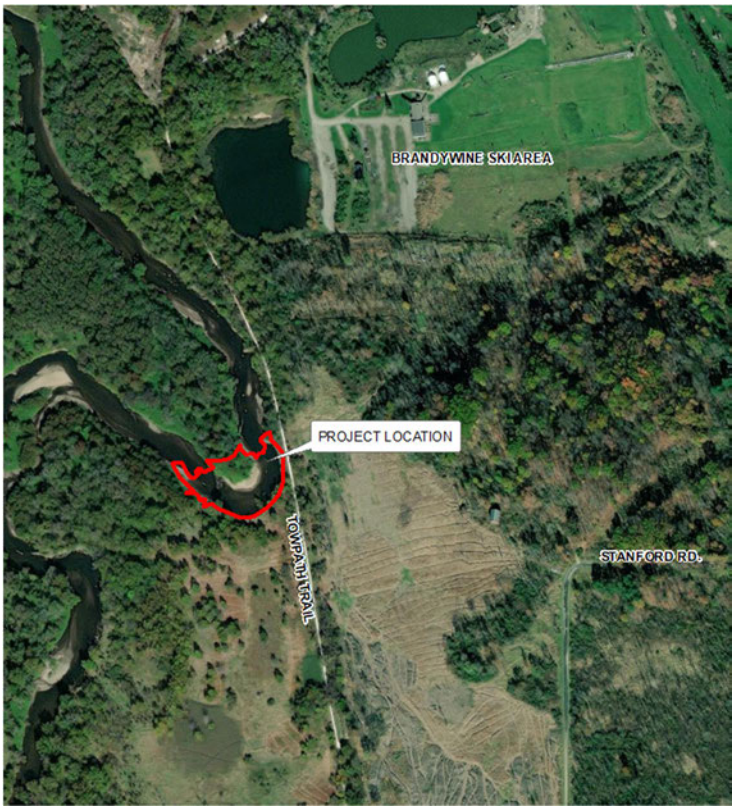
CUVA #224822 BASIS OF DESIGN REPORT

Cuyahoga Valley National Park
Mile Marker 20 South Site



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PROJECT TEAM & STAKEHOLDERS

Agency	Company Description	Expertise & Project Role
	CLIENT	
	National Park Service The National Park Service manages over 423 areas across the nation. At Cuyahoga Valley National Park they have joined forces to restore over 25-mles of river and ecological habitat within the park system. To date they have been able to accomplish the removal of two (2) dam structure, multiple stream and habitat improvement projects, and the clean-up of one superfund site. For this project they will provide expert knowledge of the park infrastructure and surrounding area, as well as, project management budgetary support.	**Expertise** • Project history and oversight • Park operations and management procedures • Consultant oversight Role • Project Manager
	DESIGN-BUILD TEAM	
	RiverReach Construction RiverReach is the prime consultant on this project. They will implement the restoration construction while also assisting with the design phase of the project. Their experience includes river restoration, dam removal, wetland restoration, dredging, trail construction, stream debris removal, landscaping and general contracting They specialize in executing complex restoration tasks while providing minimal impact to the surrounding environment.	**Expertise** • River Restoration Construction Specialists • Success on Projects of a Similar Size and Scope • Flow Management Approaches **Roles** • Contract Administration • Access and Staging Assessment • Risk Assessment • Constructability Assessment • Construction Implementation
	GPD Group GPD Group (GPD) is a sub-consultant for this project. They will assist with project management, scheduling, and engineering / design services. Their experience includes various studies, condition assessments, rehabilitation evaluation, alternative analyses, and flood control modeling for projects involving protection of structures or river features at risk, channel restoration design, hydraulic modeling, and riverbank stabilization.	**Expertise** • Restoration Design & Plan Development • Hydraulic Modeling • Surveying • Geotechnical Engineering • Structural Engineering **Role** • Engineer of Record • Geotechnical Slope Stability Modeling • Material sizing • Retaining Wall Design • Technical Advising, QA/QC
	EnviroScience, Inc. EnviroScience is a sub-consultant on this project. They will provide stream and wetland restoration, reforestation, endangered species surveys, and biomonitoring services. Their experience includes enhancement and stabilization projects for streams, wetlands, and other ecological systems to aid in their geomorphology and river restoration design.	**Expertise** • NE Ohio Leader in Stream Restoration • Historical Knowledge of the Cuyahoga River Corridor • Regulatory Permitting Experience **Roles** • Geomorphology • River Restoration

1.0 INTRODUCTION

1.1 BACKGROUND

This project includes a single, laterally migrating meander bend threatening the towpath trail. Multiple bank stabilization projects have been completed at the downstream extent of the project, but severe erosion continues along the right-descending bank.

This project is part of a wider bank stabilization project meant to protect critical park infrastructure. Consultants hired through the National Park Service (NPS) conducted analyses and developed bioengineered Schematic Design (SD) solutions for a total of eight sites located along the Cuyahoga Valley Scenic Railroad (CVSR), which runs primarily along the left (west) bank of the Cuyahoga River, and along the Ohio & Erie Canal and Towpath Trail, which runs along the right (east) bank.

RiverReach and their Design-Build (D-B) Team were contracted to re-evaluate each site for necessary repairs, reconstruction, and stabilization requirements in relation to information provided from the previous studies. Documents included the SD Basis of Design Reports, SD Plans, hydraulic modeling files, and geotechnical data reports. Based on this document review and on-site observations, the eight sites were given priority ranking for implementation and construction. A full report of the initial evaluation can be found in the SD Evaluation report dated October 2022. Phase I included design and implementation of bank stabilization measures at MP-64.1, scheduled to start construction in July 2023. The "Four-Sites" project is Phase II and includes four of the seven remaining sites, based on proximity and scope of work. The Mile Marker 20 (MM2) project will be Phase III. The design refinement and investigatory process is summarized below.

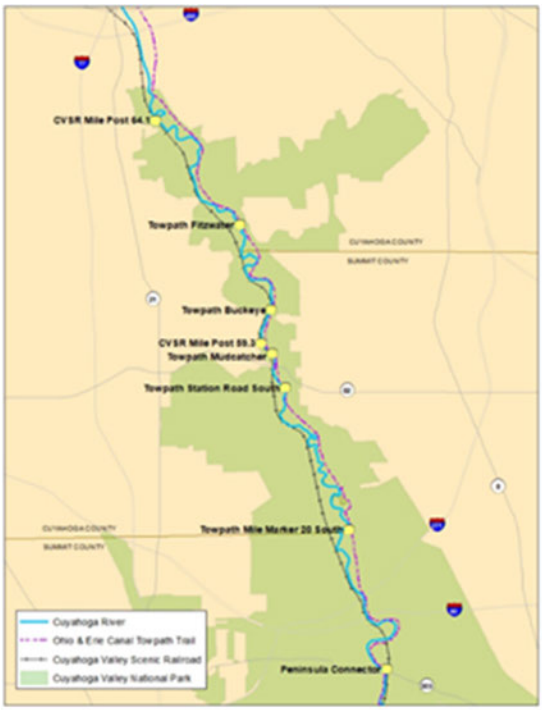

Figure 1: Project Location Map

1.2 DESIGN OBJECTIVES

As part of the Design Development (DD) phase, the D-B Team evaluated several modifications as suggested in the evaluation report:

1. Evaluate project extents and tie-in points.
2. Evaluate planform geometry of the laterally migrating meander bend and the profile of the river upstream and downstream to recommend a stable configuration.
3. Evaluate the implementational benefits of Longitudinal Fill Stone Toe Protection (LFSTP) verses toe rock or bendway weirs in terms of applicability, extents, material, and cost.

For the Construction Development (CD) phase of design, the D-B Team finalized the design approach and refined working models, and calculations as described in the following basis of design report.

2.0 BASIS OF DESIGN

2.1 TOPOGRAPHIC SURVEY

GPD collected additional field data during fall/winter of 2022 and spring of 2023. Survey control was based on Ohio State Plane North Coordinates 3401 (NAD 83 and GRS80) and completion of the general topographic and bathymetric survey. The vertical datum was based on the North American Vertical Datum of 1988 (NAVD 88). Existing ground data was collected through the extents of the project reach, including banks, stream channel, and any adjacent park assets (i.e. trails). Control points were used during geomorphic stream assessment surveys and will be used for layout during construction.

When applicable, data collected in the field was supplemented with the 2018 topographical basemap developed for the DD work.

2.2 GEOTECHNICAL INVESTIGATIONS

2.2.1 SUBSURFACE SOIL CONDITIONS

As part of this study, GPD reviewed previous subsurface information prepared by HDR, dated August 18, 2021. Information contained within the HDR report included three (3) borings performed at the top of slope at Mile Marker 20 South site. In addition, the boring logs (prepared by HDR) included description of the encountered soils, split-spoon samples, in-situ moisture contents, unconfined compression strengths, Atterberg Limit results, and grain size distributions.

