



United States Department of the Interior

NATIONAL PARK SERVICE
Water Resources Division
1201 Oak Ridge Drive, Suite 250
Fort Collins, CO 80525

IN REPLY REFER TO:

October 21, 2011

L54(2380)
RICH/General

Memorandum

To: Superintendent, Richmond National Battlefield Park

Through: Gary Rosenlieb, Acting Chief, Water Resources Division (WRD)
Gary Smillie, Acting Chief, Water Operations Branch (WOB)

From: Larry Martin, Hydrogeologist, Water Operations Branch, WRD

Subject: Trip Report to Drewry's Bluff Unit of Richmond National Battlefield Park
September 13, 2011

Summary: Natural geologic processes have resulted in formation of near-vertical faces along some parts of the escarpment near the top of Drewry's Bluff. In other areas, the upper slope of the bluff is a more stable, gentle slope. The near-vertical faces are unstable and will eventually fail, slumping down the hillside as a series of small debris flows. There is nothing that can be done to prevent these slumps from occurring. Areas adjacent to the vertical bluff faces should be fenced and signed to warn persons about the inherent instability of these areas. If there are important artifacts or infrastructure in these areas, they should be removed to save them from otherwise inevitable destruction.

It is unlikely that any type of engineering solution would stabilize the slopes of the bluff in their current condition.

Discussion: Drewry's Bluff overlooks the James River about 10 miles downstream from Richmond. The bluff was the site of a Confederate fort during the Civil War. Its strategic location on a high point of land overlooking the river provided an advantageous position for cannons to fire on Union ships traveling upriver to attack Richmond.

In recent years, park staff have been concerned about the unstable slopes on the bluff between the river's edge and the fort at the top of the bluff. Several studies have been conducted to investigate the cause of the slumping, but the experts disagree on the root cause of the instability and therefore the appropriate remedial actions to stabilize the slopes. A variety of projects have been proposed to stabilize the slopes, but all have been deemed either too disruptive, too expensive, or both.

Some of the previous investigations have hinted that the flow of the James River at the toe of the slope is the cause of erosion on the slopes of the bluff. That is incorrect. The toe of the slope is fairly stable, eroding only very slowly. There is no need to construct walls, place riprap, or any other mitigation actions as they would likely cause more harm than good.

Some of the previous investigations have suggested removal of trees from near the edge of the bluff; the thought being that the weight of the trees at the edge of the bluff contributed to slumping. Other investigations suggest that planting trees and shrubs will help to stabilize the slopes. It is my opinion that the intertwined root mass of trees and shrubs slows the rate of retreat and slumping. The attached photos show examples of trees at the edge of the bluff with a near-vertical face of 10 feet or more. It seems obvious to me that the root systems are the only thing provided structural support to the exposed sand and gravel comprising the bluff face. Rather than removing trees, park staff should investigate planting additional trees or shrubs that will develop deep, intertwined root systems to provide additional structural support and slow the rate of slumping.

I have reviewed the various proposals for stabilization of the slopes at Drewry's Bluff. The common elements to the proposals are; regrading the slopes to a more stable angle, installing horizontal drains, and planting vegetation to stabilize the regarded slope. These actions would likely result in a more stable slope. However, the regrading would necessarily cut back the top of the bluff, removing most of the historic features that we want to protect.

Recent proposals have suggested installing horizontal wells or drains to reduce the groundwater pressure in the underlying sediments and to reduce the seepage of groundwater from the face of the bluff. This might slow the rate of slumping, but it will not fix the problem. The vertical faces will remain and these areas will eventually fail, resulting in further retreat of the edge of the bluff.

The 2011 request for technical assistance, which led to this trip, asked for assistance in installing monitoring wells and a rain gage to provide data to characterize groundwater response to storm events. Three borings were constructed at the site in December 1991 (Virginia Geotechnical Services, report dated March 1992). The locations of the borings are shown on Figure 1. Depth to water was noted at 57-61 feet below ground surface in these borings. The occurrence of the water table at that depth places it a few feet above the clay layer observed in the outcrop near the base of the bluff. Groundwater seeps from sand or gravel lenses at various locations higher up on the face of the bluff are temporary, perched groundwater lenses resulting from infiltration of precipitation. These features would not register in monitoring wells screened below the water table, more than 60 feet below ground surface.



Shallow monitor wells might be constructed in an attempt to monitor the occurrence of the shallow, perched groundwater lenses. However, locating these shallow monitoring wells in perched aquifers is a hit-or-miss proposition as the perched aquifers are small, discontinuous, and it is impossible to predict the extent or location of any particular perched aquifer. If a monitoring well was located in a perched aquifer, it would be dry most of the time.

