APPENDIX D - STRUCTURAL ISSUES

STRUCTURAL ISSUES AND FEASIBILITY

Moffatt &Nichol Engineers

GEOLOGY

The rock formations that are present at the Great Falls site are principally basalt (known as Orange Mountain Basalt) and brownstone (Passaic Formation). Both layers are utilized as local building material. The basalt, or traprock, is generally crushed and used as aggregate for roadbeds as well as railroad ballast. The brownstone is a well know building material in this area used for foundations and fascia on buildings. At this site the brownstone is overlain by a thick basalt layer. These layers are slightly tilted, with the brownstone and basalt dipping to the west and rising to the east. At the Great Falls, only the basalt layer is visible, while further to the east near the animal shelter the brownstone layer penetrate the crust at the base of the cliff. The falls themselves spill over the harder more resistant ridge of basalt into a chasm carved in the lower flow of the Orange Mountain Basalt that overlies the upper contact of the Passaic Formation.

The Orange Mountain Basalt is a dark greenish gray to black, fine grained, dense, hard basalt composed mostly of calcic plagioclase and clinopyroxene. Basalt is a volcanic rock which locally contains spherical to tubular gas escape vesicles near flow tops, some filled by zeolite minerals, quartz, or calcite. At the Paterson site the basalt is known as columnar basalt which means that it has formed into vertical, polygonal, columns or joints. These columns form when basalt erupts from volcanic vents and cools. Vertical columns can form the basalt shrinks and cracks during the cooling process. Well developed columns result from homogeneous lava cooling at a uniform rate. Examples of well developed columns include Devils Tower in Wyoming and the Giants Causeway in Ireland, see Photo 1. The basalt at the Great Falls does not exhibit the same well developed columns as these two examples but it does have shrinkage cracks or joints throughout the formation which are clearly visible at the cliff near the animal shelter.

In addition to the columnar joints this site also exhibits tectonic joints in the basalt. The tectonic joints are commonly obscured by the more pervasive cooling joints, however at the Great Falls the tectonic joints are very pronounced. The tectonic joints are typically planar, well formed, smooth to slightly irregular, and variably spaced from a few feet to tens of feet. In the immediate proximity of a tectonic joint (commonly referred to as a fault) the joints are spaced on the order of a few inches to 1 foot. The most pronounced example of a tectonic fault is the cliff that forms the back wall of the power plant, extending from McBride Avenue north past the power plant to the footbridge adjacent to the Great Falls

Tunnel Option

One alternative being investigated at this site is the construction of a tunnel through a portion of the Orange Mountain Basalt Formation. Preliminary investigation, discussions with Richard Volkert, a State Geologist, confirms our original assumption that a tunnel can be constructed through the basalt layer. As mentioned earlier the basalt is a hard rock and as a result cannot be easily excavated. The technique that will most likely be required to construct the tunnel will consist of drilling holes into the face of the rock to permit explosive charges to be set so the rock can be blasted out. This process will be repeated several times until the tunnel has been completed.

The previously mentioned tectonic faults and columnar joints in the basalt will further complicate the work. First the blasting will have to be done carefully and with small charges as the vibrations from the blasting could result in loss of some of the exterior face of the cliff due to shear failure in the rock at a joint location. In addition, as joints will most likely be encountered in the tunneling process, it is presently believed that the tunnel will have to be reinforced using drilled in rock anchors and a shotcrete lining. This technique will help prevent rock failure which could result in injury to pedestrians. The rock anchors are threaded steel rods that are fastened into the solid rock by means of an expansive end sleeve that is inserted into holes drilled into the rock face of the tunnel. After the anchor has been secured a steel plate is placed over the exposed end of the treaded rod and a nut attached to secure the plate. This assembly is then protected from corrosion by encasing the assembly in concrete liner that is shot onto the interior face of the tunnel wall. None of this constitutes an unusual tunneling or mining technique, but certainly will add to the overall cost and time to construct.

As the basalt rock is jointed and fractured, it is likely to loose small to large sections periodically due to freeze thaw expansion of water in the joints. This is more likely to be a problem during early winter and spring. Therefore, to protect the public, the walkway leading into and out of the tunnel, for viewing of the Great Falls, should be protected from falling debris by means of a chain link (wire) mesh. This wire mesh is typically anchored into the rock face by means of rock anchors, similar to those described about. In this case however they would not be protected by shotcrete, but rather exposed to the elements as is the mesh.

