ROCK SLOPE STABILIZATION PROJECTS
LETCHWORTH STATE PARK
PORTAGEVILLE, NEW YORK

INTRODUCTION

The New York State Office of Parks, Recreation and Historic Preservation (OPRHP) operates Letchworth State Park in Wyoming and Livingston Counties, New York. The park is located along the Genesee River, which traverses a deep rock gorge. At two locations along the gorge, the instability of the soil and rock on the gorge face created concerns for OPRHP (see Figure 1 for location plan).

A section of the rock face adjacent to the Middle Falls was undermined creating safety concerns for those viewing the Falls. Additionally, a section of the gorge face beneath the park road had fallen into the gorge undermining the road and threatening its stability. The OPRHP retained TVGA Consultants and McMahon & Mann Consulting Engineers, P.C. (MMCE) to develop plans to stabilize and instrument the rock slope at these locations. This paper describes the subsurface explorations, engineering evaluation and the methods employed to stabilize the gorge face at these sites.

The paper presents the gorge road project first, followed by the Middle Falls project. The stabilization methods at the gorge road site included rock scaling, installing soil nails and shotcrete along with rock anchors and horizontal drains. At the Middle Falls site, loose rock was scaled and high strength bar anchors were installed 40 feet into the slope to improve its stability. Because of access restrictions, much of the work had to be completed from ropes. The rock

anchors are equipped with strain gauges that provide measurements of slope movement with time, allowing OPRHP to plan slope maintenance work.

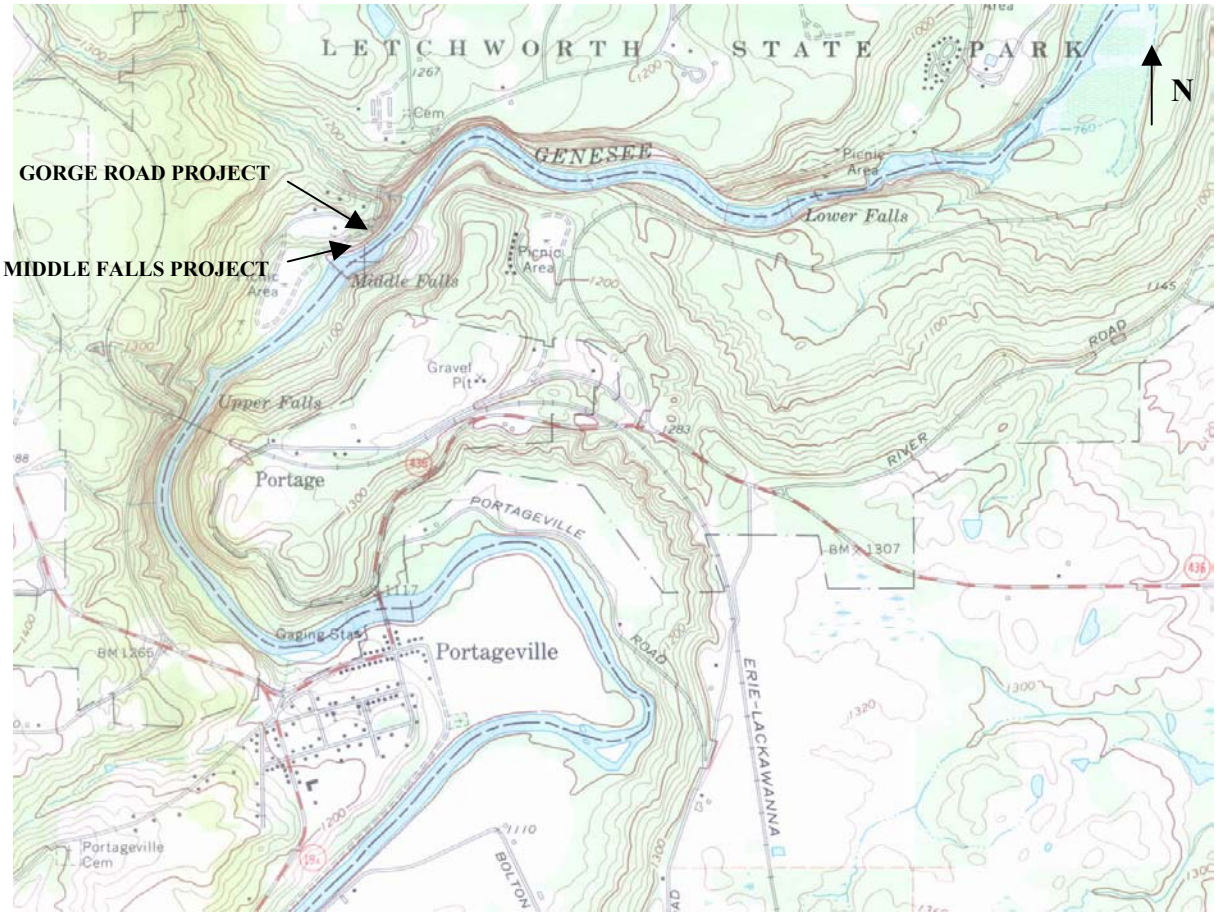

Figure 1 Location Plan

GORGE ROAD PROJECT

Background

In 2005, OPRHP workers noticed an unusual absence of trees and brush along the west edge of the gorge, north of the Glen Iris Inn and the Middle Falls. The gorge in this area has nearly vertical walls and the edge of the road is within a few feet of the gorge wall, making it impossible to observe the gorge wall beneath the road. OPRHP personnel photographed the area

from the opposite (east) side of the gorge (see Figure 1) and noted some apparent irregularities in the gorge wall at this location.