In summary, I see nothing to be gained from installing monitoring wells. Water levels from deep wells will not correlate with the occurrence of seeps higher up on the bluff face. Shallow monitoring wells are unlikely to be screened in the perched aquifers, and if they were, they would be dry most of the time.

During my site visit, I noted what seems to be a correlation between the active slump areas and excavated areas near the bluff. The fort was an earthen structure, constructed by excavating a trench and piling the excavated earth adjacent to the trench to form an earthen embankment. These trenches might now act as infiltration beds. Rainfall and runoff from adjacent areas flows toward the bottom of the trenches where it infiltrates in a more concentrated area and then flows toward the face of the bluff, discharging at discrete zones where coarse sand and gravel overlie less permeable sand and silt layers. These areas of concentrated groundwater discharge are inherently weaker and may be the trigger points for formations of slumps. We might be able to intercept and redirect the flow of groundwater under the trench areas by constructing French drains along the bottom of the trenches. There might be two, or more, parallel drains along the bottom of a trench area. The excavation might be 2 feet deep. A perforated pipe in a gravel bed would be laid in the trench, with the pipe sloped away from the slope to drain the water toward the east until the drainage pipe can daylight and discharge its water into the natural drainage of the creek system. A sketch of a potential design for a drain system is shown on an attachment to this report. The final design should be done by someone with expertise in designing drainage systems.

Further investigation is needed to determine whether there is correlation between the active slump areas on the face of the bluff and the excavations on top of the bluff associated with the fort. If the described drainage project is deemed feasible, then a detailed topographic map of the top of the bluff will be needed to plan the design of the drainage system. Installation of the drains would require significant excavation and construction within the area of the historic fort. The drain system might slow the rate of slumping and bluff retreat in some areas, or it might have almost no benefit. The existing vertical faces near the top of the bluff will eventually fail and slump down the hill regardless of any action that is taken to reduce groundwater flow to the face of the bluff.

The measure of the effectiveness of the French drains would be observation of the rate and quantity of water flowing from the discharge end of the pipe. However, draining groundwater in this manner may, or may not, have a direct correlation with stabilizing the face of the bluff.

It may be useful to conduct an annual GPS survey of the location of the top of the bluff to document the rate of retreat and the area lost to erosion and slumping.

This issue may be comparable to lighthouses near the coast. NPS has moved several lighthouses that were in danger of being lost as natural processes caused erosion of the coastline toward the lighthouse. In a similar manner, NPS may need to move the overlook back from the crest of the bluff, and cut some trees, etc. to recreate the desired viewpoint at a safe distance from the edge of the bluff.

A summary of previous site investigations and plans for remediation of the slope instability issue is attached to this trip report.

If there are any questions regarding this trip report, please call me at (970)-225-3515.

cc:

RICH – Kristen Allen

NER – John Karish

WRD – Gary Smillie, Alan Ellsworth

GRD – Julia Brunner, Deanna Greco,

NCR – Marian Norris, Doug Curtis



Photo of a near-vertical face at the top of the bluff. Failure and slumping of this area is inevitable. When that happens, the edge of the bluff will have migrated some distance to the right of the area shown in the photo.



Photo of a near-vertical slope at the top of the bluff. This area is inherently unstable. Slope failure and slumping is inevitable. The material exposed on the bluff face is sand and gravel.



