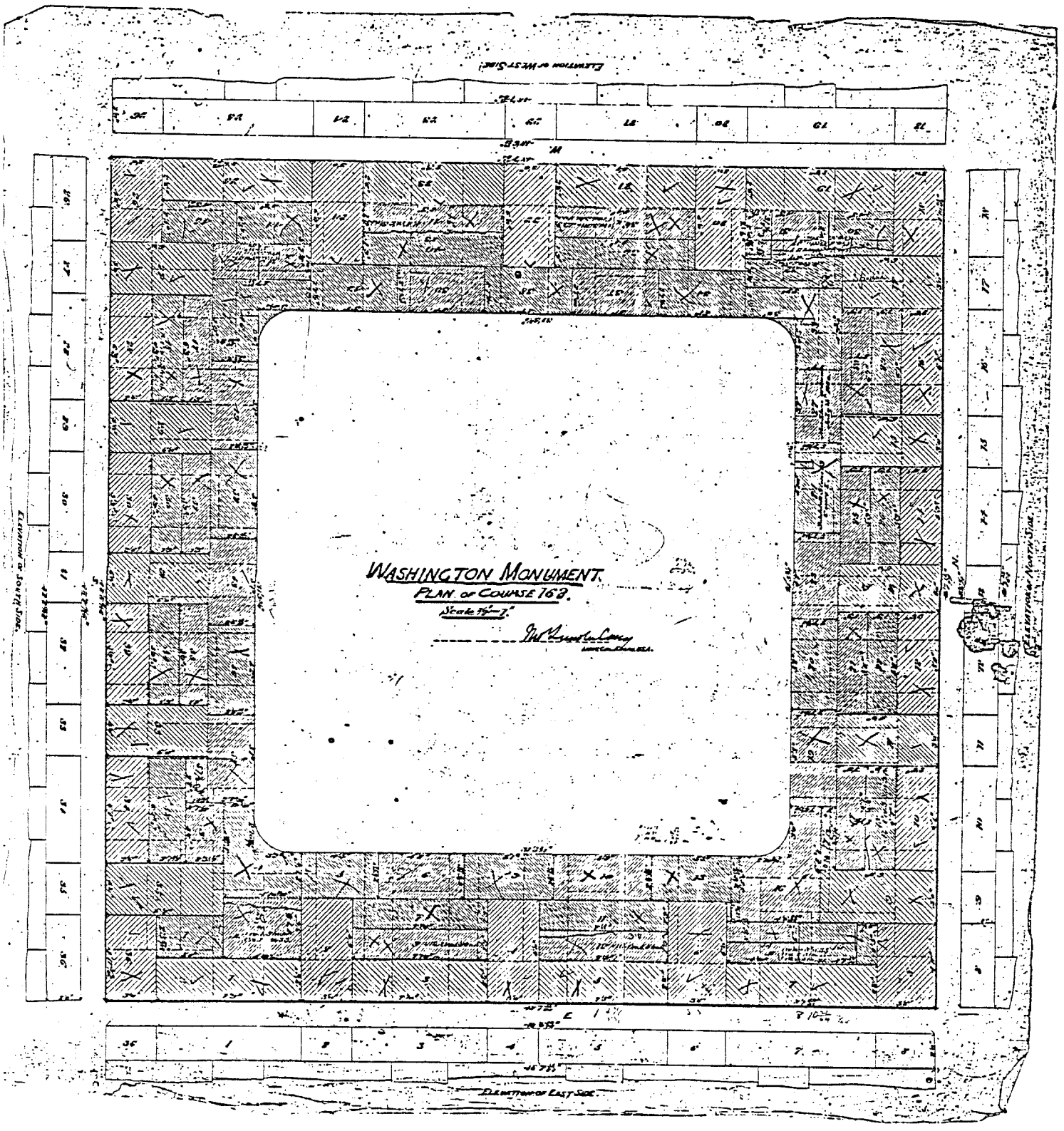

Figure 6. 162' level plan of masonry with 160' level stones dotted in to show the bonding of courses. Shading patterns indicate marble exterior and granite interior. National Archives, Record Group 79, file 74-8. Original scale 1/2" = 1'-0", reduced to approximately 1/8" = 1'-0".

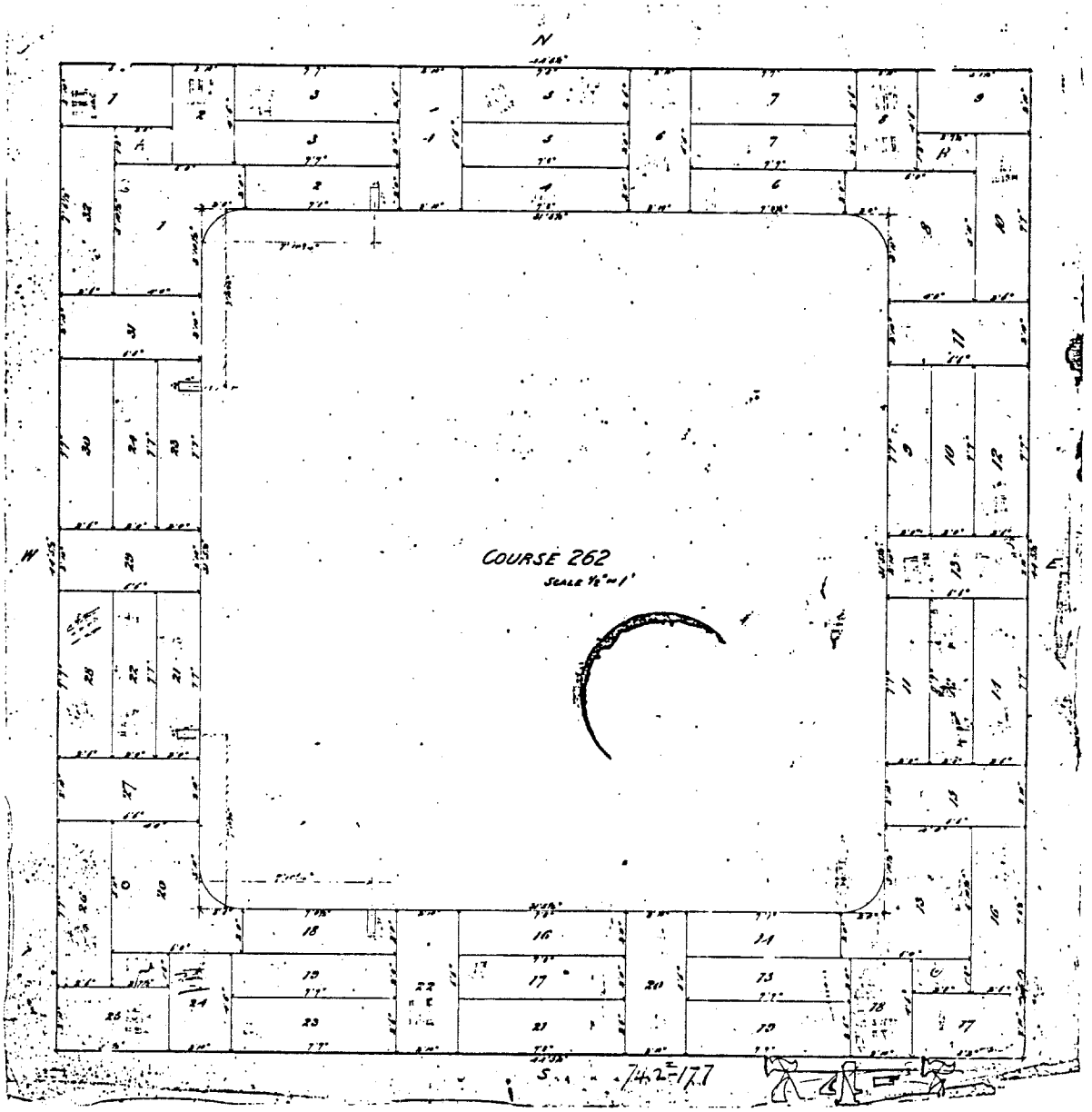

Figure 7. 262' level plan of masonry. Marble exterior and granite interior, with marble headers reaching to the interior face. National Archives, Record Group 79, file 74.2-177. Original scale 1/2" = 1'-0", reduced to approximately 1/8" = 1'-0".

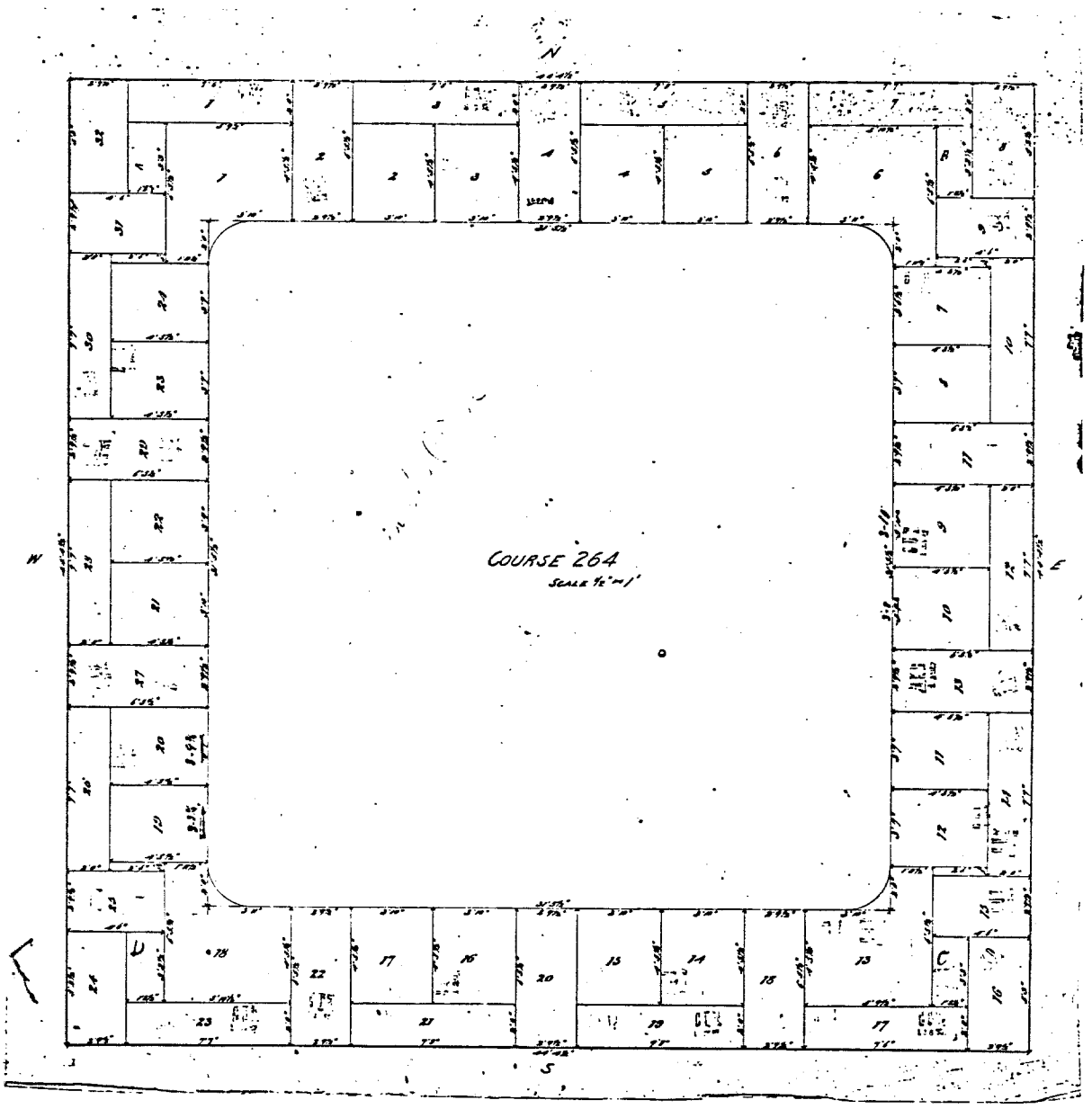

Figure 8. 264' level plan of masonry. Marble exterior and granite interior, with marble headers reaching to the interior face. National Archives, Record Group 79, file 74.2-177. Original scale 1/2" = 1'-0", reduced to approximately 1/8" = 1'-0".