The Chasm Walkway

One of the tectonic joints discussed in the geologic portion above, forms a natural chasm immediately to the east of the Great Falls. This fault has created a natural opening that extends from the top of the cliff to the water level of the upper pool running in a generally north south direction. At the top of the cliff the chasm is in contact with the opposite wall and gradually opens up to a width of 8 to 10 feet and a depth of over 60 feet at the upper pool. As this is a tectonic joint, it was noted that joints on the east wall were closely spaced at 4 to 30 inches.

One of the ideas being explored is to install a walkway within the fault to create an opportunity to get down close to the upper pool and view the falls from a unique vantage point. It seems very probable that a walkway could be installed within this natural chasm. It would consist of a series of stairs and landings that would be supported by cross beams anchored into the wall of the chasm using rock bolts. It is envisioned that the cross beams would be constructed of steel with steel framing between and steel or fiberglass grating placed over the framing. All steel elements would be galvanized to protect from corrosion as this walkway will run deep into the chasm and will therefore get little sunlight to dry it off from the mist of the waterfall. All top surfaces will be made using non-skid high friction surfaces. In some limited areas the chasm is too narrow to fit a walkway of the desired width. However, as the rock fractures have developed in vertical plains it will be easier to widen the chasm in these areas.

As with the walkway adjacent to the tunnel, there are concerns regarding the fractures or joints in the basalt. Here we would recommend that the anchors to support the walkway be embedded much deeper into the rock face to reduce the likelihood of failure of a support at a joint in the rock. Initial consideration would be to install rock bolts up to four feet into the basalt to insert them past the closely spaced joints and anchor them into solid rock. In addition, when the walkway down into the chasm reaches a depth of approximately 6 feet it is recommended that a wire mesh be installed along the rock face to catch and direct straight down any rocks which may dislodge from the cliff face due to effects of freeze thaw cycles on the rock joints. This is to prevent weathered rock from falling onto pedestrians during early winter and spring freeze thaw cycles.

Walkways next to the cliff

The walk adjacent to the cliff is will be supported by a vertical member with a K brace back to the cliff. The support members are proposed to be constructed from galvanized or coated steel members. These will be anchored back into the rock cliff using rock bolts that are drilled into the rock face approximately four feet to penetrate the exterior columnar joints an reach solid rock. To permit proper bearing of the steel support frame adjacent to the cliff a high strength grout base will be installed between the rock and the steel bearing plates.

The walkway surface can be one of many alternative surfaces. Concrete deck, galvanized steel grate deck or a timber deck could be utilized. The choice of surfaces will depend upon the cost of the each option as well as the aesthetics with the other Park features. Each material offers plusses and minuses related to the durability, cost, and pedestrian comfort. The concrete deck is solid, providing a level of security to the pedestrian, while the extra weight will increase the size or number of support frames required. Steel grating is still very solid and lighter than concrete but being able to view rock surface and water below through the grating can be disconcerting to many pedestrians (and a thrill to others). The timber deck is the lightest option but not as solid a feel as either the steel or concrete. This type of walking surface can become uneven over time due to warping and does permit some limited views of the rock and water below through the joints in the boards that are typically provided. A final decision will have to consider all these aspects.

As the walkway is adjacent to the cliff a wire mesh screen will be required on the rock cliff here as well. This screen will help to prevent possible injury to pedestrians due to falling rock as a result of water seeping into the columnar joints and expanding during the freeze thaw cycles of winter and spring. As opposed to the chasm walkway were the wire mesh will be generally hidden from public view (other than when you are walking down the chasm), the mesh for these other walkways will be visible from more areas of the Park. This will also need to be considered when selecting where to install these walkways.

Balconies

The balconies are located on the east shore of the Passaic River at the historic wall. The historic wall rises approximately 20 feet from the exposed brownstone formation at the river level to create a vertical edge defining the river from the historic industrial sites behind. The historic wall itself was actually used as a back wall for several of the industrial buildings. Within this wall are the remains of old larger clearstory windows that once lit the interior of these buildings. To take advantage of this feature, Field Operations has proposed that the balconies be installed that project beyond the historic wall and allow people the opportunity to view the river and the wall from a new perspective.

