

Memorandum – Coastal Engineering Review

RICH Compile and Assess Stabilization Alternatives at Drewry's Bluff

TAR 17669

12 February 2021 (Revised 19 April 2021)

Project Background

Drewry's Bluff is an earthen Civil War fort atop a 90' high bluff along the James River in the Richmond National Battlefield Park, Richmond, Virginia. The James River directly approaches the Park from the north, bending towards the east at the base of Drewry's Bluff which is located on the outside bend of the river. The bluff is known to have been eroding since the Civil War and NPS has been concerned with the bluff's stability for more than 30 years. Over this time NPS has completed at least five geotechnical and/or survey investigations of the site. The EA team was tasked with reviewing these previous efforts and commenting on possible next steps.

This memorandum summarizes the EA team's review of the previously completed materials and the investigation of the overall site regarding existing conditions and future impacts due to climate change associated factors. This perspective is limited to the information provided by NPS and any external reference material noted within the memorandum. EA was not tasked with, nor did the team review engineering calculations or similar background design information in detail.

Previous Investigations Summary

The EA team was provided a total of four previous investigations (1992, 1992, 1997, 2008) of the site by professional geotechnical firms, and a more recent investigation utilizing LIDAR data collection (2013, 2020). While all four geotechnical firms performed site visits and visual inspection of the bluff, the only physical data collection performed were three soil borings completed by Virginia Geotechnical Services in 1992. Monitoring wells have been proposed for us in gathering more information on the groundwater levels and seepage rates of the bluff, but no wells have been installed to date.

The previous reports draw different conclusions as to the primary erosion mode of the bluff face, provide reviews of several engineered solutions, and present recommendations for stabilization methods. These findings are summarized in Table 1.

Table 1 - Summary of Geotechnical Investigations

Study Year	Consultant	Primary Identified Erosion Mechanism	Armoring Systems Reviewed	Recommendation	EA Comments on Recommendation
1992	Virginia Geotechnical Services	River undercutting and slope sloughing failure	1. Riprap and Flattened Slope 2. Reinforced Concrete Wall and Backfill 3. Sheet Piling or Crib Walls with Reinforced Backfill	1. Sheet pile wall or 2. Soldier Pile wall both with Reinforced Backfill	Either a sheet pile wall or a soldier pile wall along the riverbank would be difficult/costly to construct and would only address riverine erosion mechanisms.
1992	Schnabel	Freeze/thaw cycle erosion	Soil slope pressures (based on cursory analysis) will not support VGS solution as reinforcement of the slope does not have required space for anchorage	Combination of soil nailing for higher slopes and riprap along the shoreline	Soil nailing along the higher slopes would remove much of the natural vegetation, which is the only mechanism currently anchoring these upper slopes. Riprap along the riverbank is probably the best solution for riverine induced erosion.
1997	Robbing B. Sotir & Associates	Uncontrolled seepage and runoff induced erosion	Revegetate slope along with: 1) Regrading 2) Reinforce toe and regrade 3) Live Slope Grating and regrade 4) Reinforced Fill regrading	Revegetate slope along with: 1) Regrading 2) Reinforce toe and regrade	Regrading the slope is not feasible without completely changing the landform of the bluff as there is little land at the top that can be cut to create a shallower slope. Revegetation would help solidify soils, but efficacy is unknown so long as the erosion mechanism remains unknown.
2008	Qwg Applied Geology	A combination of previous studies	Review of all previous options	1) Draining unconfined aquifer on-site 2) Protect toe of slope 3) Do not remove trees	Draining water away from the slope/river in the vicinity of the fort will provide relief from several erosion mechanisms.

An aerial photograph with GIS information of the site was provided within the 2008 report, Geotechnical Review and Recommendations for Drewry's Bluff/Ft. Darling Slope Stabilization: Richmond National Battlefield Park, Richmond, Virginia, 2008 and this is duplicated as Figure 1 below to provide a general overview of the site to the reader.