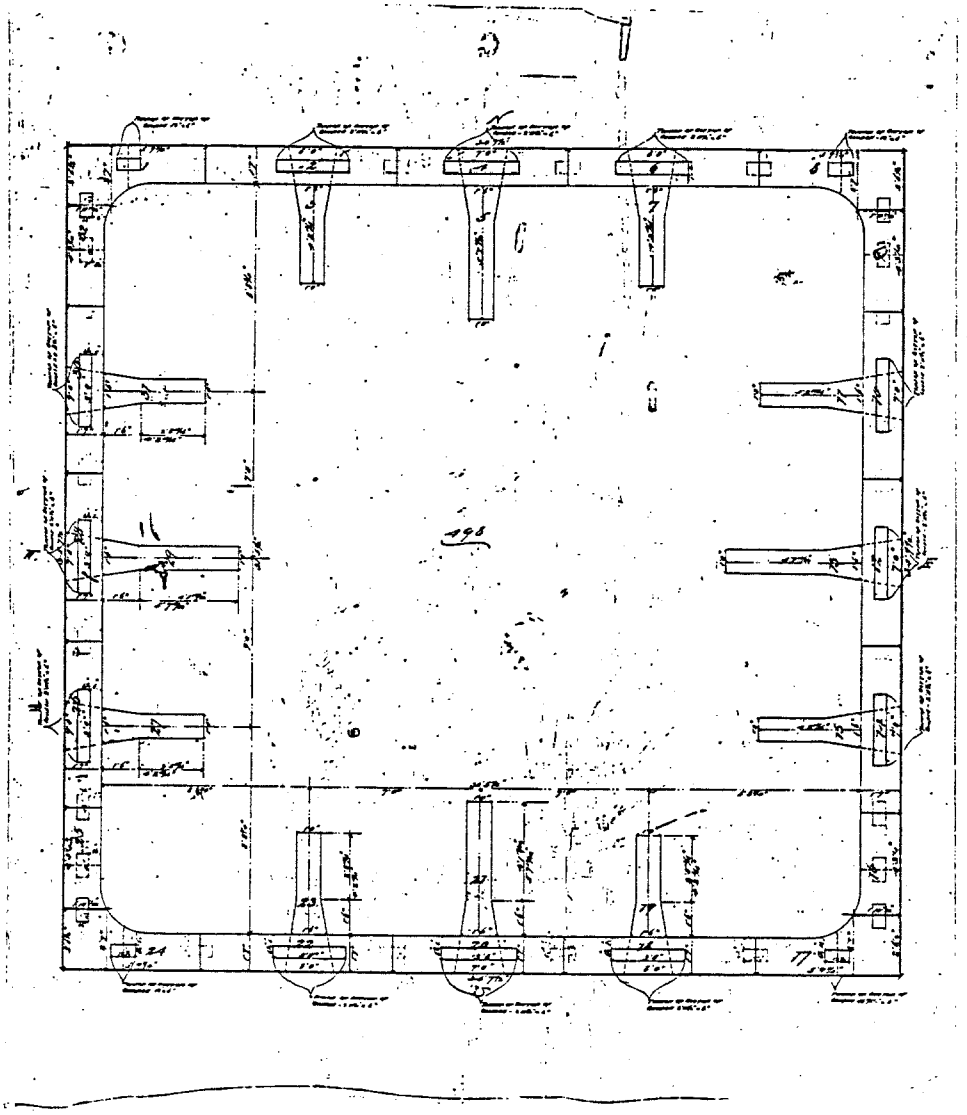

Figure 9. 498' level plan of masonry. Walls are a single thickness of marble with tenons into the course below. The twelve ribs support the walls of the pyramidion. National Archives, Record Group 79, file 74.2-182. Original scale 1/2" = 1'-0", reduced to approximately 1/8" = 1'-0".

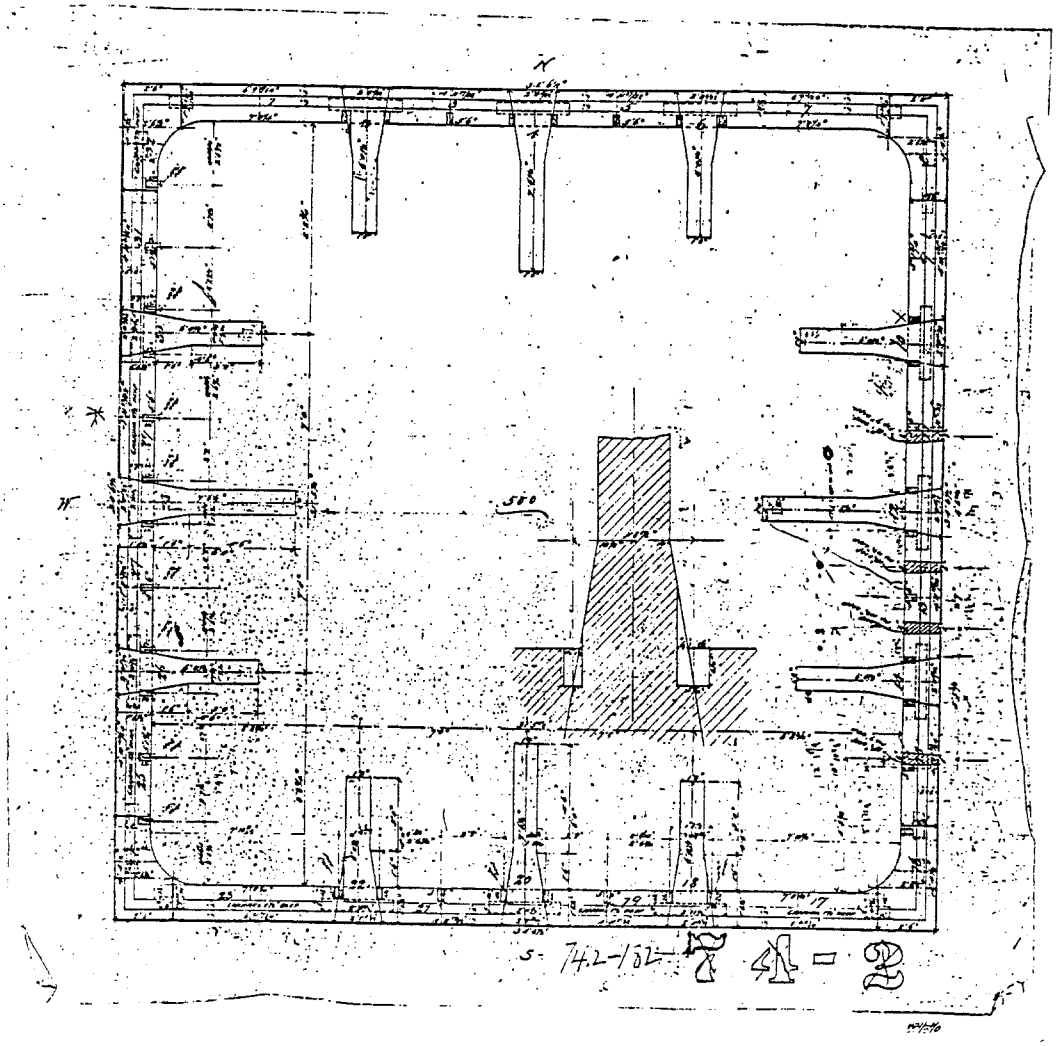

Figure 10. 500' level plan of masonry. The walls are a single thickness of marble with tenons into the course below. The twelve ribs support the walls of the pyramidion. A 1 1/2" deep channel in the top of the stone receives the bottom course of the walls of the pyramidion. National Archives, Record Group 79, file 74.2-182. Original scale 1/2" = 1'-0", reduced to approximately 1/8" = 1'-0".