According to these reports the site consisted of:

A combination of clays and silts were encountered to depths of 45-feet below existing grade. Material was considered very loose to medium dense and soft to medium stiff Bedrock was not encountered in the borings. Supplemental Wildcats performed along the slope toes generally encountered soils with consistencies ranging from very loose to medium dense and very soft to stiff.

Detailed information can be found in the HDR report.

A detailed Geotechnical Engineering Report is provided in Appendix IV.

2.2.2 SLOPE STABILITY ANALYSIS

The proposed slope conditions along the project length as analyzed using a numerical application of the slice method called Discontinuity Layout Optimization (DLO) within the modeling software. This is achieved by creating multidirectional soil geometry slices (free-body diagrams) from a nodal network. The interslice forces are analyzed to find the path of least energy, which indicates a failure mechanism for each set of slices selected from the network within the models. Rotational failure is determined using a combination of rotation and translational analyses based on moment forces exerted on each slice. These discrete moment forces on each slice were combined in the model to create logarithmic spiral analyses.

The parameters for the modeling included soil strata, effective cohesion, effective internal friction angle, slope profile, and soil weights based on field data collection. The slope profile was derived from available topographic survey data. Available geotechnical data from Others, in conjunction with the three (3) supplement soil test locations performed by GPD, were used to establish estimated soil strength parameters for the stability models.

The results of the analysis were compared against collected field data, expected failure mechanisms, failure geometry, and minimum criteria established by GPD.

Slope failures were categorized into type, severity, and location. Failure was defined as wedge, rotational, sloughing, or a combination based on the movement pattern of soil material along the failure plan. Severity was defined as either minor (depth less than 3-feet), moderate (depth greater than 3-feet and less than 8-feet), or deep-seated (depth greater than 8-feet). Location was defined as top, middle, or bottom of slope.

Proposed Conditions

The proposed model considered remedial solutions consisting of rock bank armoring and planform geometry modifications. Model results achieved an acceptable Adequacy Factor for long- and short-term global stability at all cross-sectional locations. Based on the results, the proposed rock toe exceeds minimum Adequacy Factor requirements for the site as summarized in Table 2.

Table 1. Slope Stability Results under Proposed Conditions

Site Name	Station ID	Modeled Adequacy Factor		Failure Type of Governing Scenario[1]
		Proposed LT Condition	Rapid Drawdown Condition	
Mile Marker 20 South	640+50	1.55	153	Minor Wedge Failure
	641+05	1.65	1.64	Moderate Rotational Failure
	642+57	1.75	1.75	Moderate Rotational Failure

Rotation Failure	Occurs by the rotation on the slip surface, usually by the outward and inward movement of soil, and the shape of the slip surface is curved. Rotational failure may occur in three cases, including face failure, toe failure and base failure.
Wedge Failure	Also referred to as block failure or plane slope failure, and it occurs along an infinite plane. It mostly happens when the wedges and distinct blocks of the soil mass become separated. It is also common when there is a soil layer that has the weak bearing capacity, joints, or fissures and the slope has two different materials.
Moderate	Failure Depth less than 8-ft
Deep-Seated	Failure Depth greater than 8-ft

2.3 MORPHOLOGICAL ASSESSMENT

2.3.1 DIMENSION

Riffle cross sections were measured upstream and downstream of the project site.

A dimensional analysis at Old Portage gage based on 2019 data, associated a 404-square miles drainage area with an average bankfull width of approximately 102-feet, a mean depth of 4.74-feet and a cross sectional area of 483-square feet. At the project site, the Cuyahoga River has a drainage area of approximately 527 square miles. Interpolating data from the Old Portage gage suggests this site has a target bankfull width of approximately 123.3-feet. Two riffle cross sections were measured, one upstream and one downstream of the project reach. The upstream riffle had a bankfull width of approximately 131.6 feet, the downstream riffle had a bankfull width of approximately 122.6 feet. The width to depth ratios of these cross sections were 27.1 and 20.3, respectively. The width to depth ratios of the riffles suggest that the upstream cross section is backwatered by the project reach, causing it to be overwide. Visual observations confirm this assessment, with active lateral migration and erosion visible along the left descending bank and depositional features throughout the riffle. Because the upstream riffle appears to be backwatered by the project reach, the downstream riffle and the regional curve data were used to estimate a bankfull width for the project reach. Based on the available data, a bankfull width of 123 feet was used for development of dimensionless ratios to assess viability of the proposed

geometry.

While the primary goal of the project is stabilization of the bank, the active lateral migration of the meander at the site indicates that additional consideration must be given to the sediment transport and planform geometry of the final design. Active aggradation along the left descending bank, and field observations of stable meander bends upstream and downstream of the site, indicate that the current channel is overwide. Additional consideration was given to the potential impacts of previously installed rock toe and bank barb structures downstream of the site. A deep protrusion scour pool adjacent to the first large bank barb of the older bank stabilization project suggests that the barb is oversized and may be contributing to the instability of the site.

This site is unique in that the river still has lateral connectivity with its floodplain along both banks. The lack of steep valley wall slopes near the stream means that less structural fill is required to stabilize and revegetate the slopes after construction. Development of additional lateral connectivity at the bankfull elevation will further decrease scour potential and allow shear stresses in the channel to be alleviated at higher flows.

2.3.2 PATTERN

The current alignment of the meander bend, and the recent migration, are unusual in that the meander is migrating in an up-valley direction. This indicates that the belt width of the system is constrained by the trail and by historic bank stabilization along the right descending bank of the river.

To match upstream and downstream tie-ins and control the volume of excavation and fill, a revised meander curve consisting of two radii is proposed. The two radii, at the outer bankfull extent of the proposed channel, are approximately 207 feet and 152 feet. Using the field determined bankfull width, these correspond to radii to bankfull width ratios of 1.68 and 1.24, respectively. The upstream half of the existing meander bend, at the time of topographic data collection, has a radius of approximately 140 feet.

The project areas will become more resilient to pattern adjustment post-stabilization due to the modification of both the planform geometry, scour protection and bio-engineering proposed at the site.

2.3.3 CHANNEL CAPACITY & SEDIMENT TRANSPORT

The proposed meander geometry will promote sediment transport by improving the hydraulic efficiency of the meander bend. Additionally, as shown in the hydraulic modeling, the large bank barb at the downstream extent of the project causes a significant lateral scour pool. Re-work of this feature will remove this hydraulically inefficient point in the river, further promoting sediment transport and decreasing lateral erosion pressures in the project reach.

2.4 ECOLOGICAL ASSESSMENT

2.4.1 STREAMS

A Qualitative Habitat Evaluation Index (QHEI) of the Cuyahoga River was completed by HDR and presented in their 2022 report. The MM 20 project reach (Stream B19 in the HDR report) scored a 71.5. This score is consistent with a narrative ranging of ‘Good’ and designates these reaches as a ‘Warmwater Habitat’ with regards to the aquatic life use (ALU) potential. Common substrates within this reach include boulder, cobble, gravel, sand, silt. The adjacent corridor lacked sufficient canopy and diversity to provide adequate coverage of the stream, and sever erosion is occurring along the right descending bank.

Based on these findings, the D-B Team agrees with the initial approach of HDR to include bio-engineering to promote diversity and quality of cover which will help improve aquatic habitat along this project reach. Woody

habitat features would also be desirable to increase roughness of the rock toe and provide habitat value, but the ability to incorporate woody material may be limited by the amount of clearing required to complete the project. Typically, trees and woody material removed as part of access and grading are re-used in the project. The next phase of design will better estimate exact trees slated for removal.

2.4.2 WETLANDS

An initial delineation was performed by HDR in the Summer of 2021, and primarily included areas along the Cuyahoga River and adjacent corridor. During November and December 2022, EnviroScience performed a wetland delineation within the proposed construction limits, which included construction, staging, and access areas. Two wetlands (Wetland complex B16/17/18 delineated by HDR and Wetland W-9 delineated by ES) were identified within the MM 20 project reach. Wetlands were categorized using the Ohio Rapid Assessment Method (ORAM). Based on this assessment Wetlands B16/17/18 and W-9 assessed within the range of a Category 2 wetlands. All wetlands will be avoided for site access and construction activities. Permanent impacts to Category 2 wetlands will remain below the 0.5-acre regulatory threshold. Timber mats will be used as the primary means of avoidance and minimization of impacts to wetlands. The access routes from the Stanford Road barn and staging area as well as along the south side of the project meander will be moving through delineated wetland areas.