Figure 2 - Photo by OPRHP personnel of west side of gorge.

OPRHP retained TVGA Consultants, (TVGA) and McMahon & Mann Consulting Engineers, P.C. (MMCE) and Earth Dimensions, Inc. (EDI) to visit the site and observe the gorge condition using a crane and a man basket.

Observations and Site Conditions

MMCE, EDI and OPRHP personnel observed the site conditions in May 2005 with the assistance of a crane and operator provided by Clark Rigging Company. The crane operator lowered personnel over the side of the gorge using a man basket (Figure 3).

We observed a rock outcrop extending to about 7 feet above the road on the west side of the road at the location being studied. Based on the "Geologic Map of New York, Niagara Sheet," by Fisher and Rickard (1970), the rock is shale, sandstone and siltstone of the West Falls Group. Our observations confirmed that the rock is alternating layers of shale, sandstone and siltstone.

Figure 3 Man Basket Used for Observations

We observed the rock jointing pattern in the Genesee River and on the east gorge wall (opposite side of the river – Figure 4). Two sets of near vertical joints are evident, one approximately perpendicular to the river (estimated to be about N 55˚W) and another approximately parallel to the river and alignment of the gorge walls.

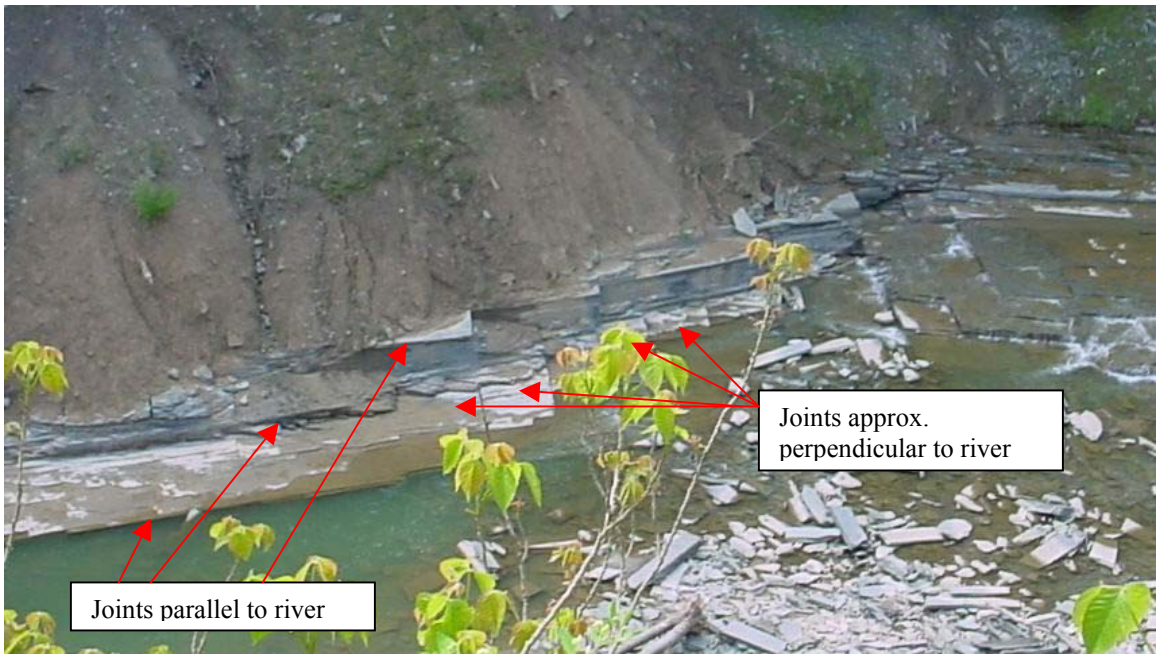

Figure 4 - Looking east across gorge at rock joint pattern

The area immediately beneath the road is not rock but is comprised of loose stones, soil and concrete. It appears that this area was a natural swale that workers who constructed the road filled in with stacked stones and concrete. Both the stones and concrete are disturbed and have fallen out of place for a distance of about 40 feet. A concrete grade beam could be seen spanning the area where stones have fallen out (Figure 5). Support had been lost for approximately 10 to 15 feet of the wall and road.

Figure 5 – View (looking west) showing undermined area.

Two rock blocks or columns, one at each end of the approximate 40-foot disturbed section, were observed to be separating from the gorge wall (Figures 6 and 7).