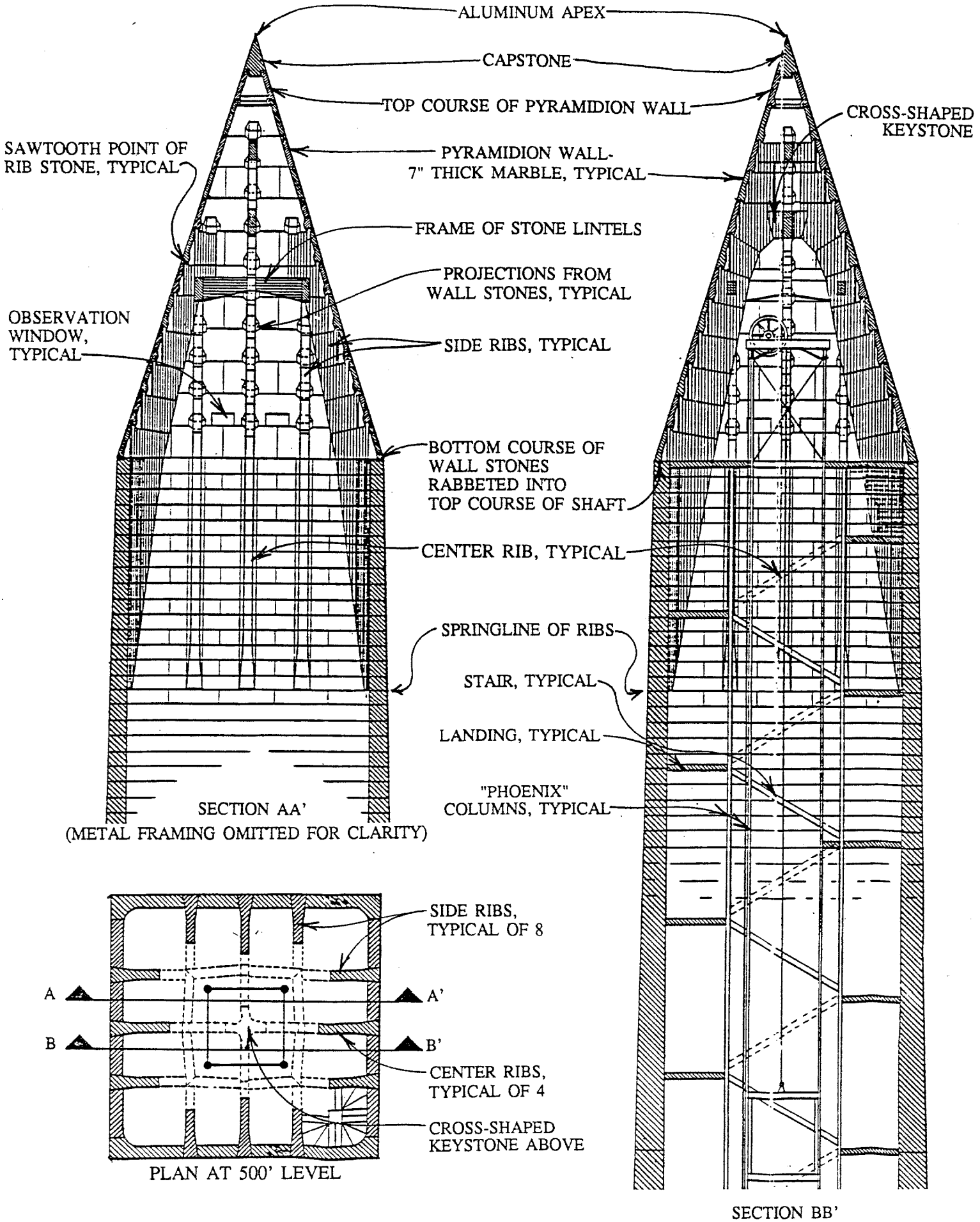

Figure 11. Sections and plan of pyramidion. Drawing by Engineering Office of the Washington Monument, Thomas Lincoln Casey Engineer in Charge, 1884. National Archives, Record Group 79. Notes on drawing by Oehrlein & Associates Architects.

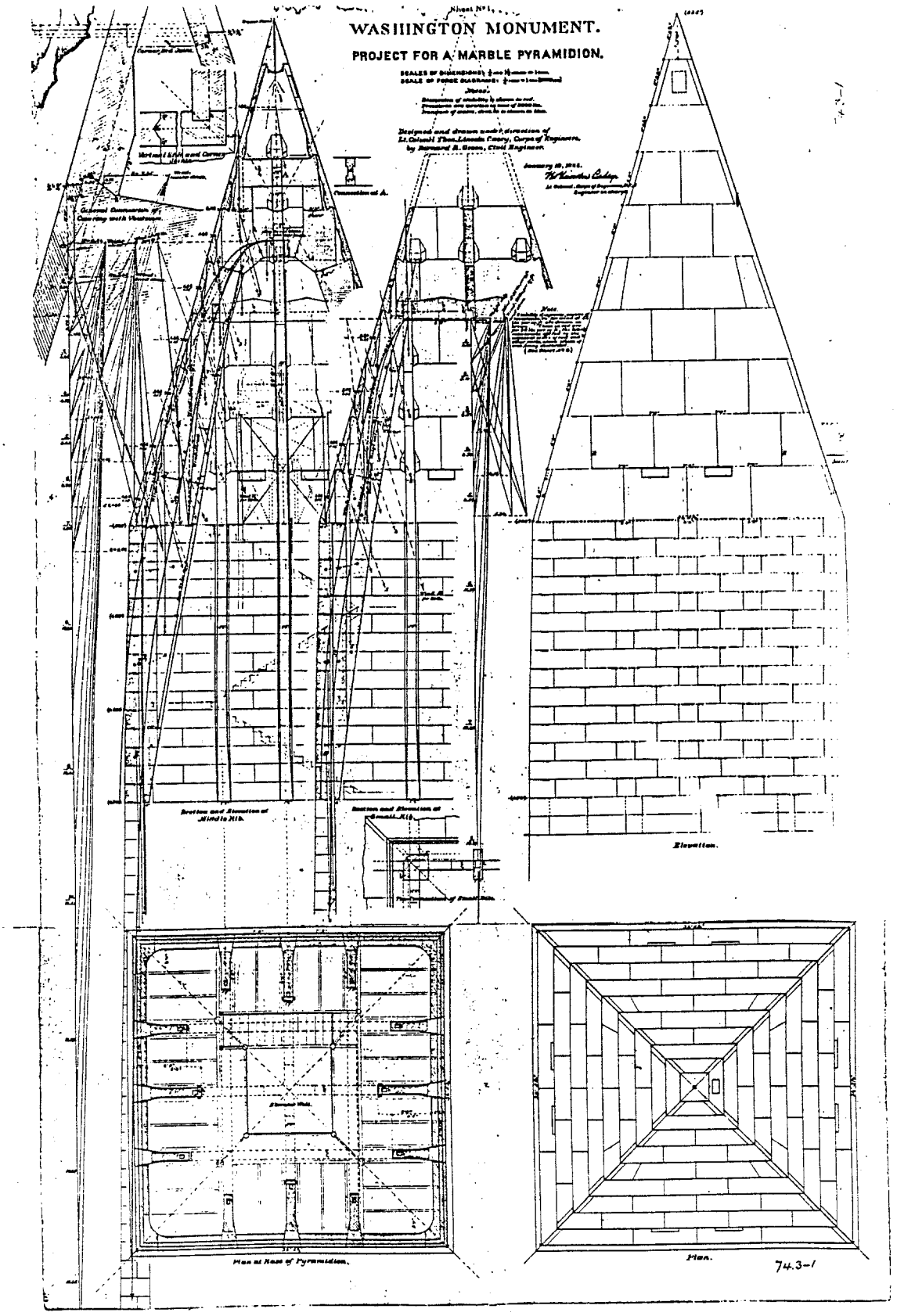

Figure 12. Study drawing for the construction of the pyramidion. Details in the upper left corner show the joints between stones of the pyramidion walls and the connections between the stones of the walls and the stones of the ribs. Drawn by Bernard Green under the direction of Thomas Lincoln Casey, January 19, 1884. National Archives, Record Group 79, File 74.3-1.

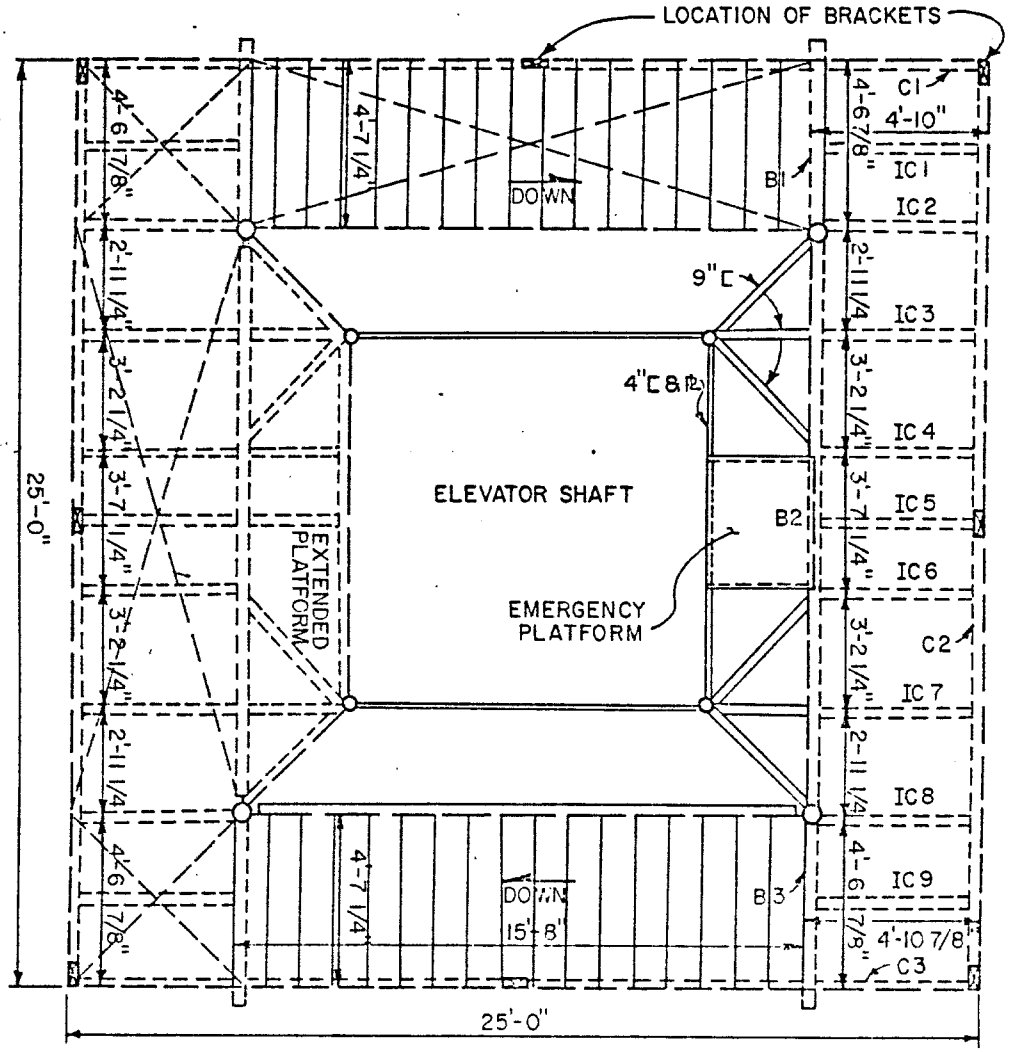

Figure 13. Typical stair and landing framing plan, 30' level through 150' level. The existing framing is a combination of the original iron and replacement steel. Scale 3/16" = 1'-0". Robinson Engineering, Interior Structural and Mechanical Analysis, 1973.