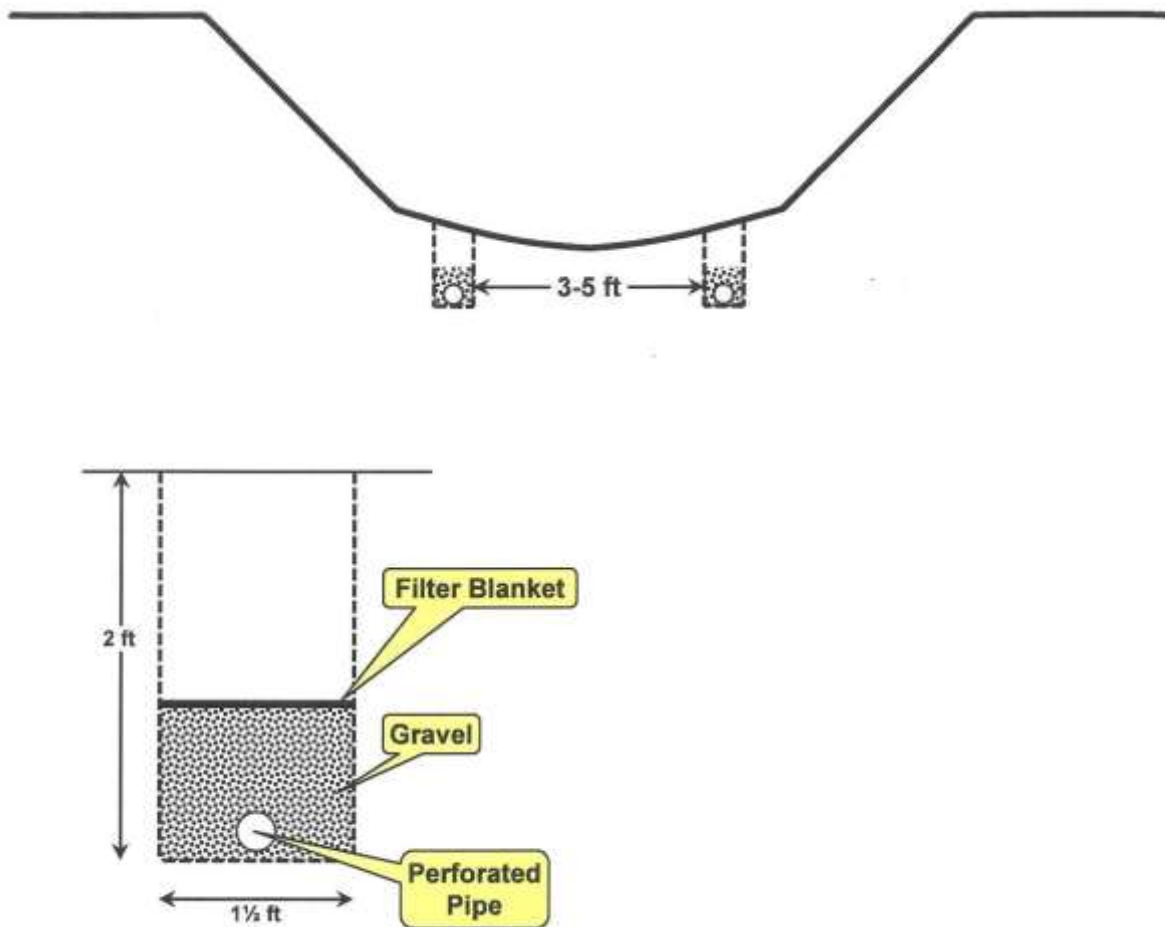
Photo of one of the trenches excavated during the construction of the fort. In this area, two parallel trenches might be constructed with perforated pipe to intercept infiltration and drain the water away from the bluff. Dashed lines show approximate layout of drainage pipe.



Another photo of a trench area where we could install a French drain to intercept infiltration and drain it away from the bluff. This photo is taken from near the edge of the bluff, looking back toward the footpath near the entrance to the fort. Dashed lines show approximate layout of drainage pipe.

Schematic drawing of a French drain system

Installation of a French Drain system may provide an alternative to previous proposals for bluff stabilization. A French drain system could be installed in stages; constructing first at a trial site away from the main fort area. If the trial site showed that it was effective at intercepting infiltration, additional drains could be installed at other areas closer to the fort. The drain system would start with excavation of shallow trenches in the swale areas. The trenches would be backfilled with gravel and drain pipes to intercept water infiltrating into the ground and pipe the water away from the bluff, possibly discharging the water to the unnamed creek on the west side of the fort.



Detailed view of a trench

The design shown in this schematic is only to present the concept for discussion and consideration. If park management desires to pursue this alternative, advice should be sought from engineers or other professionals with expertise in design and construction of drainage systems.

Chronological History of Erosion Studies at Drewry's Bluff (Fort Darling)

Concerns about slope stability at Drewry's Bluff have been an issue for at least 50 years. Following are brief summaries of studies that have been conducted to identify the cause of slumping on the steep slopes of the bluff and potential actions that could be taken to stabilize the slopes of the bluff.

March 1992

Dave Sharrow conducted a site visit in March 1992 and noted that the park was planning to soon take action to address an erosion issue at Drewry's Bluff. Surface water runoff from the parking lot and hiking trail was causing rapid erosion of a gully down the slope toward the unnamed creek. Concentrated runoff from the parking lot had created a gully extending about 150 feet down the slope. Through most of its length, the gully was 1-2 feet deep, but up to 5 feet deep in places. Park staff were concerned that remediation measures should be taken as quickly as possible to prevent additional erosion.

Sharrow noted that there probably wasn't sufficient area at the top of the bluff to construct a stormwater detention basin. He recommended placing a culvert from the top of the bluff, where the runoff could be collected, and transporting down the face of the bluff in a culvert and allowing it to discharge in the creek. He noted that an energy dissipation structure would be needed at the bottom end of the culvert to prevent erosion at the creek.