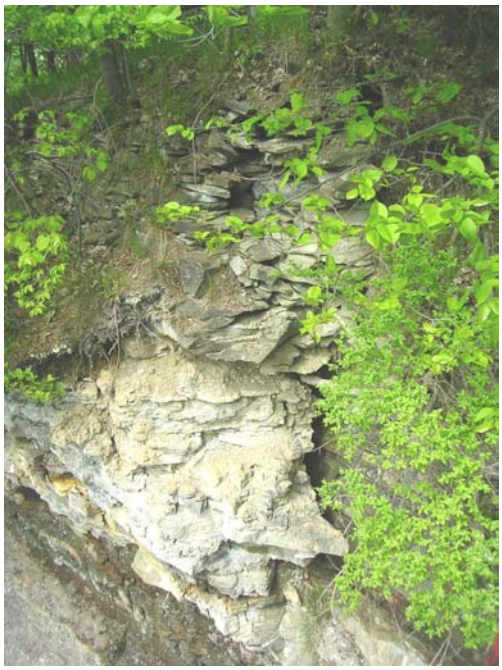

Figure 6

The rock column at the south end (Figure 6) appeared to be separating from the gorge face along a nearly vertical joint parallel to the gorge face. The rock column at the north end of the disturbed area (Figure 7) appeared to also be separated along a near vertical joint but had moved laterally slightly less. Each column appeared to be composed of more competent rock at the bottom and loose rubble near the top.

Figure 7 - Rock Block on north side of undermined area separating from gorge face

Figure 8 is a schematic elevation view of the gorge face prior to remediation.

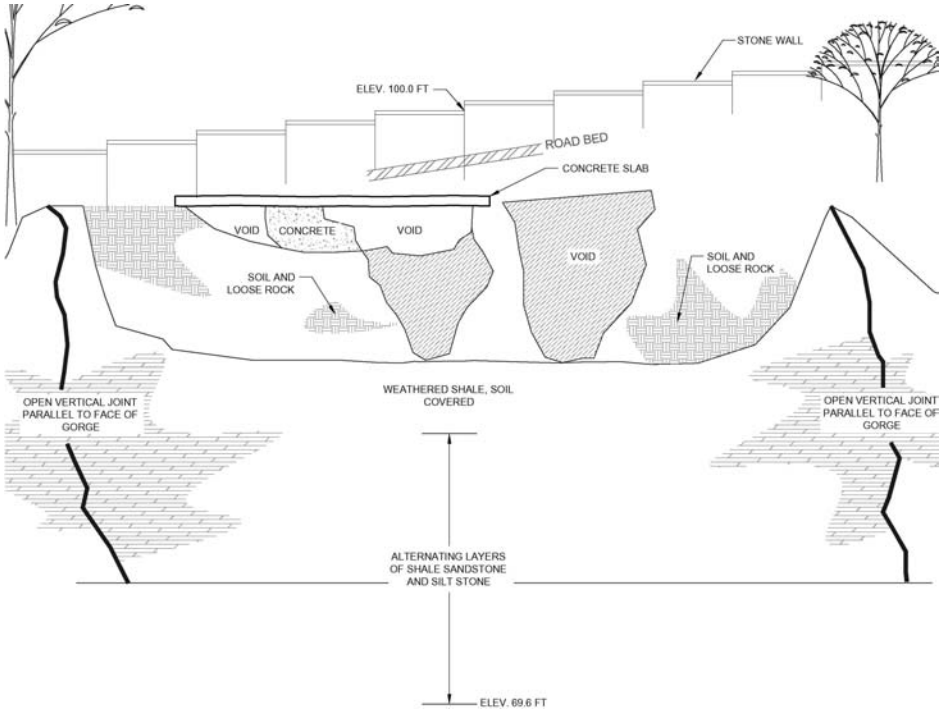

Figure 8

Remedial Design and Construction

OPRHP closed the road to traffic and requested that MMCE and TVGA prepare plans to remediate the undermining. EDI drilled borings in the roadway to define the subsurface conditions. Figure 9 is a cross section of the road and gorge face based on our observations and the borings.