As the condition of the historic wall is unknown, the plan is to cantilever the balconies out through the windows without having them supported by the historic wall. This will eliminate the need to do a detailed inspection and evaluation of the historic wall while also avoiding potential damage to the wall due to the application of new loads. It is proposed that the balconies be constructed from concrete to create a stable, maintenance free structure. The balcony itself will be constructed of a single 8 foot wide by 25 foot long panel of prestressed concrete. The prestressing will allow the panel to be as thin as possible, thus reducing the weight of the cantilevered element. In addition, prestressing the panel will help eliminate the development of cracks in the concrete panel, thus reducing the pathways into the concrete where moisture and oxygen could cause corrosion. This will provide a longer service life with reduced maintenance requirements.

To support the panel it is proposed that a concrete beam be extended through a slot cut in the wall. The concrete beam will act like a teeter tauter with the balcony panel acting as a load at one end while a rock anchor acts as a load at the other end and a spread footing acts as the fulcrum near the middle. Between the historic wall and the beam, a compressible joint material will be used to minimize any possible load application to the wall. The rock anchor at the far end of the beam will be drilled and grouted into the brownstone bedrock which is approximately 20 feet below the surface. The spread footing will be placed behind the historic wall. Some additional study will be required to determine if the spread footing will impart too great a lateral load on the historic wall and if so then a concrete pile could be drilled and cast-in-place to transfer the vertical load at the fulcrum point to the underlying bedrock.

Pedestrian Bridge

The pedestrian bridge is located at the east end of the Park, spanning over the Passaic River. This bridge will be the link between the south half of the Park and the north half. The bridge offers an interesting engineering challenge in that it is curved with about a 170 foot radius. This is a tight radius, but as we are supporting only pedestrian loads it can be economically constructed. The plan calls for two interior bents to support three equal spans of about 96 feet each. One of the interior bents will be located on the island in the river while the other will be located in the river channel. The plan presently calls for the pedestrian bridge to be 10 feet wide.