The data for wetlands at this site are included in the report prepared by HDR dated January 2022 and the Amendment report prepared by EnviroScience dated January 2023. The combined report includes all sites associated with this study.

2.4.3 THREATENED AND ENDANGERED SPECIES

The U.S. Fish and Wildlife Service's (USFWS) Information for Planning and Consultation Tool (IPaC) was used to research federally listed species that have ranges that include Cuyahoga County.

Endangered Species

Indiana bat (*Myotis sodalis*) & Northern long-eared bat (*Myotis septentrionalis*): The Indiana bat and northern long-eared bat prefer living or dead trees no smaller than 3-inches in diameter at breast height (DBH). In addition, sheds and barns may serve as roosting habitat for the northern long-eared bat. No winter hibernaculum, barns, or sheds were observed within the construction limits. Specific habitat trees were not identified as part of this project. However, any forested areas may provide habitat for federally listed bat species.

Proposed Endangered

Tri-colored bat (*Perimyotis subflavus*): Tricolored bats roost in trees or man-made structures similar to that of the Indiana Bat and Northern long-eared bat, although they primarily utilize clusters of leaves of live or recently dead deciduous hardwood trees. No winter hibernaculum, barns, or sheds were observed within the construction limits. Specific habitat trees were not identified as part of this project. However, any forested areas may provide habitat for federally listed bat species.

Threatened

Northern wild monkshood (*Aconitum noveboracense*): Preferred habitat for northern monkshood is cool, moist, shaded cliff faces or talus slopes in wooded ravines, near water seeps. Suitable habitat for the northern monkshood was not identified within the MM 20 project reach.

Protected

Bald eagle (*Haliaeetus leucocephalus*): The bald eagle is protected under the Bald and Golden Eagle Protection Act of 1940. The bald eagle prefers open bodies of water with an abundance of fish and requires mature stands of trees for roosting and nesting. No bald eagles or their nests were observed within or near the construction limits.

Mussels (*various species*): No federal or state-listed mussel species are identified within Cuyahoga County; however, all native freshwater mussels are protected within the State of Ohio. The Cuyahoga River is listed as a Group 3 stream and requires a mussel survey per the Ohio Mussel Survey Protocol. A mussel survey was performed by Mad Scientist Associates in September 2021 which found no mussels within the survey limits at the MM 20 project reach. Data for the mussel survey conducted at the site is included in the combined mussel survey report prepared by Mad Scientist and dated October 2021. The combined report includes all sites associated with this study.

2.5 HYDRAULIC MODELING

2.5.1 BASELINE MODEL

Hydraulic modeling was performed along an approximately 15-mile stretch of the Cuyahoga River, but the analysis presented in this report focuses on the Towpath Mile Marker 20 South (MM20) site. The modeling was completed utilizing USACE's Hydrologic Engineering Center's River Analysis System (HEC-RAS) modeling program version 6.3.1. The 2-dimensional (2D) hydraulic model was developed for this Design Development phase by layering surveyed terrain data with LiDAR and a burn-in stream layer which was developed during the SD project phase, meant to estimate channel depth across the entire project reach. Figures 2 and 3 below show the 2D mesh geometry and the polygons which were used to extract and analyze 2D hydraulic results in ArcMap. Also shown are the profile polylines which were used to extract data for the scour analysis and 100-yr water surface elevation comparison between existing and proposed conditions.

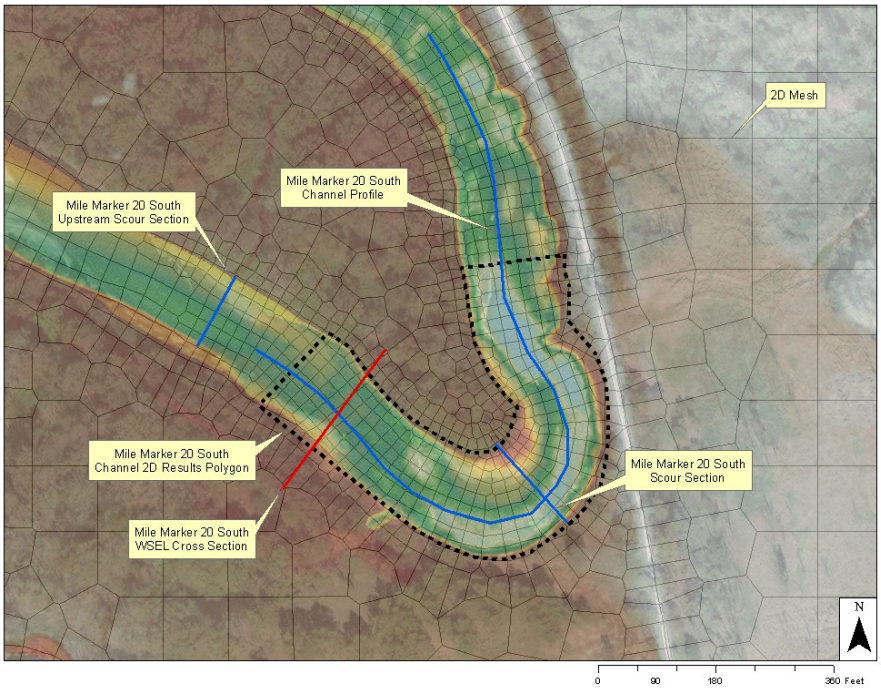

Figure 2. HEC-RAS 2D Model Layout for Existing Conditions

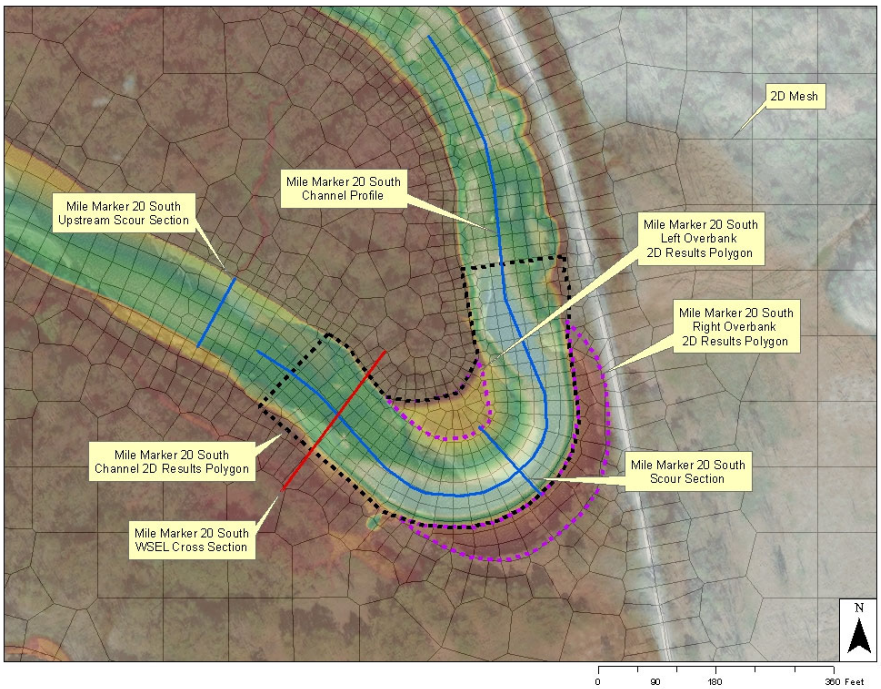

Figure 3. HEC-RAS 2D Model Layout for Proposed Conditions

The Basis of Design Report for Preferred Schematic Design Alternatives completed by HDR in October of 2021

details the development of hydrology for all sites. The report indicates the hydrology was developed from the USACE Buffalo District 1-dimensional (1-D) Eco Restoration Model. The only consistent events between all site locations include the 1-, 1.5-, 10-, and 100-year events. Only peak flow data was provided, and is reported below in Table X. The table below shows the peak flows in the 2D hydraulic model, with the ones relevant to the current project areas highlighted in yellow.

Table 2. Schematic Design Flows

Site	Location	Flow (CFS)*			
		1-yr	1.5-yr	10-yr	100-yr
Peninsula Connector	Downstream @ West Streetsboro Rd	5160	7053	12112	17617
	Downstream @ 3-mile marker	5161	7079	12152	17664
Towpath MM 20 South	Upstream @ Unnamed Tributary Confluence	5173	7137	12252	17799
	Downstream @ Brandywine Creek Confluence	5264	7509	12912	18710
Towpath Station Road South	Upstream @ Unnamed Tributary Confluence	5264	7532	12942	18733
Towpath Mudcatcher**	---	---	----	---	---
CVSR MP 59.3	@ Aura Rd	5335	7878	13567	19608
Towpath Buckeye**	---	---	---	---	---
Towpath Fitzwater	Downstream @ Tinker's Creek	5368	9179	15842	22582

During the proposal phase it was assumed that detailed hydrologic modeling was performed due to the utilization of the 2D model. Upon further review it was found that the 2D model utilized a hydrograph with a constant flowrate. The limitations of the 2D model that spans approximately 15-river miles are as follows:

- Limited survey or bathymetry below the water surface of the river. The channel terrain outside of the survey area was estimated and "burnt" into the LiDAR that was used as the base terrain layer.
- Structures and/or bridges that might have a hydraulic impact are not included as the data collection and modeling of structures or bridges was not included in the scope of work.