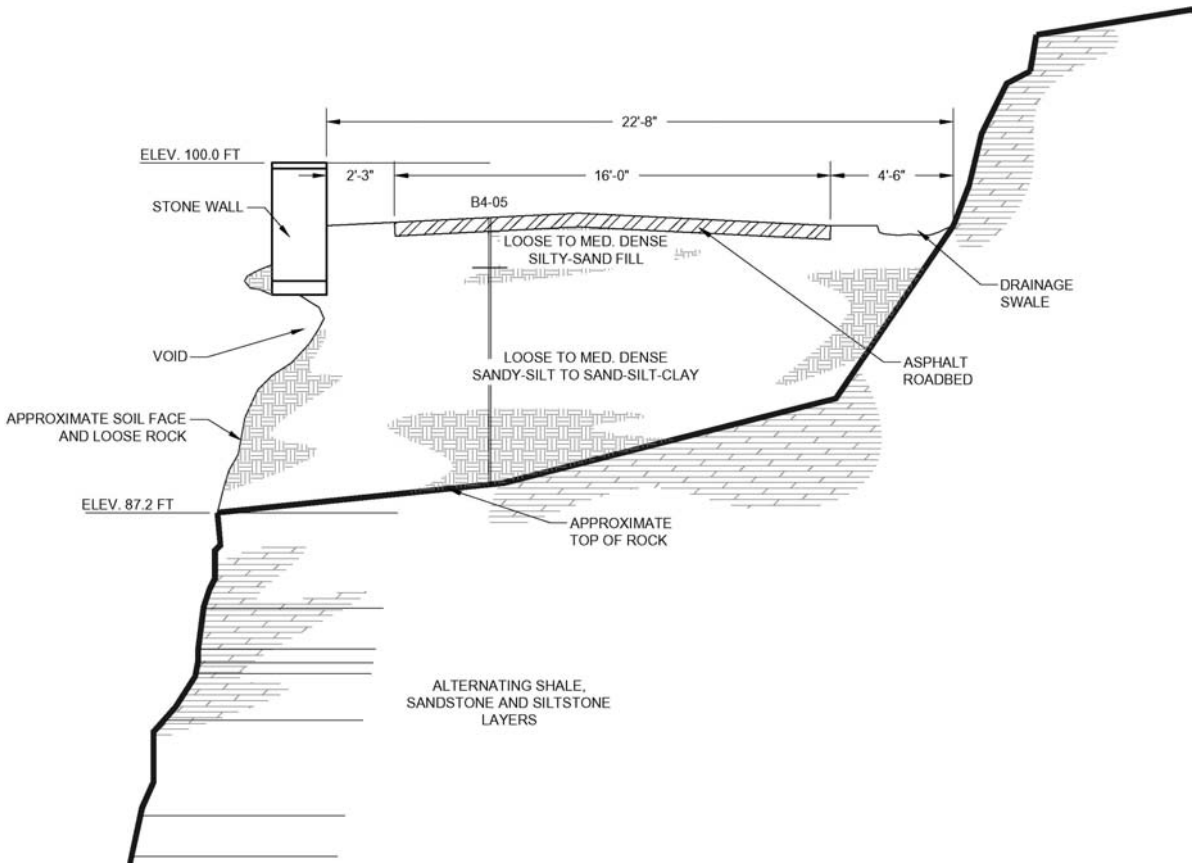

Figure 9 – Typical Section Prior to Construction

Because the road was undermined it was not feasible to complete the remedial work from a crane located on the roadway. It was necessary to develop a design that was constructible considering the site access restrictions. We contacted Janod Inc. (Janod), a specialty subcontractor for rock scaling, shotcreting and rock nail and anchor installation, for design consultation relative to the feasibility of constructing various remedial features. We developed the design based on discussions with the contractor regarding what was feasible and stability calculations for the roadway. Figure 10 is a cross section illustrating the components of the remedial design.