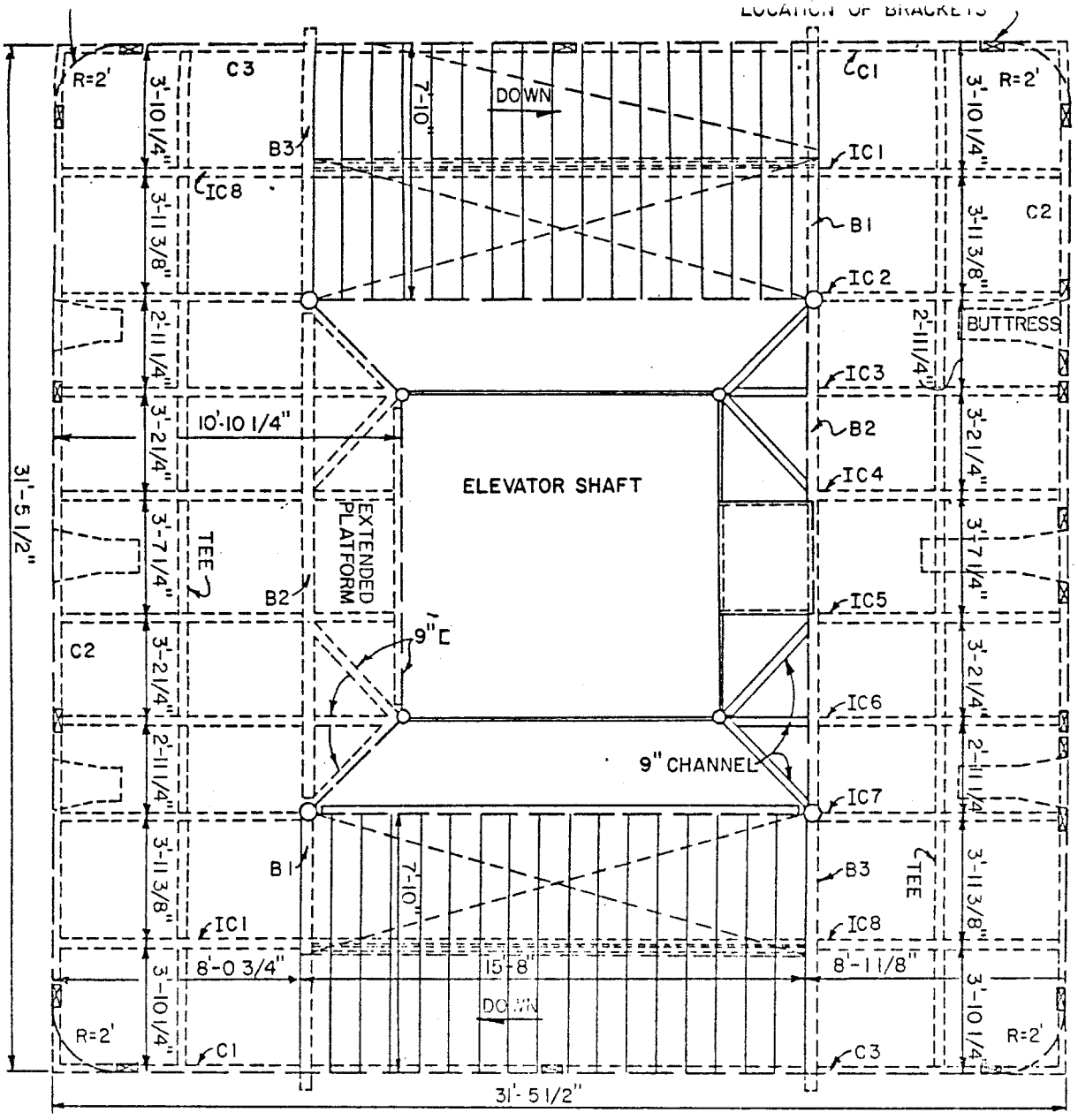

Figure 14. Typical stair and landing framing plan, 160' level to 490' level. The existing framing is a combination of the original iron and replacement steel. Scale 3/16" = 1'-0". Robinson Engineering, Interior Structural and Mechanical Analysis, 1973.

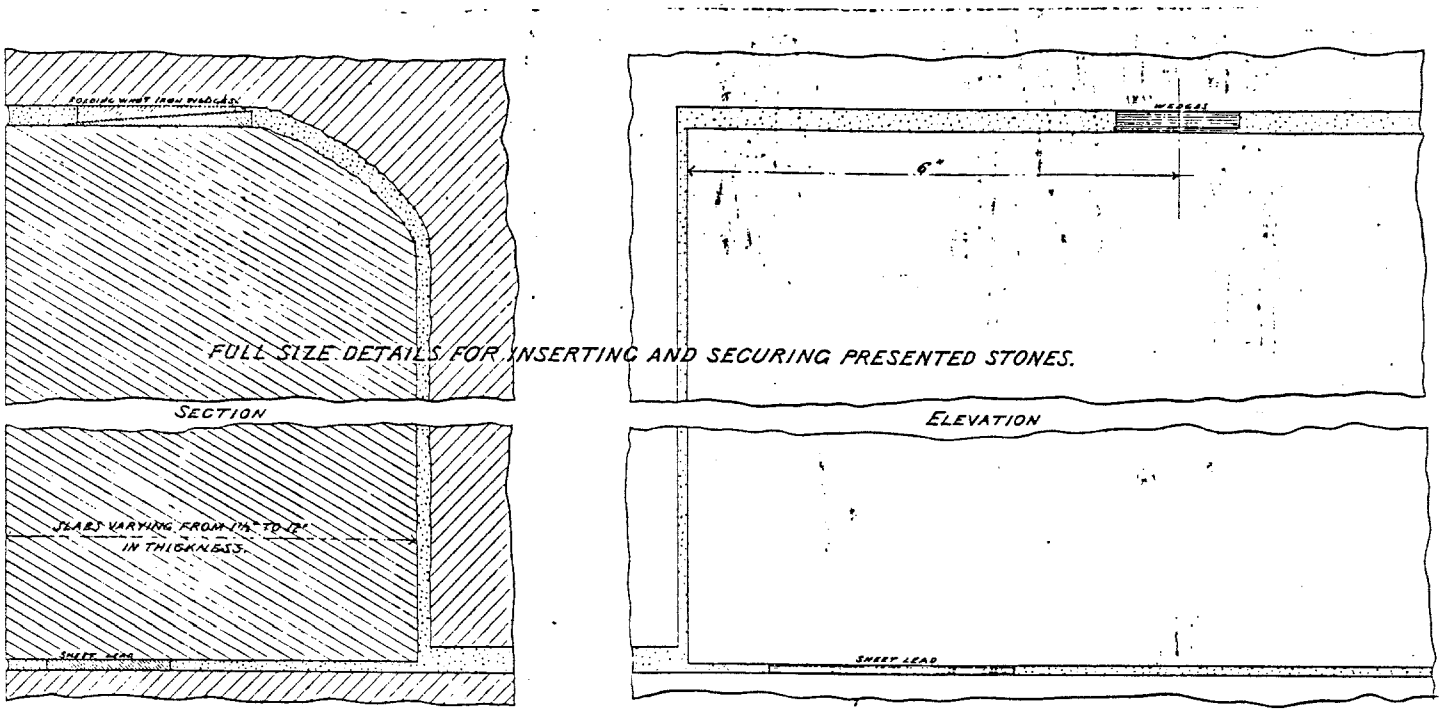

Figure 15. Memorial stone attachment details. Many of the wrought iron wedges shown in this detail have corroded and are damaging the surrounding stone. National Archives, Record Group 79.

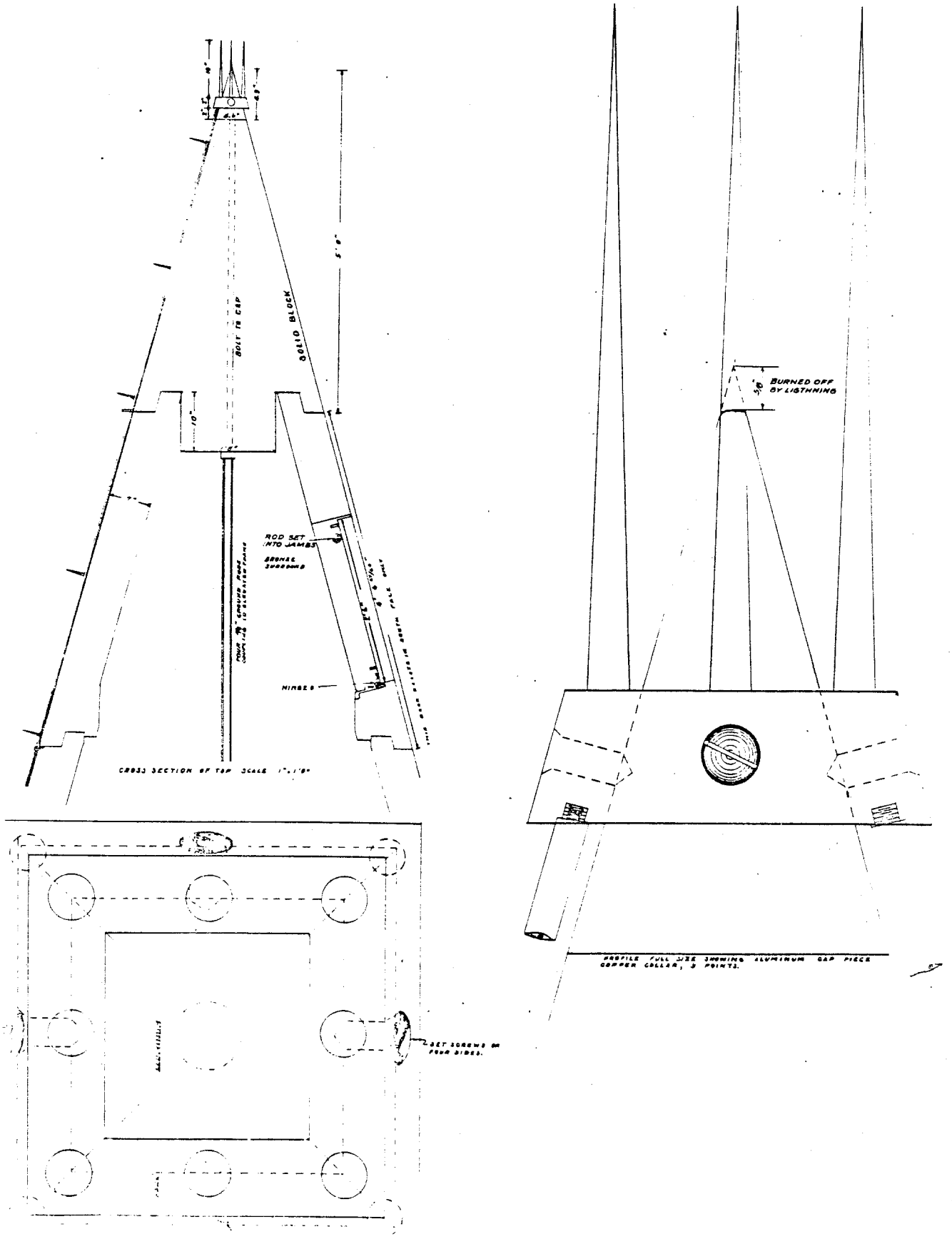

Figure 16. Lightning protection system. This system was installed in 1934 and is still in use today. NCP Files.