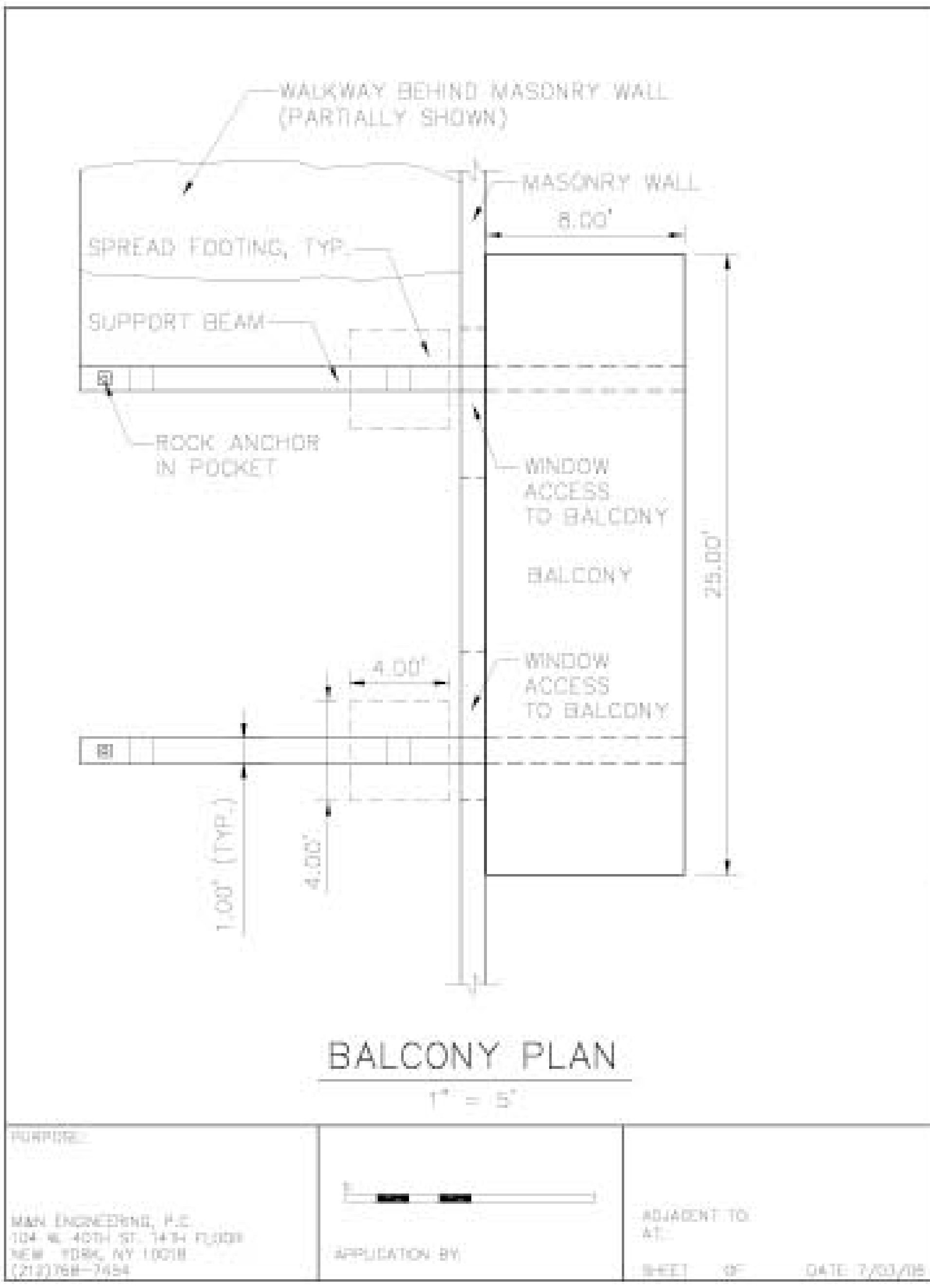
It is envisioned that the pedestrian bridge will consist of a concrete deck surface that is supported by curved steel plate girders. The end bents will be solid structures designed to retain the fill behind at both shores. The interior bents will be either steel or concrete structures. The preferred material would be concrete due to possible corrosion and maintenance issues associated with steel. However, if a concrete foundation is constructed to an elevation above the normal pool elevation of the Passaic River, then a steel structure could be constructed from the concrete footing to the steel superstructure. This would provide plenty of access and opportunity to recoat the steel supports during normal maintenance cycles.