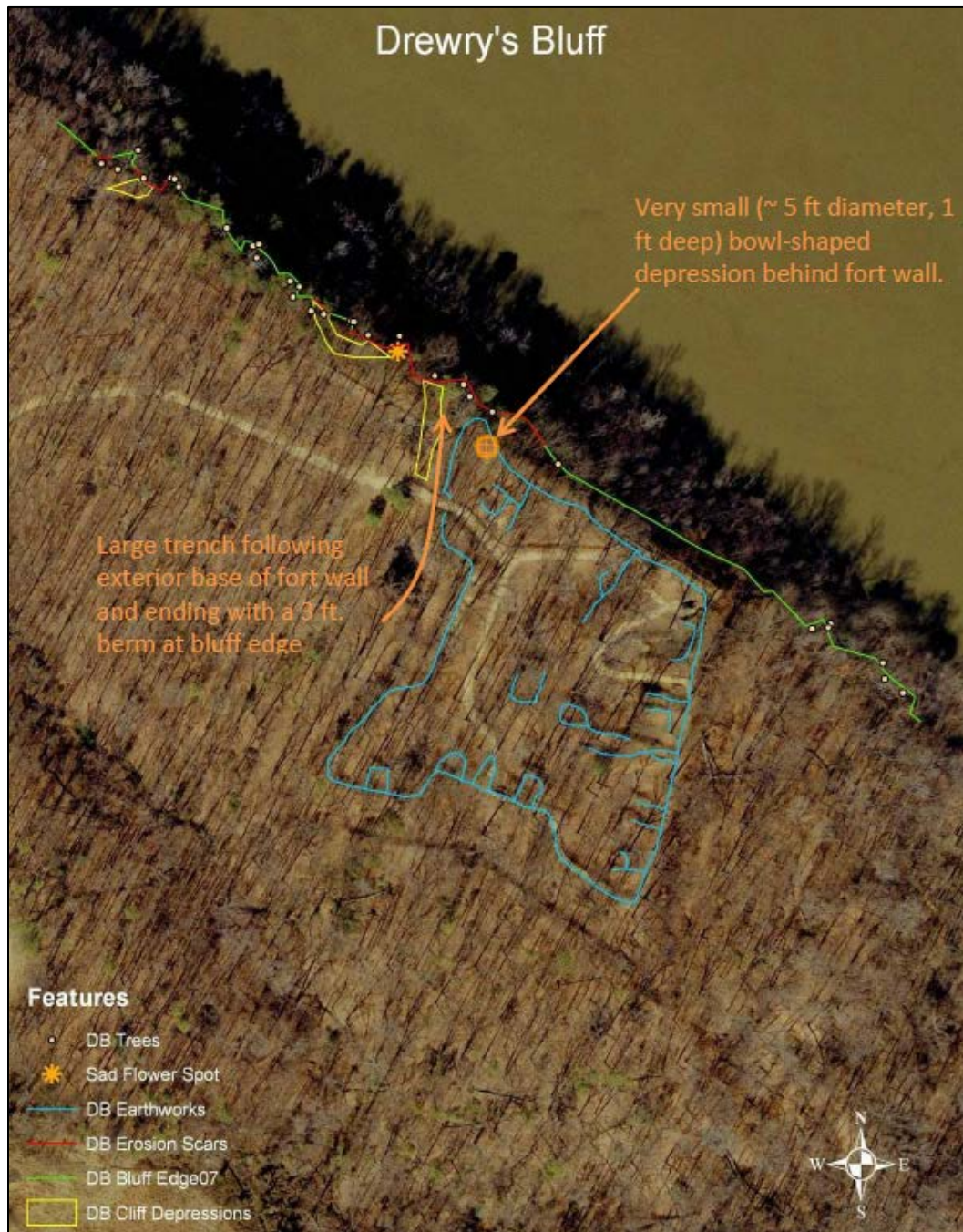


Figure 1 – Aerial Photograph with GIS data of the Drewry's Bluff Area including the James River at top of image from Geotechnical Review and Recommendations for Drewry's Bluff/Ft. Darling Slope Stabilization: Richmond National Battlefield Park, Richmond, Virginia, 2008 (GIS completed by K. Allen and A. Trivizas from NPS)