Sharrow further noted that the erosion along the hiking trail could be addressed by constructed several small ditches to disperse smaller volumes of water, at multiple locations, to the adjacent areas before it could concentrate in larger volumes and create a channel alongside the trail.

March 1992

Virginia Geotechnical Services (VGS) submitted a *Report of Subsurface Exploration and Preliminary Geotechnical Evaluation for the Proposed Fort Darling Slope Stabilization Project*. They concluded that the bluff, which rises 80 to 90 feet from the James River, is unstable and will continue to erode if measures are not taken to protect the toe of the slope from erosion and regrade the steep slopes above the river. They proposed placing riprap, concrete revetments, or other hard structures at the base of the bluff to stabilize the toe of the slope. They further proposed regarding the upper, near-vertical slopes to reduce the potential for failure by slumping.

Costs were estimated at 5 to 7 million dollars. The report was reviewed by Schnabel Engineering Associates. Schnabel disagreed with Virginia Geotechnical Services that the main cause of the erosion is the James River; Schnabel indicated that the normal freeze-thaw weathering cycle was the main cause. The U.S. Army Corps of Engineers independently reviewed the report and conducted site visits and agreed with Schnabel's views.

June 1992

Schnabel Engineering Associates (SEA) was contracted to review the Virginia Geotechnical Services report (see previous section) and consider additional options for remediation and preventing additional slumping. Schnabel agreed that erosion at the toe of the slope was part of the cause of the unstable slopes. They also theorized that the instability on the upper part of the

slope was due to freeze/thaw processes. (That would partly agree with others who identify the small, local seepage faces on the bluff where groundwater discharge occurs as being the causative agent for erosion. The wet seepage faces would be more prone to freeze/thaw actions in the winter months, and simply weaker zones due to their wetness in the summer months.)

Schnabel proposed a massive project that would have included regrading the slope to a lesser grade, installing soil nails (drilling boreholes, installing rebar, and filling with concrete), and covering the hillside with shotcrete.

November 1997

Robbin B. Sotir and Associates (RSA) was contracted to develop more “environmental” alternatives to stabilize the slopes. They proposed bioengineering measures but conceded that vegetation alone would not be sufficient to stabilize the slopes. They identified groundwater seepage at the face of the bluff as the major cause for erosion and slope instability. They acknowledge wave erosion at the toe of the slope, but not as the primary cause of bluff retreat. They propose that the primary sources of water at the bluff face are either; 1) infiltration from on top of the bluff that percolates down to the groundwater system and eventually emerges as seepage on the face of the bluff, and/or 2) surface water flowing down draws and gullies toward the bluff and over the bluff crest. (Gerstel did not see any evidence for surface flow over the crest of the bluff, instead theorizing that the high permeability of the near-surface sediments allowed for rapid infiltration of any surface water, rather than channeling and overland flow.)

RSA summarizes their suggested remedy as;

“The treatment strategy should consist of controlling seepage and runoff, revegetating the bluff face with appropriate vegetation, and defending the toe. It is very important to intercept and divert both surface runoff and subsurface seepage by means of drainage systems. The opportunity for water to collect in the earthworks of catchment area atop the bluff should be eliminated by some judicious regrading and installation of surface and subsurface drains.”

January 2003

The *Water Resources Management Plan* included a short chronology of previous investigations and actions to remediate the erosion/instability problems of the bluff at Fort Darling. These included;

- **1970** – Project construction proposal in excess of \$1.2 million was approved to stabilize about 100 feet of the bluff. The money was not programmed.
- **1975** – A safety fence was installed across the crest of the bluff to prevent visitors from getting too close to the edge of the bluff. However, the fence was built too low and was easily crossed by visitors.
- **1976** – The Soil Conservation Service proposed an expensive, complicated construction of a massive free-standing structure of riprap at the base of the bluff.
- **1987** – NPS coordinated a bluff erosion study with two other parks (COLO and PETE), where general alternatives were discussed and possible solutions offered. Full stabilization costs were estimated at several million dollars.
- **1990** – Nancy Ibison (shoreline engineer, Virginia Department of Conservation and Recreation) met with Pete Baril and Erv Gasser at the unit for advisory assistance

concerning shoreline erosion problems. She recommended; 1) all trees and shrubs growing on the bank and within 50 feet of the bank edge should be cut, 2) selected sections of the bank should be reshaped to 2:1 (horizontal: vertical) slope or flatter, and a vegetative cover established, 3) installation of a properly designed and constructed riprap structure, and 4) a properly designed and constructed bulkhead as an alternative to the riprap structure.