The results from the updated model were evaluated to inform the bank stabilization design and to confirm that the change in water surface elevation between the existing and proposed condition was less than or equal to the target change specified in the project Request for Proposal. Results are presented in the following tables and modeling output can be found in Appendix IV.

Velocity

The average predicted channel velocities across all events ranged from 1.13- to 3.19-feet per second (ft/s). The maximum reported velocity of 6.89-ft/s occurred during the 1-yr event. Average and maximum velocities were reported as being highest during the 1-yr event and decreased with each subsequent event. This trend appears to be due to a higher percentage of the flow being conveyed in the floodplain versus the channel during the 1.5-yr, 10-yr and 100-yr events. Table 3 displays a summary of the 2D results extracted from the polygon indicated

in Figure 2.

Table 3. Existing Channel Velocities (ft/s)

Location	Event											
	1-yr			1.5-yr			10-yr			100-yr		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Towpath MM20 South	3.19	0.00	6.89	2.85	0.00	6.22	1.69	0.01	3.97	1.13	0.02	2.88

Shear Stress

The average channel shear stress calculated from the 2D output from HEC-RAS is 0.13-pounds per square foot (psf), with a maximum predicted value of 0.77-psf during the 1.5-year storm event. The 2D calculations in HEC-RAS provided a better estimate of shear stress in the channel versus 1D model results as the value is being calculated at each 2D cell face. Table 4 displays a summary of the 2D results from the channel polygon indicated in Figure 2.

Table 4. Existing Shear Stresses (psf)

Location	Event											
	1-yr			1.5-yr			10-yr			100-yr		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Towpath MM20 South	0.22	0.00	0.66	0.18	0.00	0.77	0.07	0.00	0.31	0.03	0.00	0.37

Depth

The average predicted channel depths ranged from 10.29- to 13.26-feet across the different storm events. The maximum predicted channel depth of 25.90-ft occurred during the 100-year storm event. The greatest depth coincides with the lateral scour pool created by the structures in the previously constructed, downstream bank stabilization. Table 5 displays a summary of the 2D results from the polygons indicated in Figure 2.

Table 5. Existing Channel Depths (ft)

Location	Event											
	1-yr			1.5-yr			10-yr			100-yr		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Towpath MM20 South	10.29	0.00	22.25	11.10	0.00	23.28	12.27	0.01	24.80	13.26	0.07	25.90

Water Surface Elevation

The Mile Marker 20 South site is located within the FEMA Zone A Special Flood Hazard Area (SFHA). In Zone A SFHA's, an increase in water surface elevation of up to 1-ft is permitted by the FEMA National Flood Insurance Program standards. The project RFP indicated that the target increase in water surface elevation is 0.05-ft upstream extent of the Mile Marker 20 South site. In the following section, Table 10 compares the existing and proposed water surface elevations.

2.5.2 PROPOSED MODEL ANALYSIS

Proposed conditions were modeled using the same software and baseline model as the existing conditions to analyze potential impacts to the hydraulic characteristics of the river. Proposed conditions reflect a shift in overall meander alignment of approximately 60 ft in the northwest direction. The proposed design includes comprehensive grading changes in the channel and overbanks at the site. The design includes a 2:1 (50%) slope along the right descending bank (rock toe) and a 20:3 (15%) to 10:1 (10%) slope along the left descending bank (point bar). The existing condition model was updated to a proposed condition by layering the

proposed design surface onto the terrain used by the model. Since the channel alignment varied significantly between existing and proposed conditions, breaklines were relocated within the 2D model to re-orient cells in the 2D mesh to follow the updated bank lines. The profile lines which were used in scour analysis were updated as well to capture the channel features in their new locations in the mesh. The polygon region used to capture model results in the channel was also updated and two new polygons were added to capture overbank data at the meander. See Figures 2 and 3 for profile line and polygon features within these models, as well as changes between the geometries of the models for existing and proposed conditions. Predicted values and comparative differentials are presented below. Full proposed hydraulic modeling output can be found in Appendix IV.

Velocity

The predicted average velocity increased from 1.13-ft/s to 1.31-ft/s from the existing to proposed condition. The maximum velocity occurred for the 1.5-year event with a value of 5.26-ft/s. Table 6 displays a summary of the proposed 2D results from the polygons indicated in Figure 3.

Table 6. Proposed Channel Velocities (ft/s)

Location	Event											
	1-yr			1.5-yr			10-yr			100-yr		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Towpath MM20 South	3.12	0.02	5.08	3.04	0.01	5.26	1.95	0.02	3.98	1.31	0.13	2.86
Delta from Existing	*-0.07*	*0.02*	*-1.81*	*0.19*	*0.01*	*-0.96*	*0.26*	*0.01*	*0.01*	*0.18*	*0.11*	*-0.02*

Shear Stress

The predicted average shear stress value in the channel was 0.13-psf across all events. The maximum shear stress of 1.14-psf occurred during the 1.5-yr event. Table 7 displays a summary of the results from the polygon indicated in Figure 3.

Table 7. Proposed Channel Shear Stresses (psf)

Location	Event											
	1-yr			1.5-yr			10-yr			100-yr		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Towpath MM20 South	0.21	0.00	0.61	0.20	0.00	1.14	0.08	0.00	0.37	0.04	0.00	0.18
Delta from Existing	*-0.01*	*0.00*	*-0.05*	*0.02*	*0.00*	*0.37*	*0.01*	*0.00*	*0.06*	*0.01*	*0.00*	*-0.19*

Depth

The average change in depth ranged from a decrease of –0.12 ft for the 1-yr event to an increase of 0.22 ft for the 100-yr event. Table 8 displays a summary of the proposed 2D results from the polygons indicated in Figure 3.

Table 8. Proposed Channel Depths (ft)

Location	Event											
	1-yr			1.5-yr			10-yr			100-yr		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Towpath MM20 South	10.17	0.00	22.21	11.15	0.00	23.26	12.46	0.01	24.72	13.48	0.14	25.80
Delta from Existing	*-0.12*	*0.00*	*-0.04*	*0.05*	*0.00*	*-0.02*	*0.19*	*0.00*	*-0.08*	*0.22*	*0.07*	*-0.10*

Water Surface Elevation

Table 9 compares the existing and proposed water surface elevations (WSELs) for the 100-year event at the upstream end of the project area based on the WSEL Cross section lines shown in Figures 2 and 3, in accordance with the requirements of the RFP. The current analysis indicates that the change in WSEL is within the tolerance

specified within the RFP.

Table 9. Water Surface Elevation

100-yr WSEL Increase				
Location	Existing WSEL (ft)	Proposed WSEL (ft)	Max WSEL Increase (ft)	Permitted WSEL Increase (ft)
Towpath Mile Marker 20 S.	648.62	648.62	0.00	0.05

2.5.3 MATERIAL SIZING AND SCOUR CALCULATIONS

The proposed hydraulic modeling results were used to estimate appropriate material sizes in support of the stabilization design. The key parameters for material sizing include channel top width, channel velocity, and maximum and average flow depths.

Table 10. Maximum Channel Shear Stress

Location	Maximum Shear Stress (psf)			
	1-yr	1.5-yr	10-yr	100-yr
Towpath Mile Marker 20 S.	0.61	1.14	0.37	0.18

Table 11. Maximum Channel Velocity

Location	Maximum Velocity (ft/s)			
	1-yr	1.5-yr	10-yr	100-yr
Towpath Mile Marker 20 S.	5.08	5.26	3.98	2.86

Overbank regions were also assessed for materials selection. Refer to Figure 3 for the regions of the left and right overbanks which were used to analyze velocity and shear stress. On the left descending overbank area, a maximum velocity of 5.26 ft/s occurs during the 1.5-yr event and a maximum shear stress of 0.61 psf occurs during the 1-yr event. On the right descending overbank area, a maximum velocity of 5.27 ft/s occurs during the 1-yr event and a maximum shear stress of 1.06 occurs during the 1.5-yr event.