In addition to the geotechnical reviews, Bowman Consulting Group, Ltd. (Bowman) collected a LIDAR surface survey of the bluff face in 2013 and 2020. These surface elevations were reviewed which included removing equipment noise and errors and then transforming the file information into a “bare-earth” projection where vegetation scatter was removed to the maximum extent practicable. Bowman reports that these final “bare-earth” elevations have an error of +/- 15 percent. When the 2013 surface is subtracted from the 2020 surface to determine an overall volume change, the resultant change is an approximate 2 percent increase in bluff size. Although the noted 15 percent error is greater than the noted 2 percent increase, it is important to note that the relative change presented may still be accurate. That is, if a change is indicated in a location on the bluff in the profile comparison although the volume difference may not be entirely accurate the relative loss or gain of material at a location should be noted. In these cases, erosive patterns may also be deduced. To this point inspection of the provided profiles in the Bowman report also provides locations where erosion has occurred at the bluff crest since the original survey in 2013. The Bowman survey analyzed a point cloud of data; however, the presentation is set to display profiles every 5 feet along the bluff for 694 linear feet along the top. There are 104 presented profiles. It can be deduced from these profiles that some of this material has come to rest below the crest and is now located midway down the slope in the 2020 profile at the same station. Table 2 below summarizes this observable erosion. Aside from these seven stations, the overall changes between the two profile surveys appears minimal including areas near the base of the bluff at the river edge.

Table 2 - Erosion Identified by EA in comparison of 2020 to 2013 LIDAR Survey Profiles

Station	Notes
MP 265	Crest erosion
MP 290	Crest erosion
MP 315	Crest is slightly eroded, slightly more material down slope
MP 325	Shows crest eroded and more material down slope
MP 375	Eroded area
MP 590	Accumulated material at base and one location on slope
MP 615	Accumulated material at base

Sea Level Rise Impacts:

NPS coastal guidance on sea level rise and storm surge projections (2018) do not include the subject site in the analysis projections. Utilizing the USACE online tools (https://cwbi-app.sec.usace.army.mil/rccslc/slcc_calc.html) we utilized the NOAA intermediate values for sea level rise. These provide an estimated sea level rise as +0.36 ft in 2030, +1.18 ft in 2050, and +3.93 ft in 2100. This provides a 100-year flood elevation (with wave runup) of 23 ft currently, 23.36 ft in 2030, 24.18 ft in 2050, and 26.96 ft in 2100. For reference to the information provided by the Bowman LIDAR survey, EA reviewed data for flood frequency events on the James River. The nearby USGS gauge station (USGS 02037705) for the James River at City Locks in Richmond Virginia was reviewed for historic storm events occurring since the LIDAR data was collected in 2013. The highest water elevation recorded by this station was to elevation 17 ft NAVD88, 6 ft below the 100-year storm flood elevation of 23 ft NAVD88. The FEMA FIS report 51041CV000A for this region does not define lower recurrence floods for the river, so the EA team is not able at this time to correlate this flood stage to a recurrence interval.

Refer to Figure 2 below for an elevation comparison. The reference transect shown is an idealized version based upon photographic evidence and observation and does not represent a survey of the site.