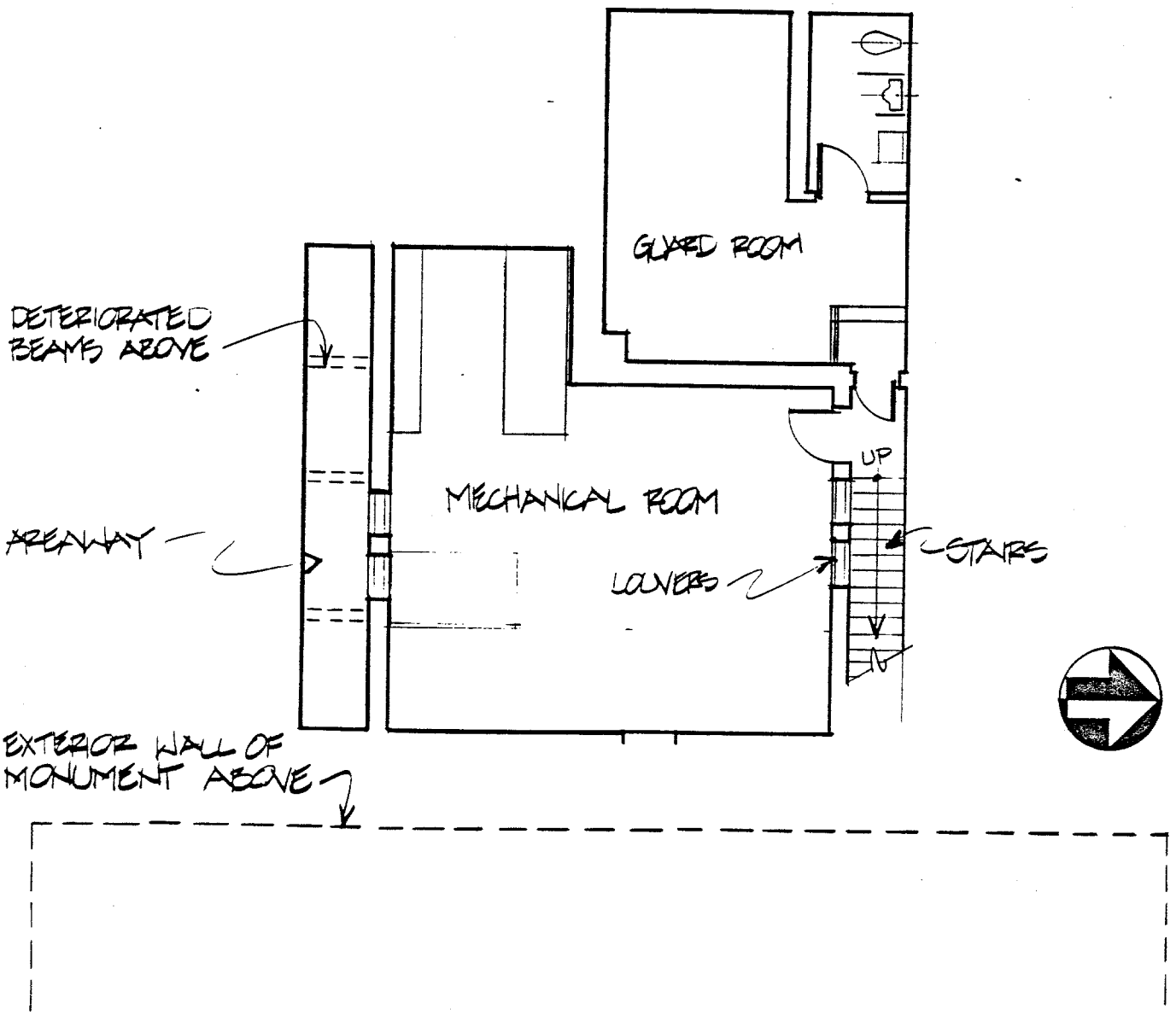

Figure 17. Plan of underground service area to the west of the Monument. Both the guard room and the mechanical room have exposed friable asbestos. Water infiltration has caused deterioration of stucco walls and concrete beams, walls and steps. Scale 1/8" = 1'-0". Drawing by Oehrlein & Associates Architects.

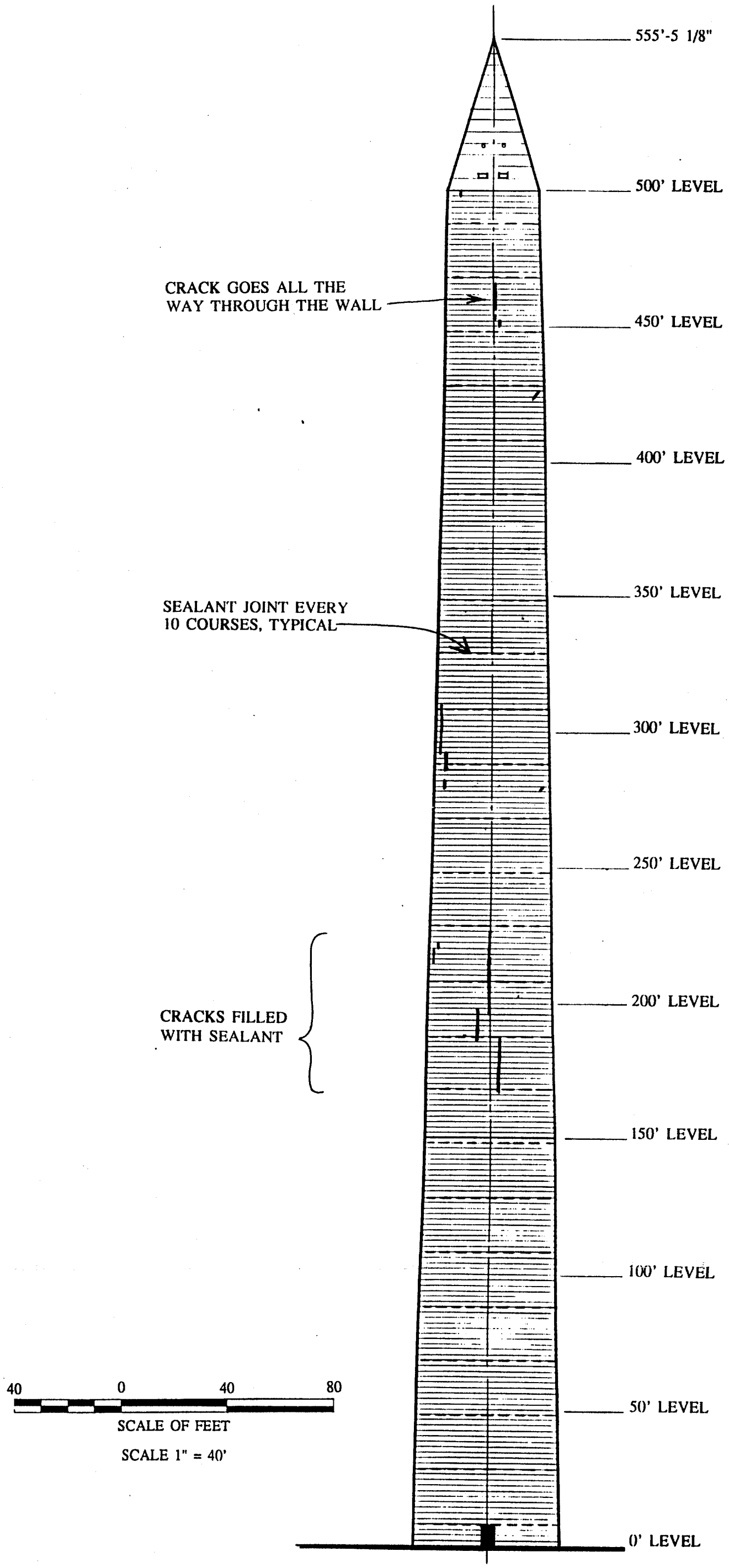

Figure 18. East elevation crack survey, April 23, 1992. The vertical lines indicate cracks which were visible from the ground using 10 x 25 binoculars. Drawing by Oehrlein & Associates Architects.

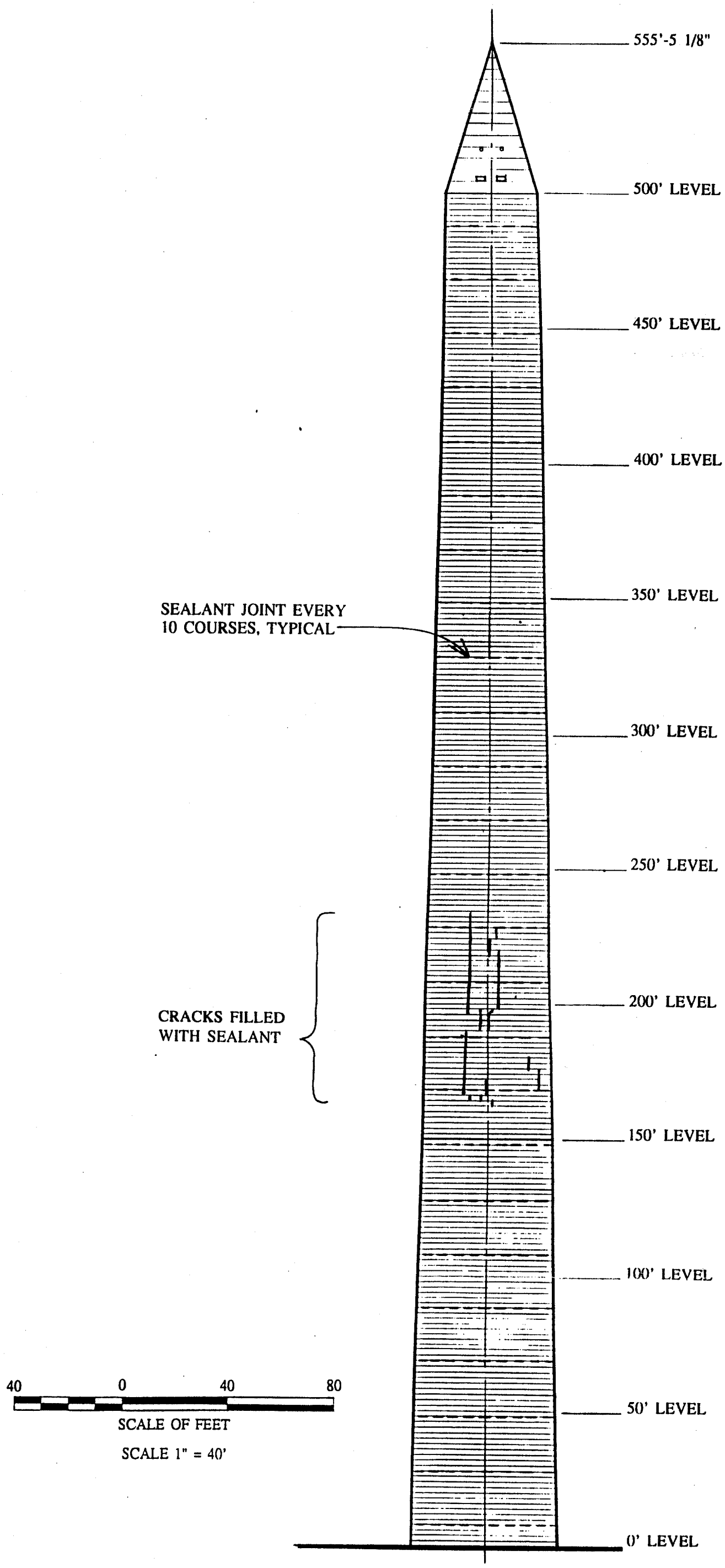

Figure 19. North elevation crack survey, April 23, 1992. The vertical lines indicate cracks which were visible from the ground using 10 x 25 binoculars. Drawing by Oehrlein & Associates Architects.