Table 12. Left Overbank Velocity and Shear Stress Model Results

Left Overbank Model Results				
Events	Velocity (ft/s)		Shear Stress (psf)	
	Avg	Max	Avg	Max
1-yr	3.96	5.08	0.35	0.61
1.5-yr	4.11	5.26	0.38	0.59
10-yr	3.26	3.98	0.22	0.30
100-yr	2.27	2.76	0.10	0.17

Table 13. Right Overbank Velocity and Shear Stress Model Results

Right Overbank Model Results				
Events	Velocity (ft/s)		Shear Stress (psf)	
	Avg	Max	Avg	Max
1-yr	0.85	2.67	0.03	0.18
1.5-yr	0.79	2.62	0.03	1.06
10-yr	0.58	1.62	0.03	0.36
100-yr	0.60	1.53	0.04	0.38

Based on this information the following design parameters have been selected at this design stage:

- Rock Toe: Mix of 12- to 30-inch sized rock (Ohio DOT Type A, B, and C)
- Overbank: Coconut fiber with net and/or live willow stakes

A scour analysis was performed to evaluate the design effectiveness against erosive forces during various flow conditions. Multiple types of scour representing instantaneous forces which cause bend and general scour, as well as long-term degradation, were evaluated. Long-term degradation type scour consists of evaluating the equilibrium slope and the formation of an armoring layer using equations from the National Engineering Handbook developed by U.S. Department of Agriculture. The average calculated scour depths are shown in Table 15. Key parameters from the proposed 2D HEC-RAS modeling included flow depth, hydraulic radius, energy slope, flowrate, maximum velocity, and maximum shear stress (see Table 11 and Table 12)Table 10. The data was pulled from the 2D model along the scour profile lines indicated on Figures 2 and 3. EnviroScience provided an estimated D50 and D90 valueTable 10, see Table 14, based on pebble count data collected at the site that was used in the scour analysis.

Table 14. Substrate Estimates

Location	D_{50} (mm)	D_{90} (mm)
Towpath Mile Marker 20 S.	23	112

Scour depth results were highest in the channel during the 1-yr design storm and decreased with each consecutive design storm. This is due to a higher percentage of the flow being conveyed in the floodplain versus the channel during the 1.5-yr, 10-yr and 100-yr events. Based on these values, the predicted scour depths ranged from 7.1-ft to 8.0-ft for the existing condition and 6.80-ft to 7.41-ft for the proposed condition across the design storm events – detailed scour calculations and equations can be found in Appendix VI.
Table 15 indicates the scour depth for the 1-, 1.5-, 10-, and 100-year events.

Table 15. Predicted Scour Depths

Towpath Mile Marker 20 South		
Average Scour Depths (ft)		
Event	Existing	Proposed
1-Year	8.01	7.41
1.5-Year	7.93	7.36
10-Year	7.60	7.38
100-Year	7.10	6.80

2.6 STABILIZATION DESIGN

The design objective was to restore the subject streambank and establish a stable geometry and toe armoring to promote sediment transport and prevent lateral migration.

2.6.1 SELECTED DESIGN APPROACH

The design includes installation of a keyed rock toe along the outer bend of the new meander. The existing bank and pool will be filled with alluvial material and capped with topsoil, bioengineered soil fill with native plantings along the bankfull elevation will create a transition from the rock toe to the bankfull bench. The depth of the rock toe key is governed by the potential scour depth determined by hydraulic modeling of the proposed conditions. Additional roughness elements can be incorporated into the rock toe to further move flow toward the center of the channel including inclusion of logs and other woody materials. Due to the lack of clearing required for access to the site and for the proposed grading, the availability of large wood elements to incorporate into the rock toe may be limited and, therefore, was not assumed at this design phase.

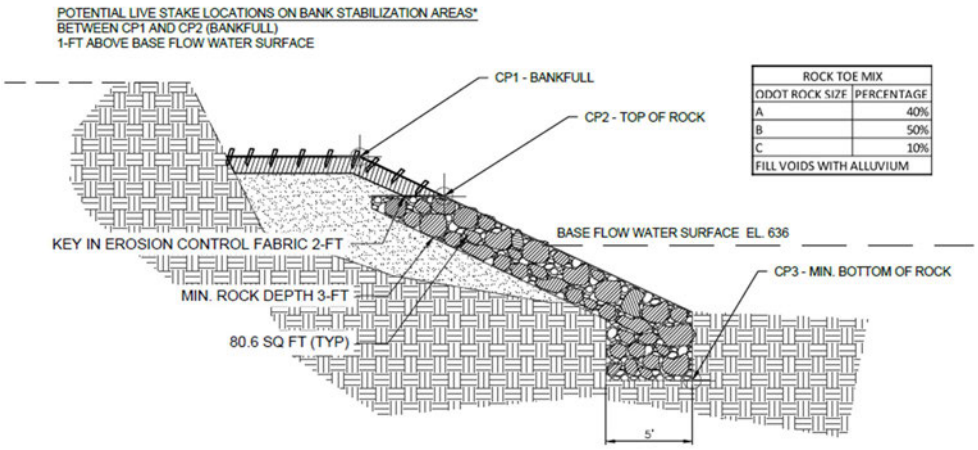

Figure 4. Bio-engineered Design Approach

3.0 PERMITTING & COMPLIANCE

3.1 STATE & FEDERAL PERMITTING

The D-B Team will secure applicable permits and/or provide support to NPS during preparation and coordination with the following regulatory agencies.

USACE Buffalo District Office:

- Nationwide Permit (NWP) 13: The project will exceed the threshold of 500-linear feet; however, this project can still be permitted under a NWP 13 per pre-coordination with USACE for this project. Permit acquisition is estimated to take **60- to 90-days**, best case scenario.
- Section 10 Permit: This project will require work within the Cuyahoga River, a Traditionally Navigable Water. Therefore, a Section 10 Permit is required to meet the conditions of the Rivers and Harbors Act of 1899. Permit acquisition is estimated to take **60- to 90-days**, best case scenario.

Ohio Environmental Protection Agency (OEPA)

- Director's Authorization (DA): This reach of the Cuyahoga is "purple zone" and therefore Ineligible for

WQC under the NWP #13. Instead, it is recommended a Director's Authorization is obtained for work within ineligible watersheds and for work exceeding the 500-linear foot threshold for the NWP #13 permit. If this is granted the anticipated authorization can be obtained within 30 days following acquisition of the provisional permit from USACE.

3.2 LOCAL PERMITTING

The D-B Team will coordinate with applicable local agencies having jurisdiction subject to impacts and mitigation of protected aquatic, habitat, and/or cultural features. The following reviews, permits and/or certifications are anticipated:

Floodplain Permitting – City of Brecksville and Sagamore Hills Township, OH

- The City of Brecksville §1159.13(g)(5) and Sagamore Hills Township §1345.03(i)(5) exempt Federal development projects from permit requirements.

SWPPP - City of Brecksville and Sagamore Hills Township

- The D-B Team shall provide the city/township with copy of Construction Plans for cursory review of proposed activities, including grading and erosion/sedimentation control best management practices subject to the proposed streambank stabilization work.

3.3 AGENCY COORDINATION

The NPS has initiated coordination with both federal and state agencies. Coordination documents will be provided by NPS to include with federal and state permit applications (Section 3.1).

U.S. Fish and Wildlife Service (USFWS):

- Four federally listed species are identified to have known ranges within Summit County, including three protected bat species. Therefore, tree clearing will have a time of year restriction from April 1 through September 30. If tree clearing is required, clearing is recommended during the winter clearing window of October 1 though March 31. It is recommended that an Information for Planning and Consulting (IPaC) review results, provided by NPS, be included in the permit package to streamline coordination between USACE and USFWS (within **1-day**). Additionally, IPaC results will be included a full Endangered Species Act Consultation request to be submitted to USFWS for review. Results of this review is anticipated to take approximately **30 days**, best case scenario.

Ohio Department of Natural Resources (ODNR):

- A full environmental review includes coordination from all four (4) divisions of ODNR including Division of Natural Areas and Preserves (DNAP), Division of Wildlife (DOW), Ohio State Parks & Watercraft, and Division of Forestry. The full environmental review response was received on August 25, 2021.'
- The Cuyahoga River is not a seasonal salmonid stream; therefore, restrictions for salmonid streams do not apply. However, in water work within perennial streams is restricted from March 15 through June 15. If work during this time is necessary, a waiver from ODNR and USACE is recommended.

National Historic Preservation Act (NHPA) Compliance / Ohio State Historic Preservation Office (SHPO) Concurrence:

- The D-B Team will provide project information to NPS in support of their effort to achieve Section 106 NHPA compliance and SHPO concurrence.
- The D-B Team is aware that cultural resources have been identified in the vicinity of the work limits.