April 2005

Trista Thornberry-Ehrlich completed the *Geologic Resource Management Issues Scoping Summary*. The document presents a summary of the geology of the park, identifies reference materials, and identifies resource management issues that might fall within the realm of geology. Included in these issues is the concern about slope stability at Drewry's Bluff. The report does not attempt to identify the cause of the slope stability, or to make recommendations to remediate or stabilize the unstable slopes. It only identifies slope instability as a problem that should be investigated.

June 2007

A workshop addressing erosion control options was convened to facilitate discussion of alternatives to stabilize the bluff. All workshop participants were NPS employees. The meeting notes provide no indication that workshop participants had any real interest in moving forward on any real stabilization work. The recommended next steps included things like; conducting an archeology survey, studying historical photos, preparing for a NEPA.

February 2008

Wendy Gerstel submitted a report, *Geotechnical Review and Recommendations for Drewry's Bluff/Ft. Darling Slope Stabilization*. The investigation was coordinated through the NPS Geoscientist-in-the-Park program. Gerstel identified two primary mechanisms of erosion at the bluff; toe erosion (bottom up) and shallow groundwater effects (top down).

Toe erosion would be initiated by removal of material at the base of the bluff, essentially undercutting the base of the bluff, and causing failure and slumping to occur starting at the base of the bluff and working its way up the slope.

A prominent seep zone was identified about 5 feet above the beach at the base of the bluff. The seepage occurs above the contact of a layer of medium-coarse sand with the underlying less permeable sandy clay layer. When the groundwater can no longer percolate downward, due to the reduced permeability of the sandy clay layer, it will then flow horizontally until it discharges at the face of the bluff. Where the seepage face occurs the sediments are less cohesive. The wet seepage face is easily eroded and initiates a slump that will work its way up the slope of the bluff. There are several similar zones present at various heights on the face of the bluff, providing multiple locations for formation of small, local seepage faces that are susceptible to erosion and initiation of slumps and unstable slopes.

Gerstel noted a strong correlation between the location of surface depressions at the top of the bluff and slump areas on the face of the bluff. The theory being that rainfall/runoff would collect in the depressions and there would be increased infiltration in those areas. The groundwater

would then flow toward the face of the bluff, where it would discharge as a seepage face, and initiating a slump.

I cannot improve on Gerstel's summary of the process by which shallow groundwater promotes the formation of slumps and landslides on the face of the bluff.

“The presence of this transient perched groundwater regime in the upper portion of the bluff, the apparent correlation of the headscarps with the upland depressions, and the lack of evidence for surface flow over the crest of the bluff collectively suggest that the topographic depressions focus the infiltration of precipitation falling on the uplands. This water then flows through the coarse cobble gravel toward the bluff face, initiating failures in the discharge zone where sediments are weakened by pore-water pressures. Headward erosion enlarges the landslide areas toward the bluff crest, contributing to bluff retreat.”

April 2008

Randy McFarland, USGS, conducted an unofficial site visit. In subsequent emails, McFarland expressed the opinion that the majority of the slope instability was due to the formation of inherently weaker zones where groundwater seepage occurs on the face of the bluff.

June 2008

Gary Smillie, Kevin Noon, and Alan Ellsworth (NPS) visited RICH and conducted a site assessment of Drewry's Bluff. They observed that most of the erosion was occurring as mass failure in the upper third of the bluff. They opined that it appeared the failures were related to reduced pore pressure in areas where groundwater saturation occurred. They saw no evidence that surface water flow over the top of the bluff crest was causing the erosion. They state that the typical flow velocities in the low-gradient river are too low to cause significant erosion at the base of the bluff.

They suggested taking measures to reduce infiltration to the groundwater system, constructing drains to reduce seepage at the face of the bluff, and revegetation to stabilize the bluff. They proved the following summary;

“In summary, several recent visits by geologists and hydrologists to Drewry's Bluff have come to the conclusion that pore pressure from the storm water infiltrated during heavy rainfall events is the likely principal cause of rapid erosion of the embankment. Given this conclusion, WRD staff believes the correct course of action to take at this time is to reduce groundwater in the bluff and to plant vegetation to help over the long-term in providing structural strength to the bank.”

March 2009

PMIS statement #152369 was developed, “Provide emergency stabilization for key Civil War fort at Drewry’s Bluff”. The project proposed to remove trees from near the crest of the bluff, drill 75 horizontal drains into the face of the bluff, install soil pins/nails over 67,500 square feet of the slope, and undertake other stabilization measures. The project was not funded.

Summary prepared by Larry Martin
NPS Water Resources Division
2011