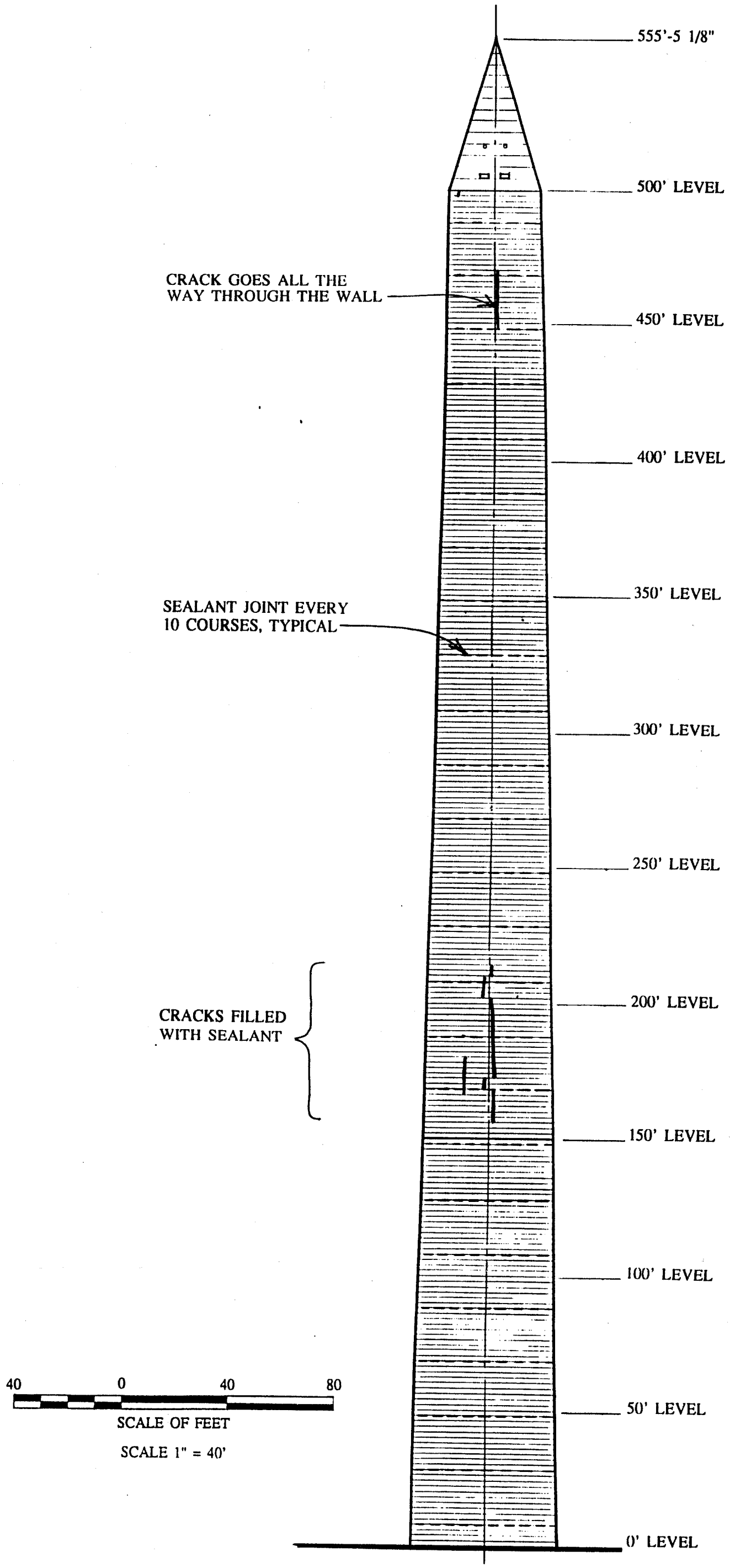

Figure 20. West elevation crack survey, April 23, 1992. The vertical lines indicate cracks which were visible from the ground using 10 x 25 binoculars. Drawing by Ochrlein & Associates Architects.

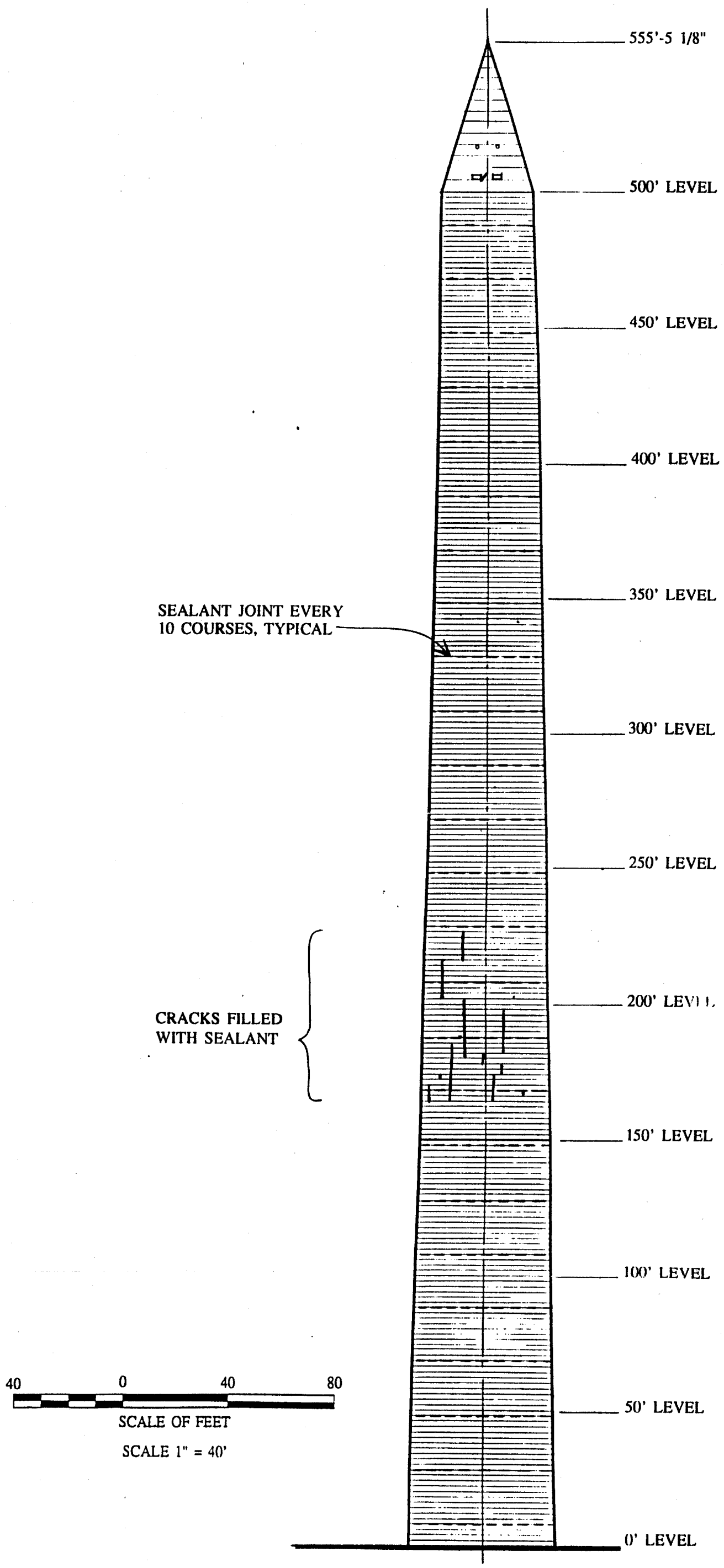

Figure 21. South elevation crack survey, April 23, 1992. The vertical lines indicate cracks which were visible from the ground using 10 x 25 binoculars. Drawing by Oehrlein & Associates Architects.