Avoidance of these areas has been considered in establishing the extents of proposed disturbance.

4.0 CODES, STANDARDS, & GUIDELINES

4.1 CODES

The Summit County Codified Ordinance Chapter 937 Riparian Setbacks was referenced subject to streambank stabilization and erosion control measures. In accordance with §937.06(b)(1) Uses Permitted in Riparian Setback, streambank and erosion control measures are permissible such that measures are ecologically compatible and substantially utilize natural materials and native plant species where practicable. Such activity requires an approved Erosion and Sediment Control Plan.

The City of Brecksville §1159.13(g)(5) and Sagamore Hills Township §1345.03(i)(5) applicable ordinances were referenced for permitting subject to floodplain development. In accordance with these ordinances the project is exempt from filing a floodplain development permit due to activities undertaken by a federal agency and which are subject to Federal Executive Order 11988 – Floodplain Management. Per the FEMA National Flood Insurance Program standards, there was an allowable increase in water surface elevation up to 1-foot in accordance with for FEMA Zone A Special Flood Hazard Areas (SFHA) for which this project met in accordance with the given tolerances as stated in the RFP.

4.2 STANDARDS & GUIDELINES

The following guidelines were referenced for design and material selection:

- Ohio Department of Transportation (ODOT) Construction & Material Specifications, latest edition.
- National Engineering Handbook
- USACE Engineering Manuals and Case Studies

5.0 CONSTRUCTION COST

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

6.0 ADDITIONAL CONSIDERATIONS & RISK

The following additional considerations and risks discussed below are based on preliminary identifiers that will be re-evaluated throughout the design and construction period.

Value Engineering

The D-B Team acknowledges that the cost of each project should ideally match with the preliminary estimates; however, changed site conditions have been recognized since the time when the Schematic Design was conducted causing additional needed material that will inherently increase project costs. Thus, in order to remain cognizant of best budget utilization, the D-B Team will endeavor to seek value engineering opportunities to achieve cost savings when available and practical. Value engineering ideas have been vetted during the design period, including the following considerations and decisions:

- Minimizing trail and ecological impact with access.
    - The use of a staging area which will not require significant impacts to trail usage through use of a single crossing point but will require a construction access using timber mats which crosses wetlands.
- Repurposing material from adjacent onsite sources.
    - Expansion of the project area to include re-work of previously installed bank stabilization features could allow re-use of rock.

Staging & Access

Site access and staging extents as well as traversing techniques have been identified to minimize overall impacts to the surrounding area. The layout depicted per plan intends to utilize park property along the towpath trail for all sites along towpath, which may cause impact to newly paved surfaces and will require potential for trail pavement restoration. Access to the railway bank may also consider high rail equipment routing along the railway. Prior to construction activity, the D-B Team will layout planned access routes to identify potential constraints and obstacles that may affect staging and access extents so as to prevent damage to vegetation, soils, utilities, and archeological resources, and to minimize air, water, soil, and noise pollution. As layout requirements continue to develop the D-B Team will be sure to consult / coordinate with the Park Resource Manager for approval.

Cultural / Historical Infrastructure

The D-B Team acknowledges that there are assets (i.e., trails, utilities, etc.) in close proximity to the construction site that must be protected / preserved throughout the construction process. All activities will adhere to the Ohio State Historic Preservation Office (SHPO) requirements and the U.S. Secretary of the Interior Standards for the Treatment of Historic Properties.

As specified by NPS, archaeological monitoring will be provided during excavation work and subsurface disturbance at each applicable site. The D-B Team shall retain and schedule qualified personnel to monitor earthwork activity in accordance with the Archaeological Resource Protection Act (ARPA) permit. Due to potential subsurface unknowns, a stop-work order may be issued should anything be discovered that may have historical significance.

Ecological Impacts

The D-B Team is aware that the area has been identified as an ecologically sensitive habitat for the Indiana and bat, northern long-eared bat, tricolored bat, the bald eagle, and potentially other species applicable under the Migratory Bird Treaty Act (MBTA). Based on this information the foreseeable time of year restriction for tree cutting is anticipated to be set between April 1 and September 30 of any year.

Underground Utilities

The D-B Team has requested available utility record information and will update the project mapping to identify potential utility constraints and requirements subject to adjacent construction activities. Based on information obtained thus far, there is a potential active communications utility located at the site. Exposed conduit is visible. Further investigation is underway.

Water Quality & Erosion / Sediment Control

Water quality during and immediately after construction will remain a priority until permanent native vegetation has been established. In general, large fluctuations in water volume between base flow and storm flow can create difficulties for stream construction. Uncontrolled water in a restoration site can create unfavorable working conditions, such as difficulty in assessing as-built conditions, grade verification problems, and the discharge of excess sediment.

Temporary impairments to water quality will be minimized through erosion prevention following the guidelines established in the project stormwater pollution prevention plan (SWPPP). Issues will be discussed and addressed daily once construction begins to guarantee the effectiveness of the installed measures and to make sure that erosion control features are maintained and continue to operate as intended. All disturbed areas will be seeded immediately after construction activities are completed in that area. A mixture of temporary native stabilizing seed and permanent native seed will be applied to all disturbed areas. NPS approval will be sought for all seed specifications used on-site.

Permit Acquisition & Agency Coordination

Acquisition of permits can be a lengthy process. For this reason, the D-B Team will initiate permitting activities as soon as possible to expedite the review and approval process. Anticipated permitting and agency coordination is as follows:

- U.S. Army Corps of Engineers (USACE) Nationwide 13 Bank Stabilization Permit
- USACE Section 10 Permit
- Ohio Environmental Protection Agency (OEPA) 401 Water Quality Certification (WQC) or Director's Authorization (DA)
- Ohio Department of Natural Resources (ODNR)
- U.S. Fish and Wildlife Service (USFWS)
- Ohio Historic Preservation (OHPO)

Public Safety / Visitor Experience

With a majority of the sites being active trailheads used by the public, the sites are ultimately accessible from a constructability standpoint with the most obvious concern being the safety of the public. Provisions, such as construction fencing, and appropriate barriers will be in place prior to construction to keep park users safe at all times. The D-B Team will work closely with the National Park staff to prepare a process for maintaining pedestrian traffic (Process) for the project, including critical items such as potential phasing alternatives, public meetings, signage, trail closures, temporary routing and new trail alignments to provide a safe environment and minimize any impact to the ongoing operation of the park. Whenever possible, public access along trails and the waterway shall be maintained, thus each project shall provide a signage plan including installation of warning signs for public safety. In addition, each project will have a project specific safety manual containing general safety programs, policies, site-specific hazard analyses, and Health and Safety Plan (HASP) to facilitate a safe work environment for employees.

Construction Schedule

Wet weather often drives the schedule for stream restoration projects. During storm events project construction will need to be suspended until the stormwater has been rescinded. As the project continues to develop, the D-B Team will coordinate with applicable agencies for any requirements subject to a design storm event.

Accuracy of Opinion of Probable Cost

The D-B Team intends to provide individual approaches in accordance with the cost set and agreed upon by NPS. However, it should be noted that the cost is dependent on availability of materials, market conditions, or data related to field constraints / obstacles. These are mostly determined by the current extreme market conditions affected by COVID-19 and escalated inflation. We are experiencing a volatile market for material costs, material availability, equipment shortages, rapid price fluctuations, and shortage of labor.

The D-B Team will work towards identifying potential cost fluctuations or changes that may affect any expected unit cost and limiting potential risk by seeking to lock in pricing on materials where available.

7.0 PROJECT EXECUTION PLAN

7.1 CONSTRUCTION ACTIVITY AND SEQUENCE

7.1.1 SAFETY

The D-B Team understands that this is an active park with patrons anticipated along walking and water trails. The team will work closely with the National Park Service staff to prepare a process for maintaining pedestrian traffic for the project sites, including critical items such as potential phasing alternatives, public meetings, signage, trail closures, temporary routing and new trail alignments to provide a safe environment and minimize any impact to the ongoing operation of the park.

In addition to pedestrian traffic measures, provisions such as construction fencing, and appropriate barriers will be placed along the working perimeter to keep park users safe out of active work areas. Flyers will be posted at portage areas to notify paddlers that "in-water" construction work may present temporary hazards and recommend planning alternatives.

In addition, a project specific safety manual containing not only general safety programs and policies but also a site-specific hazard analysis and Health and Safety Plan (HASP) will be developed to facilitate a safe work environment for employees.

7.1.2 ACCESS & STAGING

Access and staging for Towpath Trail Mile Marker 20 South will be off of Standford Road with staging of material behind the barn shown or another suitable laydown area (see Figure 8). A haul road across the field to the project site will be established as access for material and equipment.