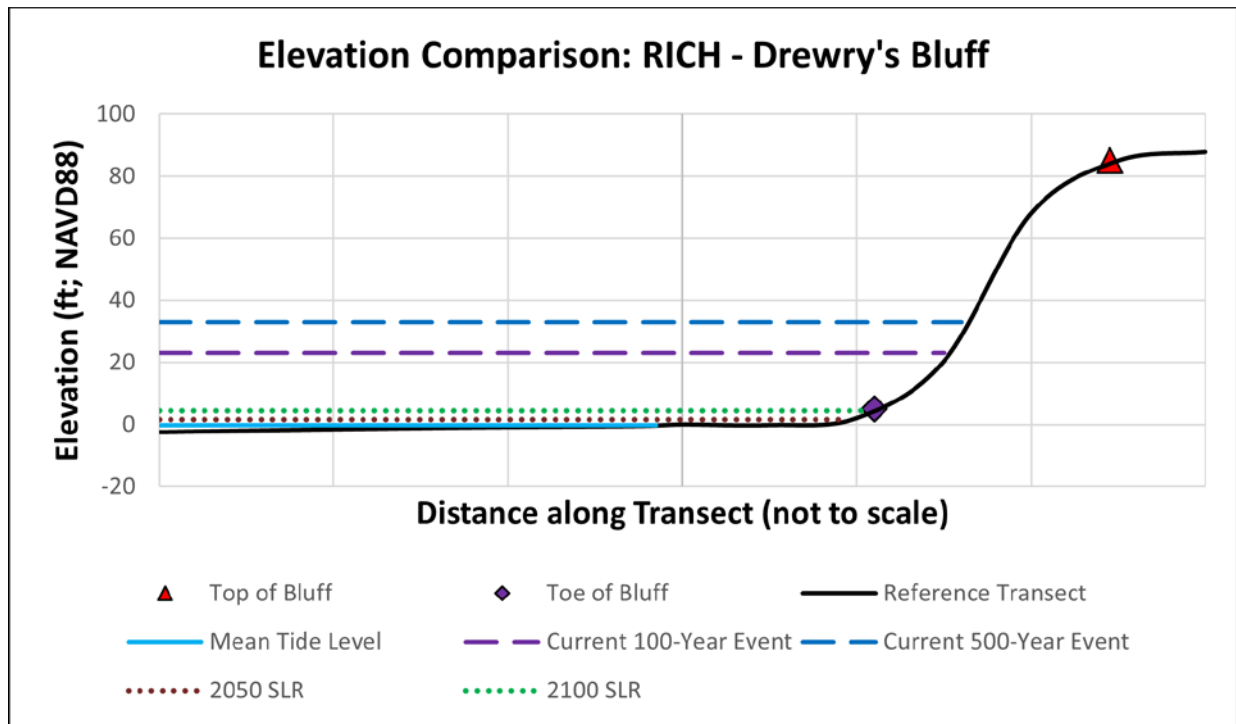


Figure 2: Elevation comparison cross section for Drewry's Bluff

Conclusions

Upon review of the existing information EA has the following conclusions:

The 2013 to 2020 LIDAR review profiles provides an important comparison of the bluff changes within this time frame. As noted previously, the overall bluff location volume is 2% greater from 2013 to 2020, which is minimal in comparison with the reported error in the processed data. However, inspection of the profiles is telling from a relative change standpoint and provides locations where erosion has likely occurred at the bluff crest with material having sloughed off and which is now apparently located midway down the slope. These instances where the bluff has visibly eroded, however, are few (in 7 of 104 profiles) and the overall change during this 7-year time frame appears minimal. It is important to recognize that erosion does not appear to be advancing rapidly at the bluff crest, nor was it visible at the toe of the bluff during this time within the profiles.

In addition to the important LIDAR information there are two key items at the site that have been established based upon the review of the previously completed investigations and supporting data:

1. The erosion at the toe of slope due to impacts from the James River is relatively low compared with the top of the bluff. This observation is also borne out by review of the LIDAR profile comparison. This is in part because the river slope at this point is low and thus the flow velocity is minimal which reduces the potential for erosion. In addition, none of the previous reports discussed impacts to the site from high river flows due to storm conditions. However it should be noted that coastal events such as storm surge could be an issue since the section of river is tidally influenced.

The potential for tidally induced erosion at the site can be expected to increase over time due to sea level rise which will continue to affect the area. The extent of erosion from this increase in sea level at the site is something that should be factored into future planning. As indicated from the sea level review within this memo, significant water elevation can be expected to impact the bluff area over time, however none will approach crest elevation to the year 2100.