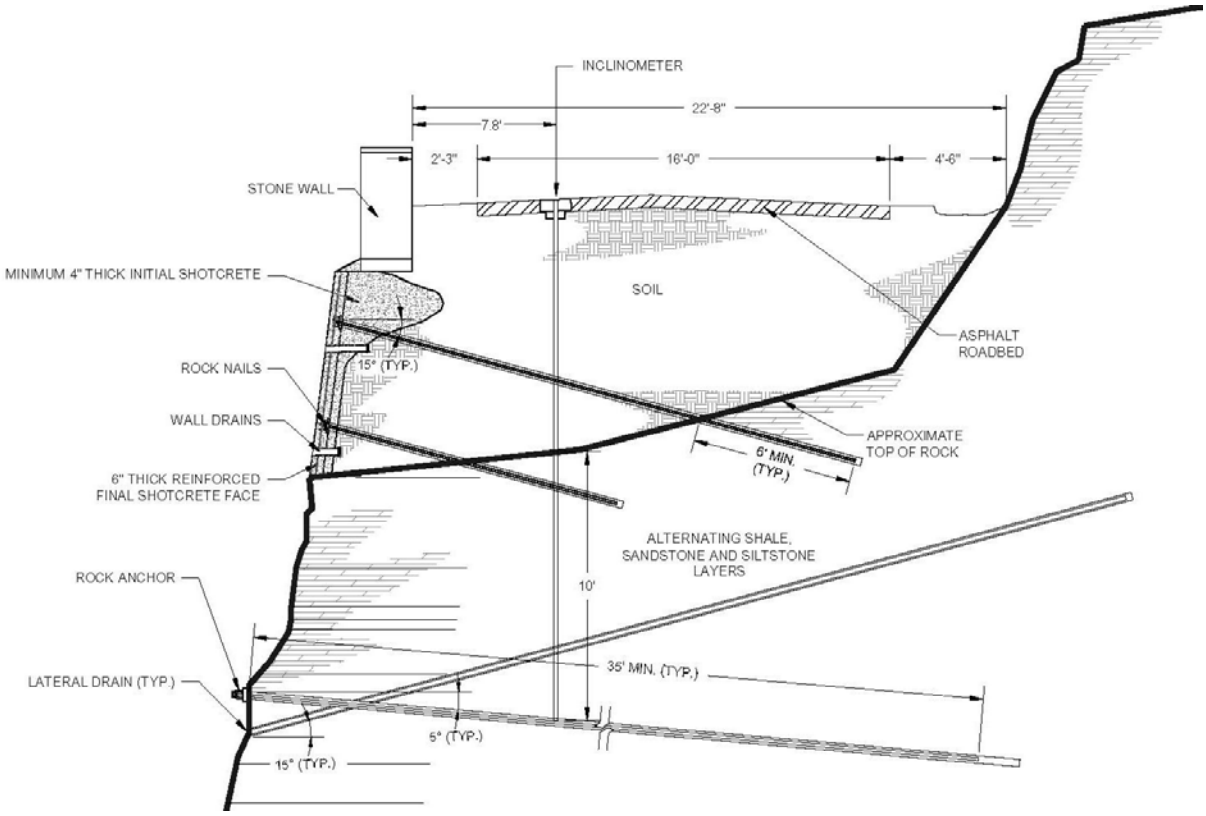

Figure 10 - Typical Design Cross Section

The remedial design includes scaling loose rock from the face then installing shotcrete to fill the voids and stabilize the gorge face. The shotcrete facing is reinforced and is secured to the gorge face by rock nails. The nails are 1-inch diameter, Grade 95 kips per square inch, (ksi) reinforcing bars, drilled at least 6 feet into rock and grouted. Plastic pipes extend through the shotcrete to provide drainage and limit groundwater buildup behind the shotcrete.

The design also includes rock anchors and drains installed in the rock below the void area. Observations of the joint spacing in the gorge indicate that joints tend to be spaced about 20 feet apart. The rock anchors are designed to extend 35 feet into the gorge face with a 20 foot unbonded zone. The anchors are specified to be tensioned to stabilize joints that may exist parallel to the gorge face along the road. The anchors consist of 1¼ inch, Grade 150 ksi, high strength steel bars.

Drains are also included in the design to drain groundwater that we observed seeping from the gorge face. The drains consist of 2-inch diameter slotted PVC pipe installed 35 feet into the gorge face.

OPRHP contracted with C.P. Ward Inc. to complete the work with Janod as the specialty subcontractor for rock scaling and rock nail and anchor installations. Construction began in the

Fall of 2005 with Janod scaling loose soil and rock from the gorge face and initial filling of the void with shotcrete. Janod placed a rubber bladder into the open joints on the north and south sides of the undermined area and inflated the bladder to remove loose material. Once the loose material was removed they began initial filling of the void with shotcrete as shown in Figure 11.

Figure 11 – Janod Filling Void with Shotcrete

Figure 12 shows the shotcrete work in progress. Once the void was partially filled, Janod lowered a drill rig over the side for use in installing the rock anchors, drains and rock nails. Figure 13 shows the rock nail installation and Figure 14 shows the rock anchor installation.

Figure 12

Figure 13 – Rock Nail Installation

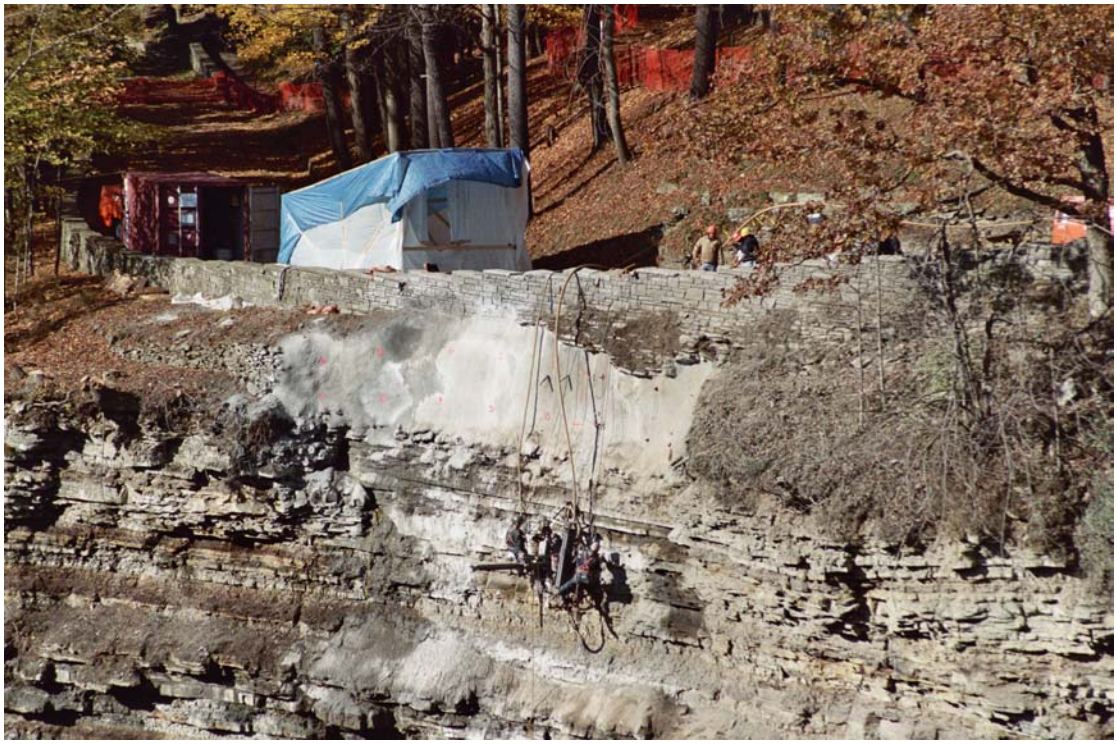

Figure 14 – Rock Anchor Installation

Janod completed performance and proof testing on rock anchors and nails. Proof tests were performed on each of the three rock anchors, a performance test was completed on a sacrificial rock nail, and two proof tests were performed on selected production rock nails. The performance and proof test results met or exceeded the acceptance criteria defined in the project specifications.