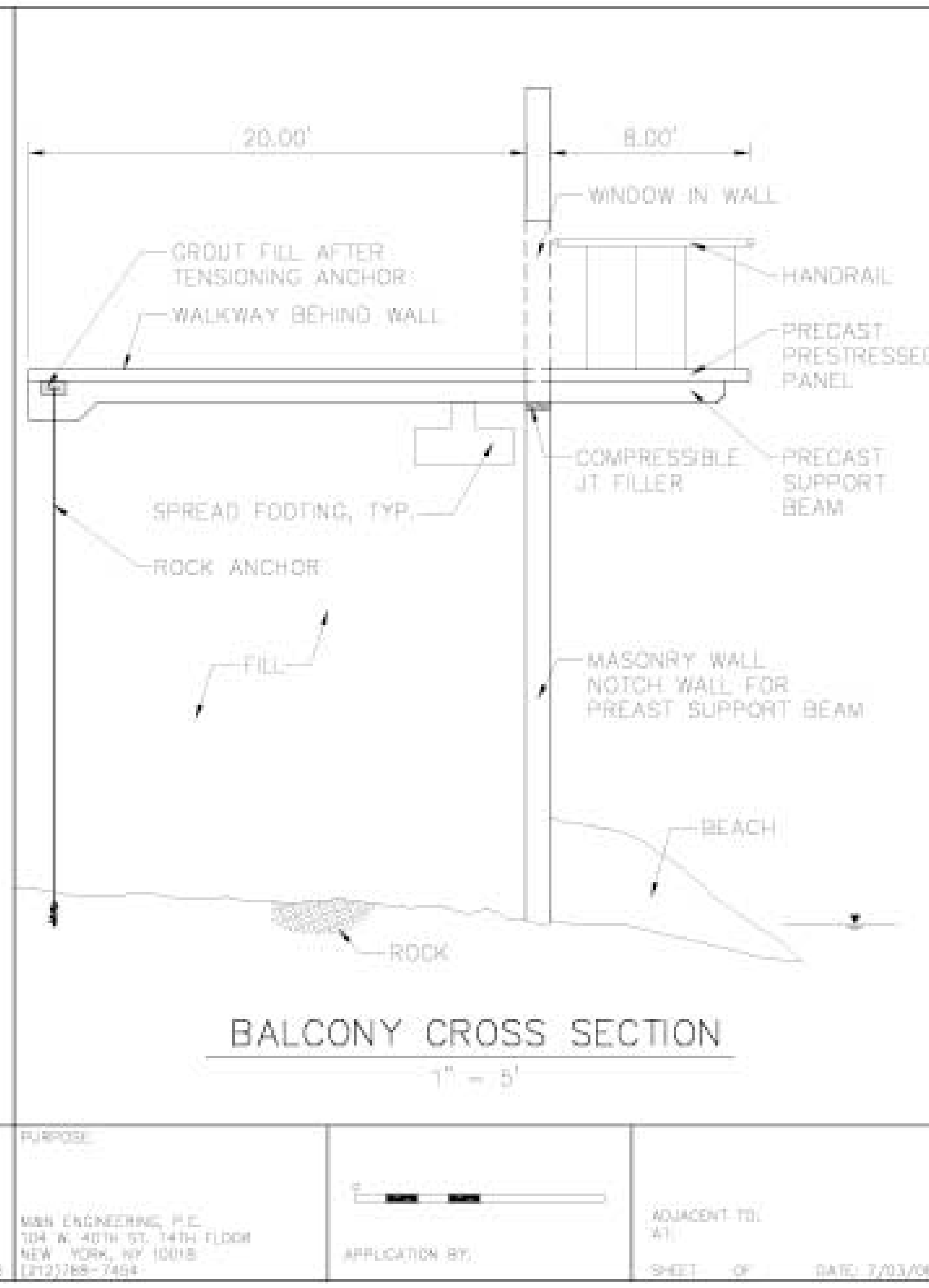
Historic River Wall

The existing masonry river wall is in poor condition and in need of repair to maintain the stability of the structure and extend its useful life. At the present time there is a contract with The Louis Berger Group to inspect the masonry river wall and prepare construction documents for repair of the wall. The total length of masonry wall included in this contract is approximately 800 feet and extends to the northeast from the cast-in-place concrete wall which terminates approximately 200 feet northeast of the hydroelectric power plant. The 800 feet of masonry wall in this contract represents the tallest segment of the wall. Additional masonry wall extends beyond the end of this contract but is a lower level wall. The maximum height of masonry wall is approximately 33 feet from river level to top of wall. This section of the wall extends above the existing grade, behind the wall, by about 13 feet. It is these sections of wall where windows and doorways still exist that balconies are being proposed. Typically the masonry wall extends to grade or just a little above grade and is about 20 feet tall.

During the site investigation by Field Operations and Moffatt & Nichol we observed significant areas of deterioration of the wall that if unattended to would jeopardize the long term stability of the wall. At the base of the wall the river has undermining of the wall due to scour. Approximately 300 feet of the 800 foot long section of wall is undermined and is scheduled to be repaired by placing concrete between the exposed bedrock and the bottom of the masonry wall. Throughout the wall freeze thaw and weather have deteriorated the masonry joints and several of the stones. The joints and deteriorated stone are presently included in the repair work under design. Another long term impact to the wall has been the growth of plants between the masonry joints. In some instances two to three inch caliper trees are growing through the wall. In these cases the masonry block will need to be removed and the tree roots traced and removed to prevent further deterioration of the wall. Once the roots have been removed the original blocks will be replaced, assuming they are found to be in good condition.

Overall, upon completion of the scheduled repairs the condition of the masonry wall could be upgraded to fair. It is our opinion that this wall should not be relied upon to support any significant additional vertical or lateral load. The placement of the riverwalk behind the wall should be done to minimize additional lateral pressure on the wall. This could be achieved by removing an equivalent weight of soil and vegetation equal to the weight of the riverwalk to be installed. Further study is needed, but it is believed the masonry wall can accommodate the live load due to pedestrians utilizing the riverwalk.