2. It was noted in several previous reports that no over-bluff stormwater runoff is occurring. This situation would be a significant contributor to bluff erosion if it were occurring. Principally, it is noted that the bluff is experiencing erosion due to the low cohesive soils at the crest in combination with shallow subsurface flow from stormwater runoff. This condition impacts the crest of the bluff in the shallow subsurface through relatively quick transmission of subsurface flow to the face of the bluff.

In addition, longer term impacts from deeper subsurface flow are derived from infiltration in areas near the bluff and immediately adjacent to this area. These adjacent areas include depressions near the crest and excavated areas which were used to gather soil to build the fort which direct flow toward the bluff. The water infiltrated at these locations concentrates at these areas and travels in the deeper subsurface and then exits through exfiltration at points along the bluff slope at various elevations. Of these two dynamics (shallow and deep subsurface flow) the shallow subsurface flow is likely the greatest immediate contributor to erosion at the bluff crest.

Climate change is expected to increase overall annual rainfall in the region by as much as 10% by the year 2100 with intensity increasing as well. Projections indicate that for the area the 100-year rainfall event may increase by 45% to 55% within this time frame. These increases in precipitation stand to increase the impacts from stormwater runoff at the site over time as well and should be considered in an adaptive management framework for the site.

Recommendations

Based upon the information reviewed to date and our conclusions, EA recommends that an adaptive management framework be established for the site. This approach will allow for steps to be taken initially to stabilize identified erosive situations while monitoring the site for further and/or increasing impacts. Based upon this information future decisions can be made for more aggressive stabilization approaches, if needed, over time. In this adaptive management construct, EA recommends the following steps be taken at the RICH Drewry's Bluff site:

Bluff Monitoring

Establishing a survey monitoring program will provide the information necessary to inform adaptive management steps at the site. This type of program could be established as soon as possible to set a baseline which could use the previous 2013 and 2020 LIDAR data sets for this purpose. A survey monitoring program could be scaled using differing technologies based upon available funding. For example, a LIDAR survey similar to those completed in 2013 and 2020 could be performed on an ongoing basis (e.g. a 2 to 5 year recurring basis). Alternatively or additionally, the monitoring program could establish a number of monitoring benchmarks (i.e. reference points or monuments) along transects or cross-sections regularly surveyed using handheld GPS receivers. Markers can be fiberglass or rebar stakes driven into the ground, or existing features of the landscape, but must be something that will not change, erode, or wash away in a storm. As many as nine monuments already exist along the bluff, according to NPS Monumentation.¹ In addition to topographic information, photographs could also be incorporated into the program reporting for comparison purposes. It is also possible SfM (Structure from Motion) based recurring photographic monitoring could be established to be executed during the winter season to reduce interference from vegetation.

River Monitoring

Monitoring sea level rise at the site will ascertain when and if the base of the bluff slope at river edges begins to experience erosion at an increasing rate. This riverine erosion tracking can also be completed as part of the survey monitoring. Based upon these reviews an adaptive management approach can be employed to determine if in the future it is necessary to implement shoreline stabilization methods as

¹ <https://www.arcgis.com/home/webmap/viewer.html?useExisting=1&layers=6f482e19f27147bf9ccd03741ce1d79c>

outlined in previous reports. These stabilization methods can include but are not limited to rip rap armoring, sheet pile walls, or revetment installation.

Trends and patterns in water levels at Drewry's Bluff can be estimated by consulting the records of two existing tidal gauges at the mouth of the James River and closer by near Richmond. However, neither of the existing gauges can be expected to accurately represent the conditions at Drewry's Bluff, due to the complex interactions of tidal influence and other physical and oceanographic factors on water levels in an estuary like the James River. Site-specific water level data may be obtained by deploying an inexpensive water level logger. Such data loggers are easy to deploy, collect water level data continuously, and the data is easily downloaded. A comparative analysis between data obtained from the site's water level logger and from the two closest tidal gauges could reveal patterns and relationships among water levels in the three areas that could be useful for adaptive management purposes. NPS has developed standard operating procedures² for the use of HOBO loggers in the Northeast Coastal and Barrier Network (NCBN) tidal wetlands and coastal areas.