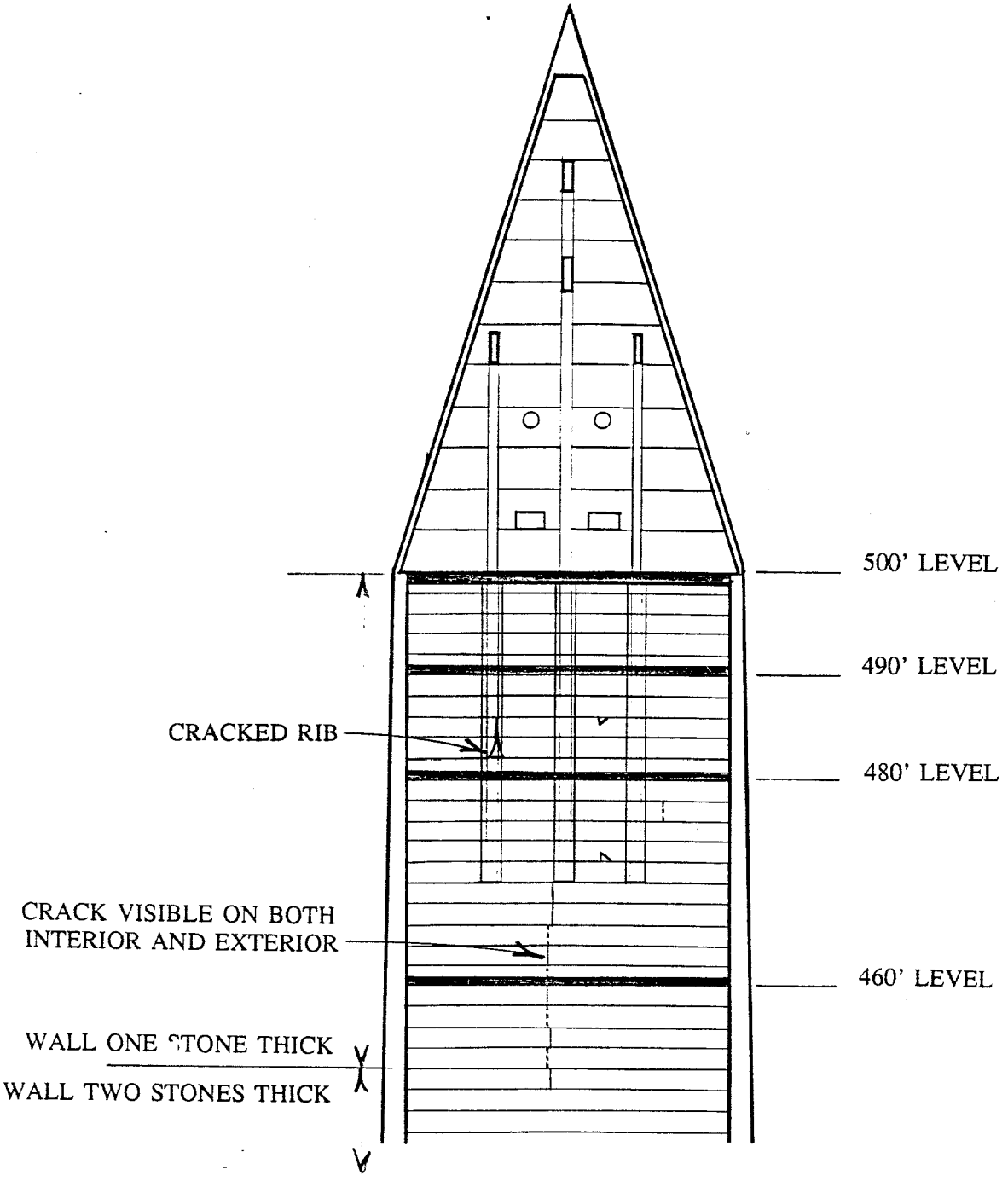

Figure 22. West wall interior crack survey, August 25, 1992. Dotted lines indicate where a crack follows joints between stones. Scale 1/16" = 1'-0". Drawing by Oehrlein & Associates Architects.

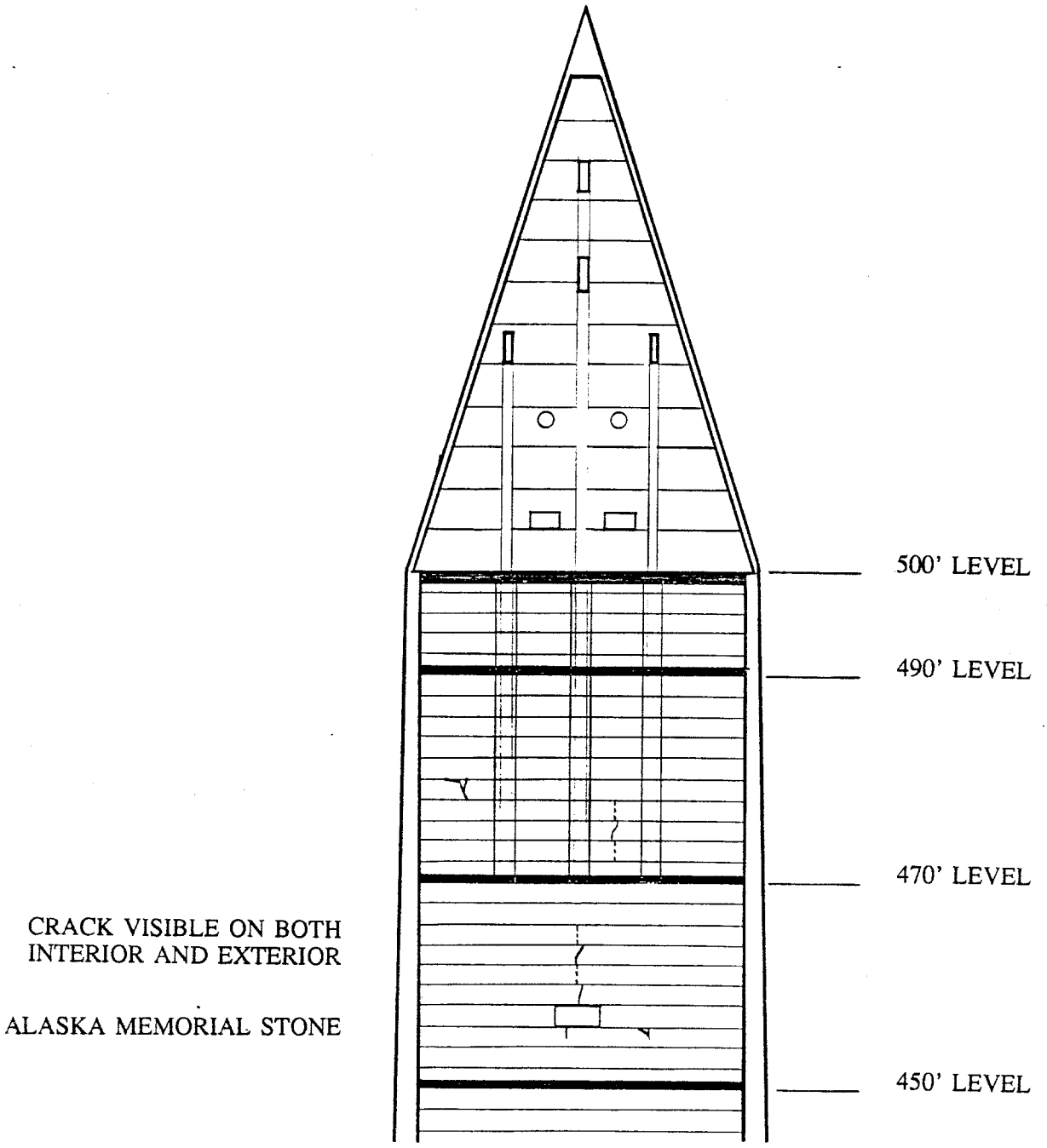

Figure 23. East wall interior crack survey, August 25, 1992. Dotted lines indicate where a crack follows joints between stones. Scale 1/16" = 1'-0". Drawing by Oehrlein & Associates Architects.

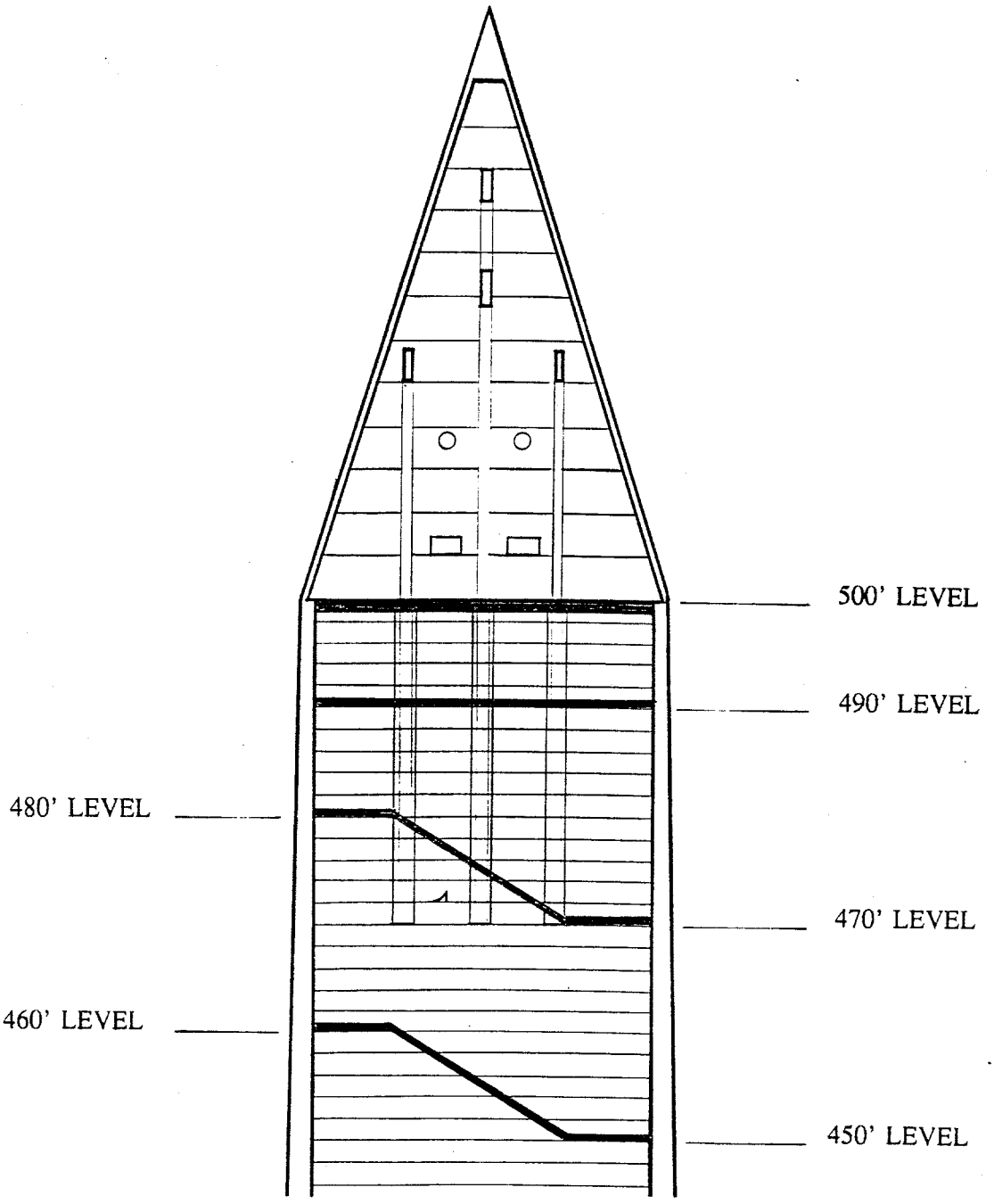

Figure 24. North wall interior crack survey, August 25, 1992. Scale 1/16" = 1'-0". Drawing by Oehrlein & Associates Architects.