EDI installed two inclinometers within the roadway area after construction was complete. These devices allow measurements of lateral movement with depth. MMCE has monitored the inclinometers since 2006 and to date have not observed lateral movement of the remediated area.

MIDDLE FALLS PROJECT

Background

The Middle Falls at Letchworth State Park (see Figure 1 for location) offers dramatic views of the rock gorge and the Falls. OPRHP personnel requested that MMCE and EDI observe an area near the Middle Falls viewer platform requiring remediation. MMCE and EDI along with the Gorge Road contractor Janod, observed the conditions and found that loss of rock on the gorge walls and a large, block of rock at this location, separated from the gorge face by an open joint. The joint was also visible on the river side of the block. The open joint and loose rock is of concern relative to the stability of the overhang, which is a prominent location for pedestrians to view the Middle Falls (see Figure 15). This poses a significant safety threat to those viewing the Falls.

Figure 15 – Middle Falls Prior to Construction – Note Open Joint

OPRHP requested that EDI collect subsurface information for design and MMCE and TVGA develop a remedial plan for the Middle Falls.

Site Studies

TVGA completed a three dimensional laser survey of the gorge face and prepared a topographic contour map. The map shows elevation contours of the gorge face from top to bottom. This map provided the orientation of the gorge face at the Middle Falls and demonstrated that it follows the joint pattern that is generally perpendicular to the flow of the river.

EDI drilled a boring approximately 20 feet back from the face of the gorge and collected rock core samples. The rock core consists of alternating layers of siltstone and shale and revealed a vertical joint. MMCE selected several rock samples for unconfined compressive strength testing. The results indicate that the unconfined strength of the core samples varied from 8,000 to 17,000 pounds per square inch (psi).

Remedial Design and Construction

The remedial design includes scaling and removing the overhang and removing loose rock from the gorge face. The design includes installing seven rock anchors in the rock block next to the Falls and eight rock anchors in the gorge face next to the rock block (i.e., the "overhang area"). Figure 16 is a schematic diagram of the design components.