Figure 5. Access & Staging Route

7.1.3 STABILIZATION SEQUENCE

Phase I – Access & Staging

Mobilization to the site will begin with staging at the barn on Standford Road. The area around the barn or

another suitable location nearby will be used for staging stone and equipment. Avoidance of delineated wetlands will be a requirement for staging and storage areas. At this time, it is anticipated that no trees will be removed, and the barn will not be impacted as part of this effort. This staging area is away from typical Park use and will minimize encounters with Park users.

Access to the project areas will be established by a single access road/path through the wetland area west of the barn. A direct path will be established through the driest areas of the wetland, where practicable, and to align with the project site such that minimal use of the towpath is necessary. A singular crossing point over the towpath will minimize Park users and construction equipment interactions. After the towpath crossing, on the west side of the towpath, additional timber mats will be used to traverse other delineated wetlands as equipment follows the existing streambank to the south and west. The access path will then cross over the river in the shallower riffle area to gain access to the point bar. This crossing will be established using a combination of existing river substrate and imported rock for a ford crossing.

Water control will be a key aspect of the Phase I staging and access. Currently, the plan identifies a proposed baseflow diversion channel across the existing point bar. Diverting the baseflow as much as possible around the active work site will minimize transport of fine sediments downstream during construction disturbance. The team used a similar approach on our recent Jackson Field restoration project for Cleveland Metroparks on the Chagrin River with positive result. The diversion channel does require significant excavation and time to create the bypass therefore, the team also has an alternative flow diversion for consideration as well. This alternative involves the installation of an overwide rock toe along the new, proposed geometry. This toe would act similar to the base stone working platform used on MM64.1. Alluvial fill material behind the stone access road would be placed out of direct flow and turbidity would essentially be contained out of direct river flow by the already installed rock toe.

Phase II – Site Preparation

Once Phase I activities have been completed, additional clearing and grubbing of trees/plant material will occur along the banks and a rough subgrade will be cut to remove any loose or unsuitable material.

Phase III – Bank Stabilization

Once Phase II activities have been completed, imported sandstone material will be placed along the toe location and choked with excavated material cut from the existing point bar. The remaining excavation from the inside point bar will be used to infill the restored bank behind the rock toe and bucket compacted. Rock keys will then be installed at locations identified on the plan set to prevent flanking of the rock toe. Imported topsoil is then placed on top of the subgrade to provide a suitable base for plant growth on the restored bank. All exposed topsoil is to be wrapped in an erosion control fabric and planted during Phase IV activities.

Phase IV – Site Restoration

Site restoration activities will include seeding and planting disturbed areas. Live stakes or other planting material will be planted along the restored bank during the seasonally appropriate planting window. The intent of the project schedule is to coincide completion of construction activities with a planting window such that planting can be completed immediately.

7.2 CONSTRUCTION SCHEDULE

A detailed construction schedule can be found in Appendix III.

Table 17. Construction Schedule

Task	Calendar Days from Start of Construction
Tree Dropping Start Date	TBD
Tree Removal Effort	Before March 30th 2024
Construction Start Date	TBD
Preconstruction Meeting	14
Mobilization & Staging Setup	35
Install Access & Haul Routes	42
Bank Stabilization	105
Substantial Completion	125
Demobilization	150
Plantings Effort	185
Final Completion	200

8.0 QUALITY ASSURANCE

The D-B Team reviewed and updated the Sustainability and Constructability Worksheets provided as part of the SD submittal package. Changes reflect site specific requirements and design changes as noted above. In addition, the team reviewed the Quality Assurance Checklists available through the Denver Service Center to ensure that the standard requirements are met. These will continue to be reviewed and monitored throughout the design and construction phases of the project. The appropriate Quality Assurance documentation has been provided for design and construction activities (refer to Quality Control Plan via separate cover).

9.0 REFERENCES

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APPENDIX I SITE PLAN

TOWPATH MILE MARKER (MM) 20 SOUTH BANK STABILIZATION

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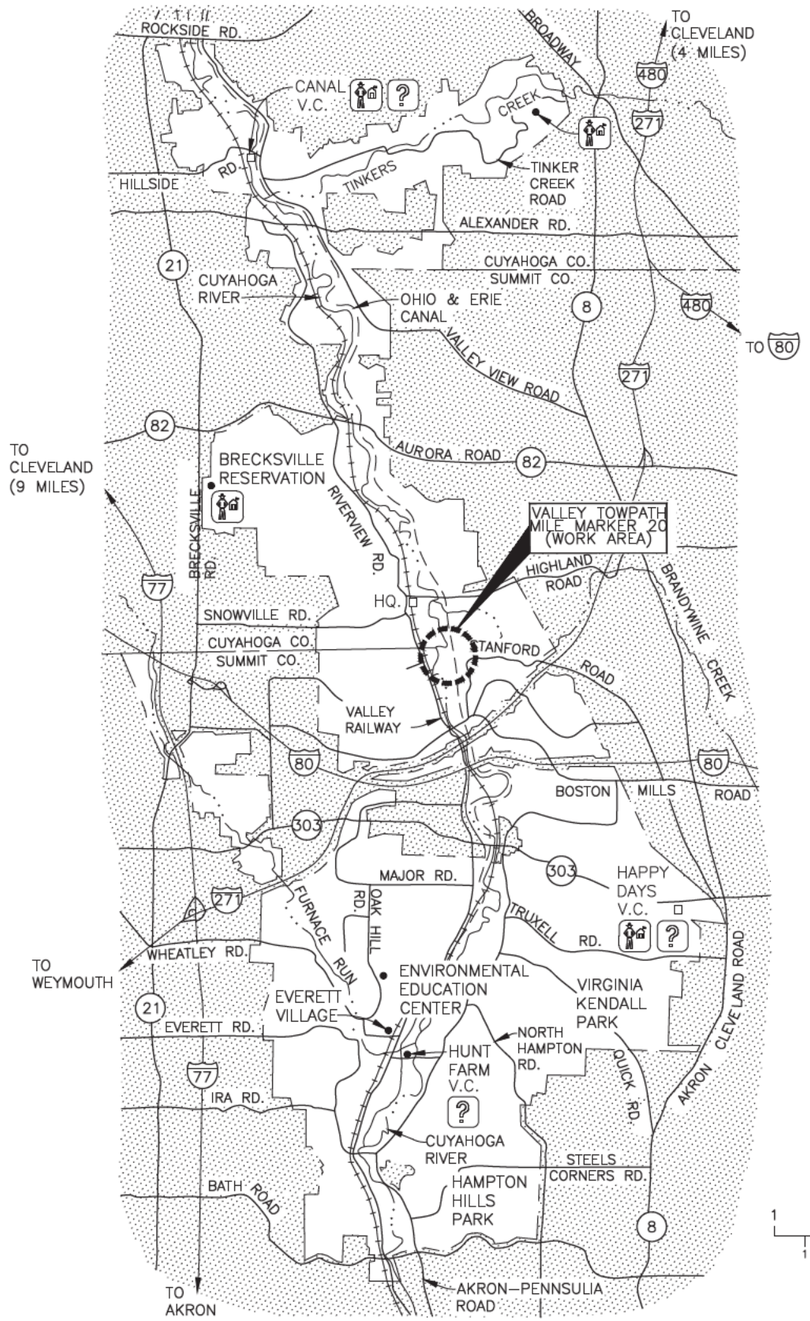


CUYAHOGA VALLEY NATIONAL PARK MAP

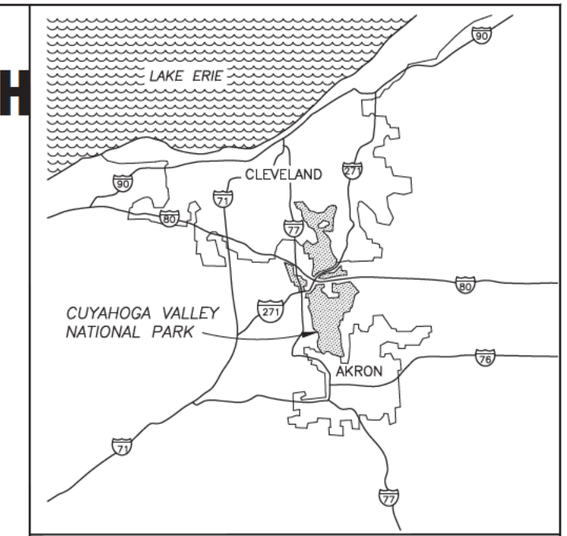
SCALE OF MILES
1 0 1 2
SCALE OF KILOMETERS
1 0 1 2 3
SCALE: 1" = 5000'