Monitoring shoreline change directly may offer advantages over water level monitoring alone. Guidance and protocols for ocean shoreline position monitoring developed by the NCBN Geomorphological Monitoring Program are available for reference,³ however applications so far have been in park units with largely ocean beach-dune ecosystems. The exact protocols may not be applicable to the shoreline at Drewry's Bluff.

Collecting data on river bathymetry via a hydrographic survey would be helpful in identifying baseline conditions at the site. Bathymetry data comprise water depths, and by association, data would also provide information about the shape, structure, and features of the river bottom. This information can inform adaptive management against shoreline erosion. However, hydrographic surveys can be costly and logistically challenging depending on the data coverage and resolution required and survey method used (e.g., acoustic sonar, LiDAR).

Bluff Stabilization

The geology and material makeup of the bluff as discussed previously is an indicator that erosion will continue unless a major project to cut the bluff crest to reduce the slope is undertaken (as proposed by VGS in the 1992 report). As described in the provided information this would be very expensive and significantly impact the historical resource and is not considered a feasible option. However, steps can be considered to help stabilize the bluff and reduce the impacts of erosion over time which can include the following:

- Maintain fencing to keep pedestrian traffic away from the highly erodible bluff crest. This fence should be a minimum of 10 to 15 feet back from the bluff edge and tall enough to prevent visitors from crossing it.
- Establish further vegetation on the bluff up to the crest and establish growth on the slope as much as feasible. This would include species of local flora which can be determined through careful planning to maximize protective benefits. This vegetation would then generally provide greater stability of the bluff through root action. With the pedestrian fence in place, this would provide further protection for the vegetative growth which in turn will help stabilize the bluff surface.
- It was noted that no over-bluff stormwater flows were observed in previous reports, however there are areas that ponding or higher infiltration of stormwater are occurring. It is recommended that alternatives for reducing infiltration in these flow concentrating areas be developed. One

² Curdts LT. 2017. Continuous water level data collection and management using Onset HOBO® data loggers: A Northeast Coastal and Barrier Network methods document. Natural Resource Report. NPS/NCBN/NRR—2017/1370. National Park Service. Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2237862>

³ Northeast Coastal and Barrier Network Geomorphological Monitoring Program — Ocean Shoreline Position. 2006. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2192968>

approach could be to fill and regrade ponding areas that currently hold water to shed water away from the bluff. In addition, selective planting of trees in the ponding areas could allow for phytopumping (removal of excess water through evapotranspiration) of water from the bluff. Another approach could be to install an engineered system such as French drains or subsurface tile drains which can spread the infiltration area. This would then lead to subsurface flows being distributed and thus not providing a possible focal point exist along the face of the bluff slope. This focal point exfiltration is a condition which can lead to increased erosion on the slope.

References

- ArcGIS. National Park Service Monumentation Viewer.
<https://www.arcgis.com/home/webmap/viewer.html?useExisting=1&layers=6f482e19f27147bf9ccd03741ce1d79c>
- Curdts, L.T. 2017. Continuous water level data collection and management using Onset HOBO® data loggers: A Northeast Coastal and Barrier Network methods document. Natural Resource Report. NPS/NCBN/NRR—2017/1370. National Park Service. Fort Collins, Colorado.
<https://irma.nps.gov/DataStore/Reference/Profile/2237862>
- Gerstel, W. Qwg Applied Geology. 2008. Geotechnical Review and Recommendations for Drewry's Bluff/Ft. Darling Slope Stabilization: Richmond National Battlefield Park, Richmond, Virginia.
- Northeast Coastal and Barrier Network Geomorphological Monitoring Program — Ocean Shoreline Position. 2006. <https://irma.nps.gov/DataStore/Reference/Profile/2192968>
- US Army Corps of Engineers (USACE). Sea-Level Change Curve Calculator (Version 2021.12).
https://cwbi-app.sec.usace.army.mil/rccslc/slcc_calc.html