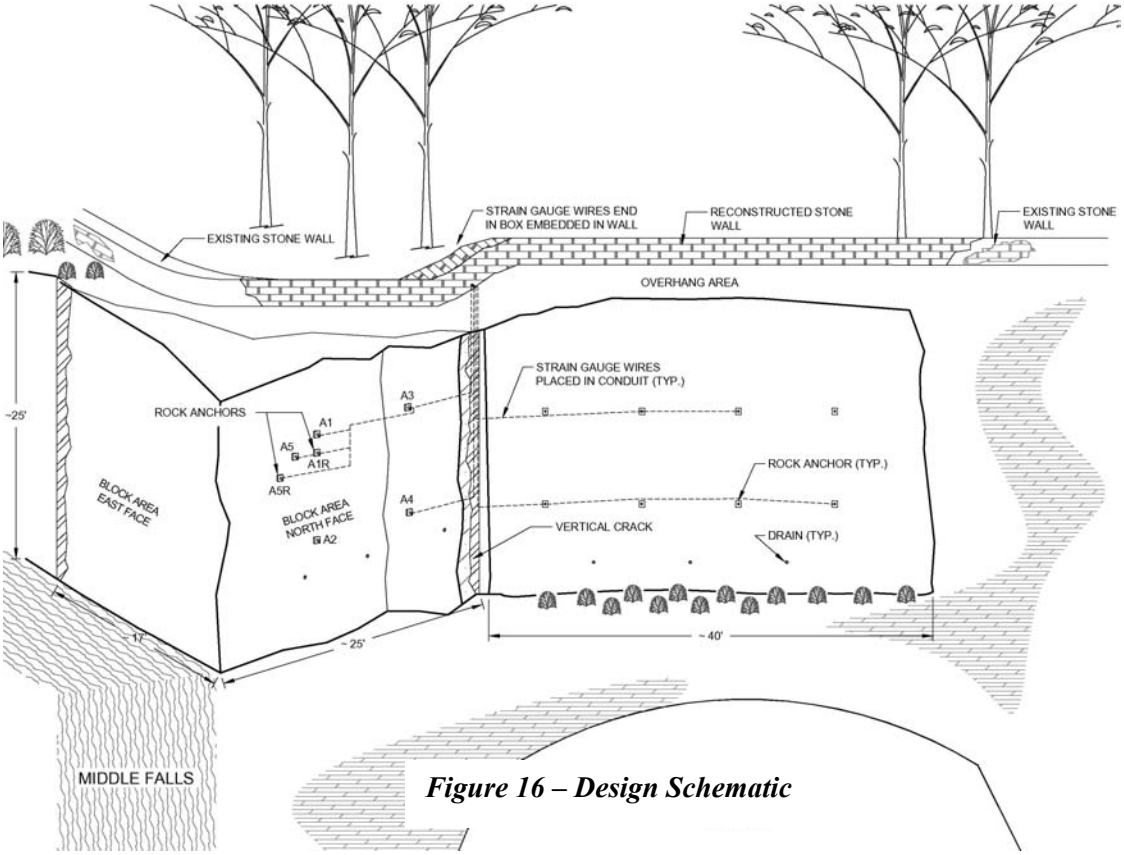

Figure 16 – Design Schematic

Drains are included in the design to provide a drainage path to the gorge face, particularly for water that accumulates in the open joint. Figure 17 is a plan of the anchors and drains in the block and Figure 18 is a typical section through the block.

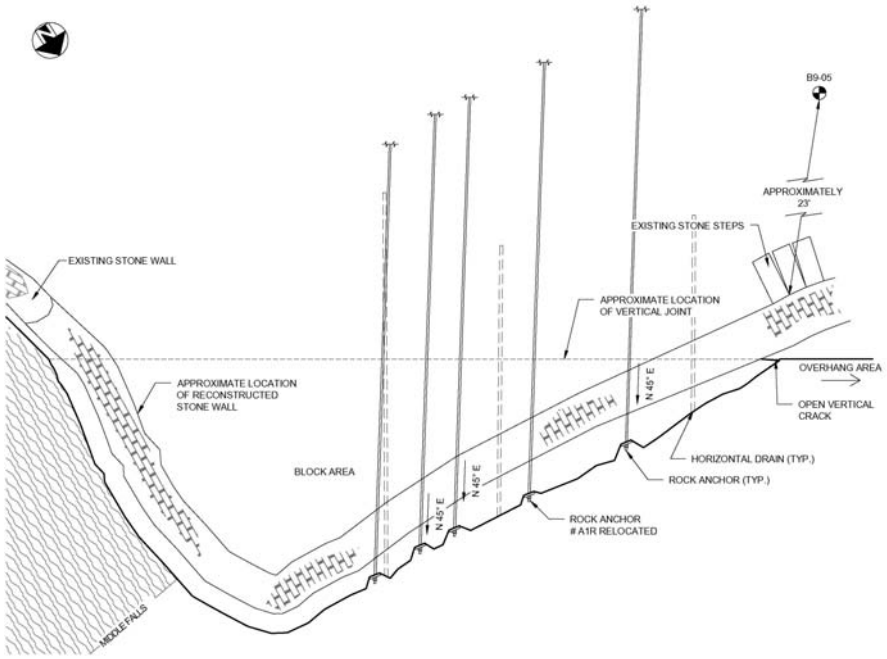

Figure 17 – Plan of Block Area

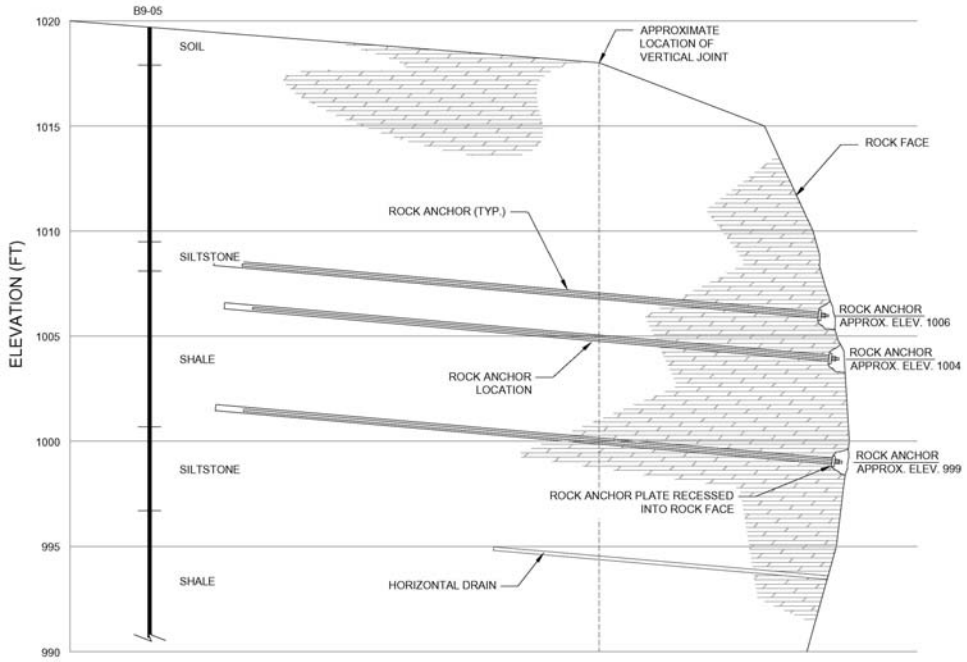

Figure 18 – Section of Block Area

The anchors consist of 1¼ inch, Grade 150 ksi, high strength steel bars. Grout socks are specified around the bars to limit grout loss, especially in the open joint.