WALKWAY BEHIND MASONRY WALL (PARTIALLY SHOWN)
MASONRY WALL
8.00'
SPREAD FOOTING, TYP.
SUPPORT BEAM
ROCK ANCHOR IN POCKET
WINDOW ACCESS TO BALCONY
BALCONY
25.00'
4.00'
WINDOW ACCESS TO BALCONY
1.00' (TYP.)
4.00'
BALCONY PLAN
1" = 5'
PURPOSE:
M&N ENGINEERING, P.C.
104 W. 40TH ST. 14TH FLOOR
NEW YORK, NY 10018
(212)768-7454
APPLICATION BY:
ADJACENT TO:
AT:
SHEET OF
DATE: 7/03/06


20.00'
8.00'
WINDOW IN WALL
GROUT FILL AFTER TENSIONING ANCHOR
HANDRAIL
WALKWAY BEHIND WALL
PRECAST PRESTRESSED PANEL
COMPRESSIBLE JT. FILLER
PRECAST SUPPORT BEAM
SPREAD FOOTING, TYP.
ROCK ANCHOR
FILL
MASONRY WALL NOTCH WALL FOR PREAST SUPPORT BEAM
BEACH
ROCK
BALCONY CROSS SECTION
1" = 5'
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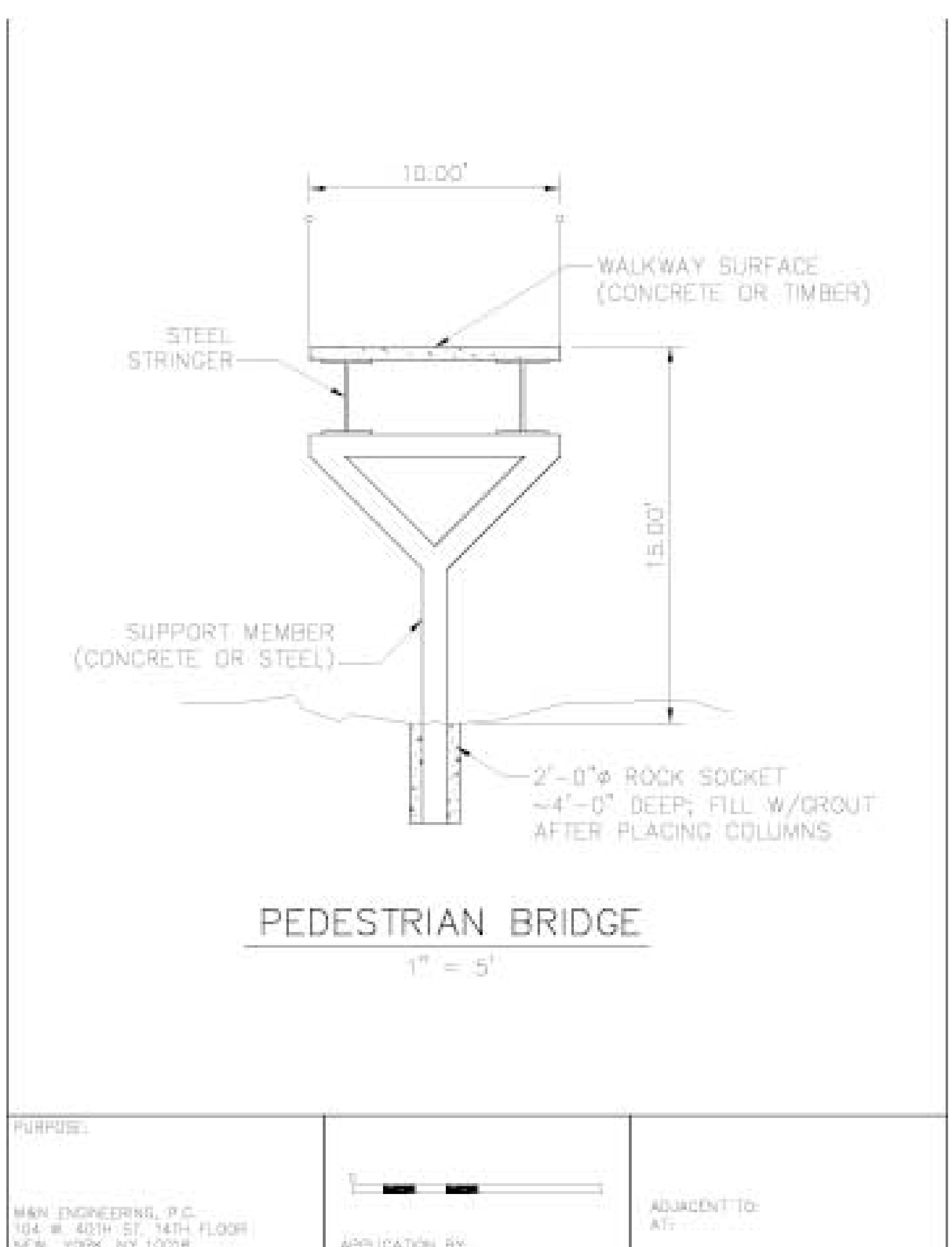
10.00'
WALKWAY SURFACE (CONCRETE OR TIMBER)
STEEL STRINGER
15.00'
SUPPORT MEMBER (CONCRETE OR STEEL)
2'-0"⌀ ROCK SOCKET ~4'-0" DEEP; FILL W/GROUT AFTER PLACING COLUMNS
PEDESTRIAN BRIDGE
1" = 5'
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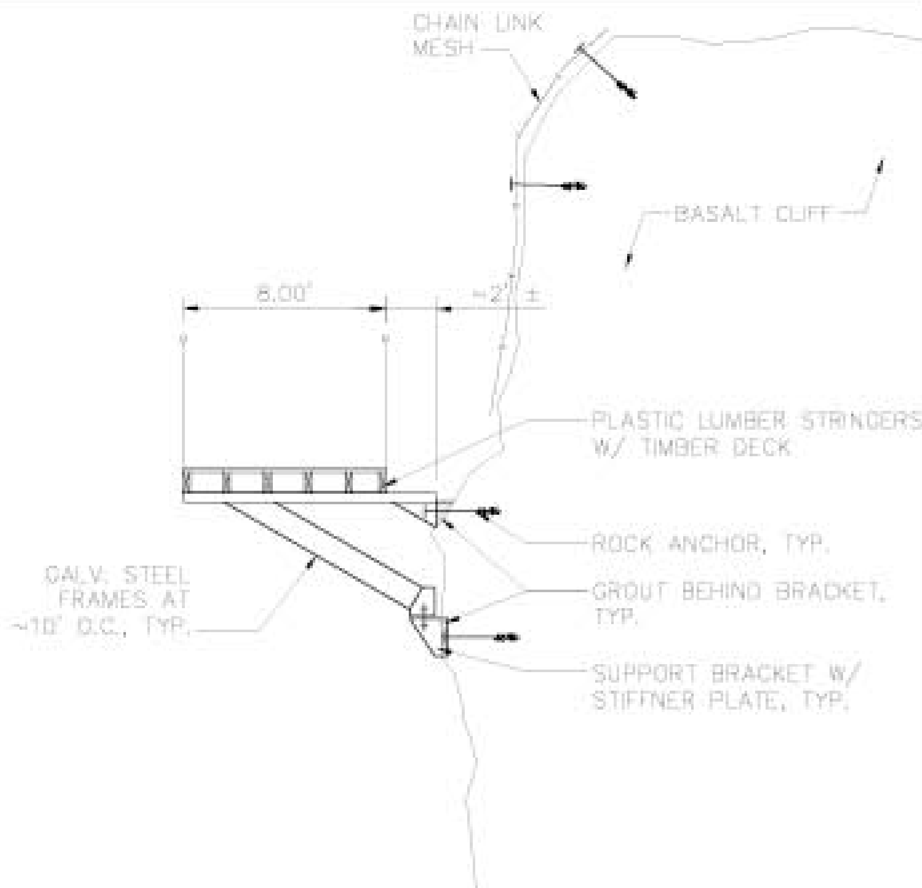

WALKWAY ADJACENT TO BASALT CLIFF

1" = 5'