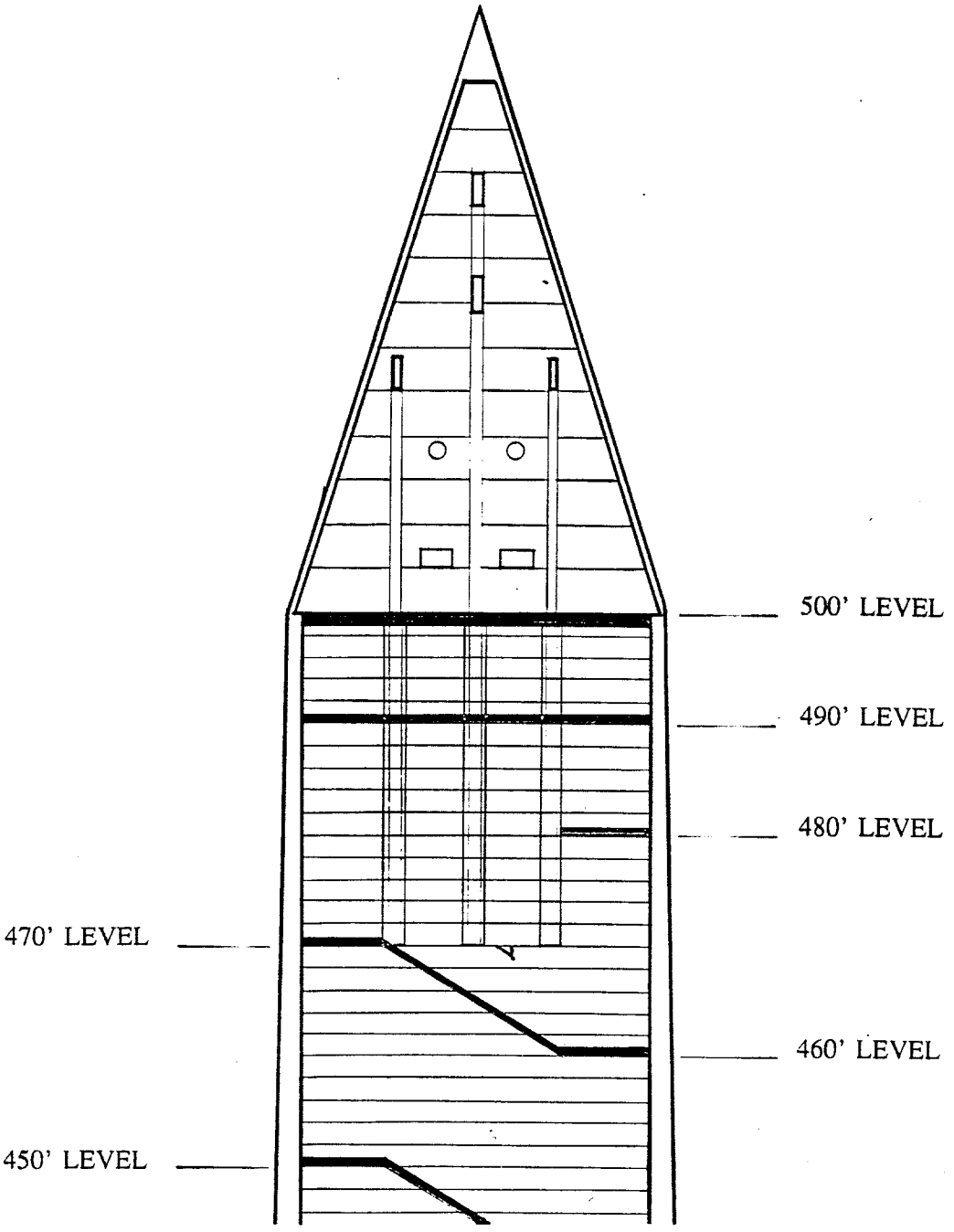

Figure 25. South wall interior crack survey, August 25, 1992. Scale 1/16" = 1'-0". Drawing by Oehrlein & Associates Architects.

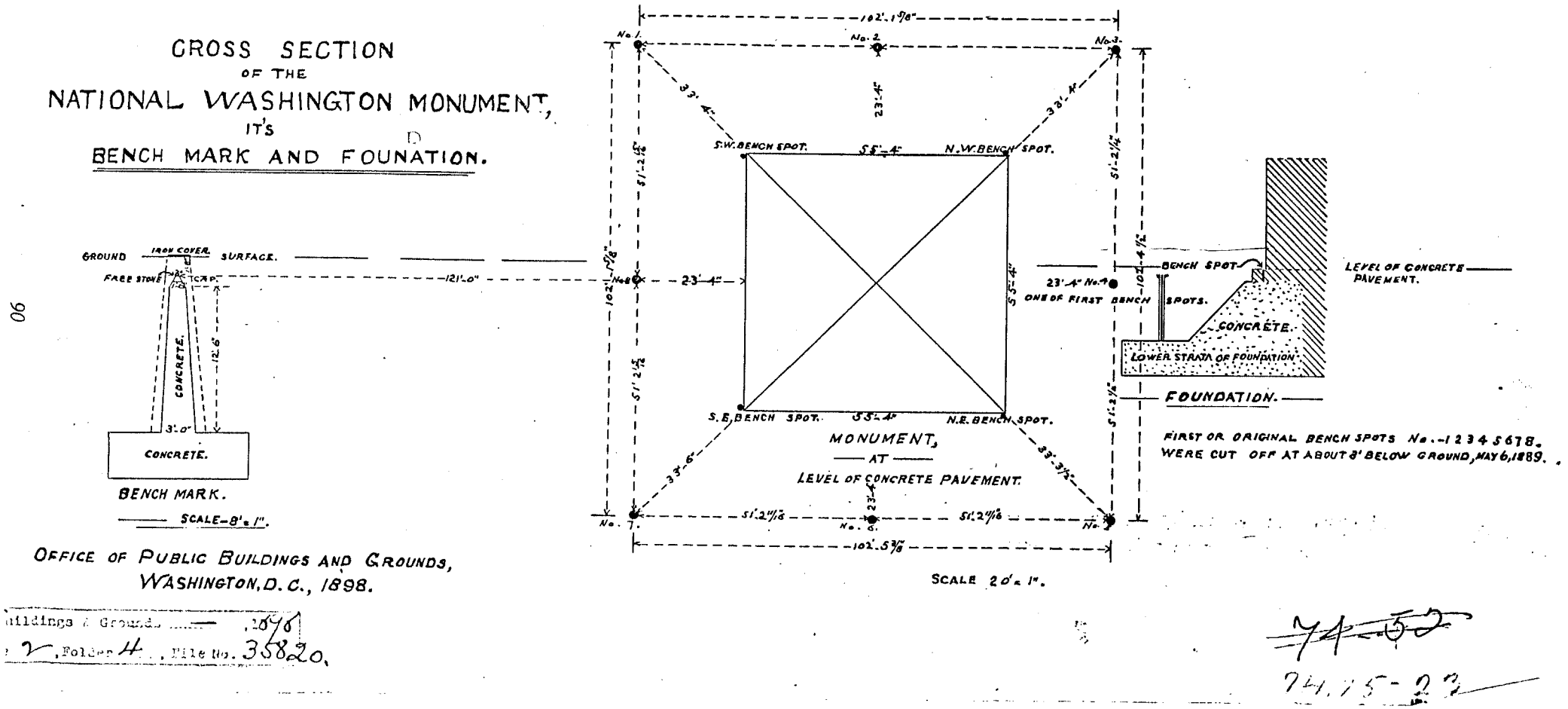

Figure 26. Diagram of survey markers installed in 1879. Using the obelisk as a bench mark, the "bench spots" at the 4 corners of the Monument have been surveyed to determine the settlement of the foundation. Drawing by Office of Public Buildings and Grounds, 1898. Scale is reduced from the original. National Archives, Record Group 79, file 74.15-23.

Photographs

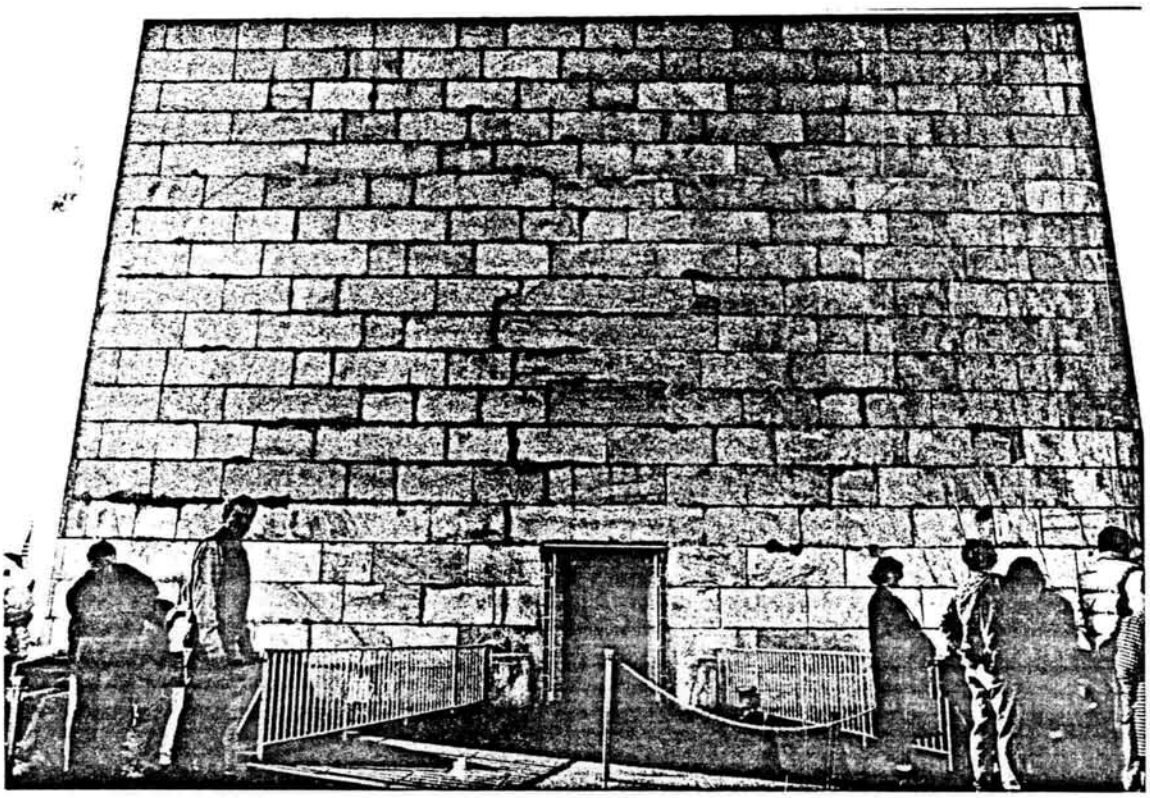

Photo 1. Exterior view of the east elevation of the Monument. The bottom four courses of stone to the 8' level are of a lighter color. Chips and spalls at the edges of stones have been filled with dark patches of mortar. The stone over the entry has odd coursing where the original 18'-6" high opening was reduced to 8'-0".