Observations of the joint spacing in the gorge indicate that joints tend to be spaced about 20 feet apart. The rock anchors are designed to extend 40 feet into the gorge face with a 23 foot unbonded zone. This is specified so that the bond zone is behind the next vertical joint. The anchor heads are recessed into the gorge face and covered with grout to blend into the gorge face.

The anchors in the block are not tensioned because of concerns that high tension forces could cause the block to rotate and or crack. Rather, the block anchors provide a stabilizing force to limit future movements of the block. The anchors installed in the gorge face are specified to be tensioned to stabilize joints parallel to the gorge face.

The design includes strain gauges attached to rock anchors in the block and the overhang area. The strain gauges are intended to provide an indication of future movement and the need for additional scaling or other remedial work. It is expected that eventually the rock supporting the block along the gorge face will erode potentially destabilizing a portion of the block.

The instrumented rock anchors serve as transducers to monitor performance of the loose block and reflect changing rock conditions. As the block begins to move, load will be transferred to the rock anchors and will be reflected in the strain gauge measurements, allowing time to plan and implement future actions.

Construction began in the Fall of 2005 with Janod removing the overhang and scaling loose soil and rock from the gorge face. Once the loose material was removed, they began installing drains and rock anchors in the loose block as shown in Figures 19 and 20. As for the Gorge Roadway, all of the work was completed from ropes.

Figure 19 – Janod Installing Anchors in Block

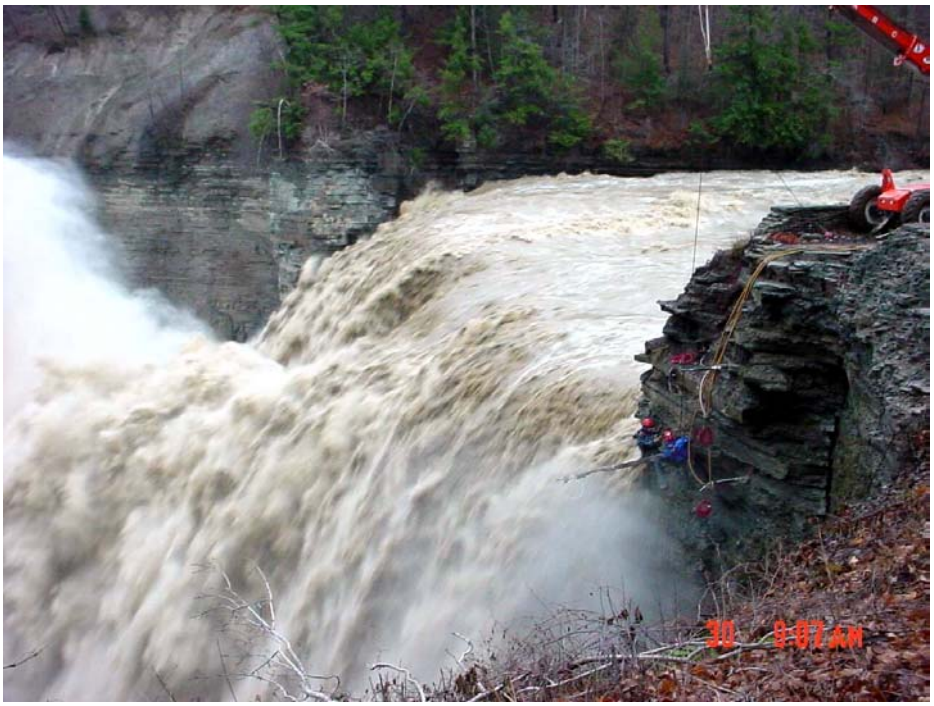

Figure 20 – Janod Installing Rock Anchors on a Rainy Day

Due to the onset of winter work was suspended until the Spring of 2006.

OPRHP contracted with Patterson-Stevens Inc. to complete the outstanding work, consisting of installing the anchors and drains in the overhang area. Nothnagle, Inc. subcontracted with Patterson-Stevens as the specialty subcontractor for rock scaling and rock anchor installations.

Instead of working from ropes, Nothnagle constructed a work platform as shown on Figure 21. The platform was suspended from a crane and attached to the gorge face with wedge bolts.

Figure 21 Nothnagle Installing Rock Anchors in the Overhang Area.

Nothnagle completed performance and proof testing on rock anchors and nails. Figure 22 shows an anchor test setup.

Figure 22

Strain gauges were installed on several rock anchors to provide a means of monitoring stress in the anchor rods and rock movement. Figure 23 shows a typical strain gauge installation.

Figure 23 Strain Gauge Installation

Wires from the strain gauges lead to a central readout box installed into the newly construction portion of the viewing platform wall. MMCE has monitored the gauges since construction was completed. The data do not indicate an increase in stress in the anchors.

Nothnagle recessed the anchor heads into the rock face as shown on Figure 24. Figure 25 shows the completed project. Although the anchor locations are evident in Figure 25, as the grout has set, it blends with the rock color making the anchor locations imperceptible to those viewing the gorge face.

Figure 24 Recessed Anchors in Overhang Area

Figure 25 – Completed Project

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