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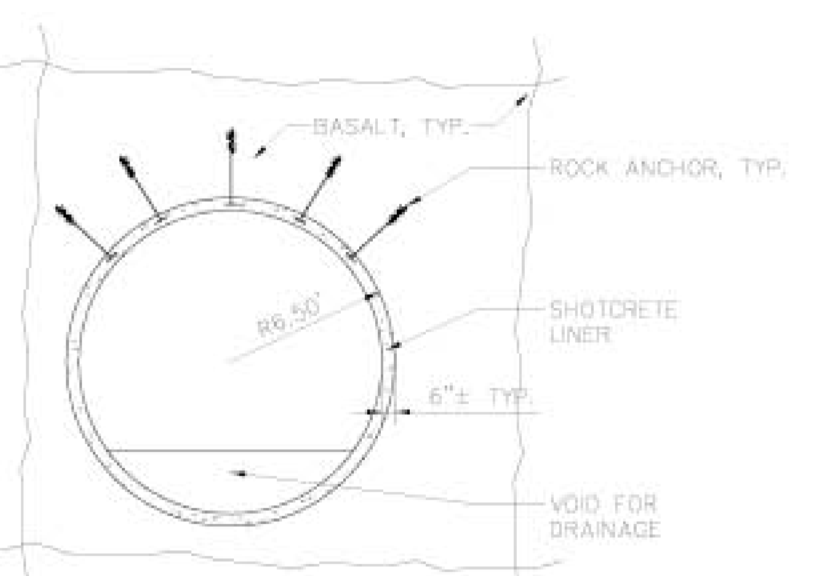

TUNNEL PORTAL

1" = 5'

NOTE:

1. LENGTH OF TUNNEL ~22'.
2. TUNNEL WILL BE CONSTRUCTED AT 2% SLOPE TO PROMOTE PROPER DRAINAGE.
3. ROCK ANCHOR WILL BE PROVIDED AS NECESSARY TO STABILIZE JOINTS IN NATIVE ORANGE MOUNTAIN BASALT FORMATION.

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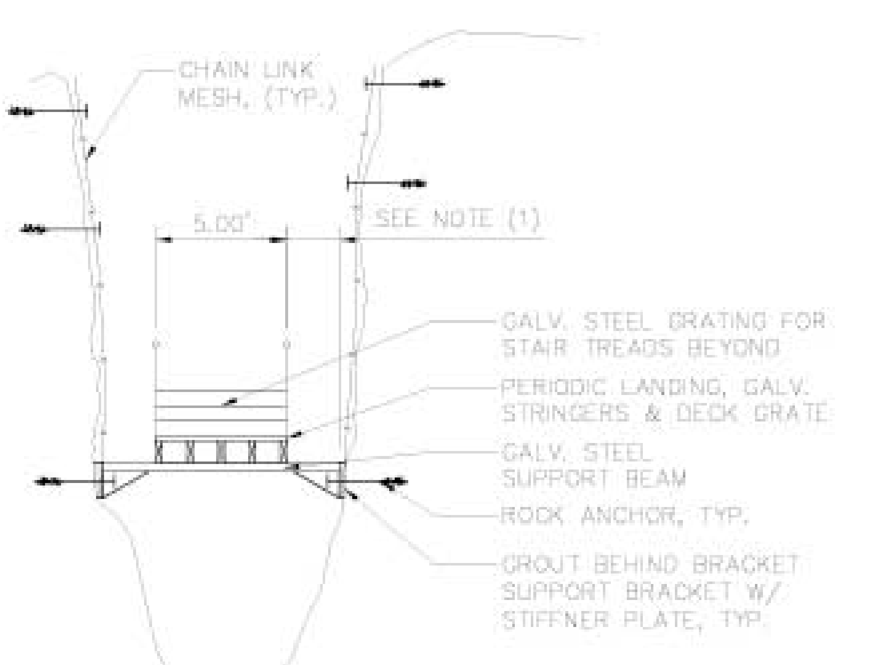

SECTION AND CHASM

1" = 5'

NOTE:

1. PROVIDE CHAIN LINK MESH TO ROCK FACE WHEN WALKWAY REACHS 6' BELOW RIM OF CHASM
2. SLOPE WALKWAY FROM TOP OF CLIFF TO ELEV. XX.XX

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