INDEX OF SHEETS

SHEET	SUB SHEET	TITLE OF SHEET
1	[G1]	TITLE SHEET
2	[G2]	GENERAL NOTES & LEGEND
3	[G3]	ACCESS & MAINTENANCE OF TRAFFIC PLAN
4	[C1]	SURVEY CONTROL PLAN
5	[C2]	EXISTING CONDITIONS PLAN
6	[C3]	EROSION CONTROL NOTES
7	[C4]	EROSION CONTROL DETAILS
8	[C5]	EROSION CONTROL PLAN
9	[C6]	PROPOSED GRADING PLAN
10–11	[C7–C8]	PROPOSED PLAN AND PROFILES
12–15	[C9–C12]	RIVER CROSS SECTIONS
16	[C13]	STABILIZATION DETAILS
17	[L1]	LANDSCAPE NOTES & DETAILS
18	[L2]	LANDSCAPE PLAN

DESIGN-DEVELOPEMENT DOCUMENTS

AUGUST 2023



VICINITY MAP

PARK MAP LEGEND

- PARK BOUNDARY
- STATE LINE
- COUNTY LINE
- PAVED ROAD
- OHIO & ERIE CANAL (UNWATERED)
- CREEK
- V.C. VISITOR CENTER
- HQ. PARK HEADQUARTERS
- RANGER STATION
- INFORMATION CENTER

ACCEPTED BY _____ DATE : _____

JIM MOYER, P.E.
EVIROSCIENCE ENGINEER
PAGES 1–XX COVERED BY THIS SEAL.

Ohio Utilities Protection Service
Call 811 before you dig

DESIGNED BY	MARK	SHEET	REVISION	DATE	INITIAL
CIVIL & ENVIRONMENTAL: ENVIROSCIENCE STOW, OHIO					
HYDRAULICS & GEOTECHNICAL: GPD GROUP AKRON, OHIO					
CONTRACTOR: RIVERREACH CONSTRUCTION BARBERTON, OHIO					

QUALITY DESIGN CERTIFICATION
- [ ] PREPARED IN ACCORDANCE WITH DESIGN DEVELOPMENT (TITLE I) _____ DRAWING NO.
- OR
- [ ] VARIANCE FROM DESIGN DEVELOPMENT (TITLE I) APPROVED BY SUPERINTENDENT ON _____ DATE
- OR
- [ ] CONSTRUCTION DRAWING NOT PRECEDED BY DESIGN DEVELOPMENT (TITLE I)

PROJECT MANAGER _____ DATE _____

100% DRAFT DESIGN–BUILD CONSTRUCTION DOCUMENTS

UNITED STATES DEPARTMENT OF THE INTERIOR

NATIONAL PARK SERVICE DENVER SERVICE CENTER

SUB SHEET NO. G1

TITLE OF DRAWING: TITLE SHEET
LOCATION WITHIN PARK: MM20 SOUTH
NAME OF PARK: CUYAHOGA VALLEY NATIONAL PARK
REGION: MIDWEST | COUNTY: SUMMIT/CUYAHOGA | STATE: OHIO

DRAWING NO. 644 / 176923
PMIS/PKG NO. 224822
01 OF 18

P:\10_PROJECT\RIVR\FERREACH\ASR\1696_CVNP BANK STABILIZATION\TOWPATH\DESIGN\DESIGN\MMZO DESIGN 30\SHEETS\MMZO_TITLE SHEET.DWG - TITLE SHEET ——— PLOTTED MAY 2021
XREFS: P:\10_Project\Rivr\Ferreach\ASR\1696_CVNP Bank Stabilization\Towpath\Design\MMZO Design 30\Xrefs\ASR_TITLE SHEET BORDER.dwg | P:\10_Project\Rivr\Ferreach\ASR\1696_CVNP Bank Stabilization\Towpath\Design\MMZO Design 30\Xrefs\ASR_TITLE SHEET BORDER.dwg

LEGEND

- EXISTING CONTOUR
- PROPOSED CONTOUR
- PROPERTY LINE
- EXISTING WETLAND
- STREAM - EDGE OF WATER
- PROPOSED CREEK BASELINE CONSTRUCTION
- EXISTING TREES
- EXISTING BRUSH LINE/LANDSCAPING
- EXISTING CONTROL POINT
- SOIL BORING (#)
- PROPOSED GRADING LIMITS
- PROPOSED ACCESS ROUTE
- PROPOSED STAGING AREA
- PROPOSED LIVE STAKE LIMITS

ABBREVIATIONS

BKF	BANKFULL ELEVATION
B/L	BASELINE
BMPS	BEST MANAGEMENT PRACTICES
C/L	CENTERLINE
CONST	CONSTRUCTION
DND	DO NOT DISTURB
EL/ELEV	ELEVATION
EX	EXISTING
MIN	MINIMUM
MAX	MAXIMUM
NTS	NOT TO SCALE
OFF	OFFSET
PI	POINT OF INTERSECTION
PROP	PROPOSED
STA	STATION
TW	THALWEG

PROJECT DESCRIPTION

THE VALLEY TOWPATH MILE MARKER 20 BANK STABILIZATION PROJECT ALONG THE CUYAHOGA RIVER WILL INCLUDE SELECT CLEARING OF THE BANKS, REBUILDING BANKS USING A COMBINATION OF ROCK AND BIO-ENGINEERED ARMORING, PLANTING NATIVE VEGETATION TO STABILIZE THE SOIL, AND RESTORATION OF THE CONSTRUCTION SITE AND EQUIPMENT ACCESS ROUTES, AS NECESSARY.

WHEN ON SITE, THE CONTRACTOR SHALL IMPLEMENT THE APPROPRIATE EROSION AND SEDIMENT CONTROL BEST MANAGEMENT PRACTICES (BMP'S) IN ACCORDANCE WITH OHIO EPA. BMP ACTIVITIES SHALL ALSO BE CONDUCTED IN COMPLIANCE WITH THE NATIONAL PARK SERVICE. THE VARIABILITY OF EROSION AND SEDIMENT CONTROL BMP'S MAY BE MODIFIED AS APPROPRIATE TO COMPLETE THE NECESSARY RESTORATION ACTIVITIES.

GENERAL NOTES

THE RIVERBANK STABILIZATION PROJECT DETAILED IN THESE PLANS REPRESENT AN APPROACH BASED ON FIELD SURVEY AND ASSESSMENTS COMPLETED DURING THE WINTER OF 2022. THE PROJECT WILL BE IMPLEMENTED BY THE DESIGN-BUILD TEAM AND MAY VARY FROM THE PLAN BASED ON ACTUAL FIELD CONDITIONS AND MODIFICATIONS NECESSARY TO BEST SUIT THE NEEDS OF THE PROJECT GOALS. ALL RESTORATION\ENHANCEMENT WILL BE COMPLETED WITH THE INTENT OF PROVIDING A STABLE AND FUNCTIONAL RIVERBANK AND ECOLOGICAL SYSTEM.

THE CONTRACTOR SHALL PERFORM WORK AS TO NOT DISTURB, DAMAGE OR DESTROY ANY FENCES, LANDSCAPING ITEMS, ETC., UNLESS SPECIFIED. ANY ITEM DAMAGED OR DESTROYED SHALL BE REPLACED AT THE CONTRACTOR'S EXPENSE. ANY ITEM DISTURBED OR IN CONFLICT WITH THE PROPOSED WORK SHALL BE REMOVED AND RESET AT THE CONTRACTOR'S EXPENSE.

THE CONTRACTOR SHALL BE RESPONSIBLE TO REMOVE MUD FROM VEHICLES USING PUBLIC ROADS. THE CONTRACTOR WILL BE RESPONSIBLE TO CLEAN PUBLIC ROADS, TOWPATH TRAIL AND VALLEY RAILWAY WHERE DIRT AND MUD ARE TRACKED BY THEIR EQUIPMENT.

THE CONTRACTOR SHALL KEEP THE CONSTRUCTION AREA CLEAR OF GARBAGE AND OTHER WASTE.

ANY SIGNIFICANT CHANGES SHALL BE COORDINATED AND APPROVED BY THE CONTRACTING OFFICER.

SITE ACCESS – CONSTRUCTION ACCESS TO THE SITE SHALL BE PROVIDED, AS SHOWN ON THE 'ACCESS & EROSION CONTROL PLAN'. ALL CONSTRUCTION VEHICLES SHALL ACCESS/LEAVE SITE FROM DESIGNATED ACCESS POINTS.

NO TREE REMOVAL SHALL BE PERMITTED BETWEEN APRIL 1ST AND SEPTEMBER 30TH. TREE REMOVAL SHALL NOT BE PERMITTED OUTSIDE THE LIMITS OF WORK INDICATED ON THE PLANS UNLESS AUTHORIZED.

EARTHWORK

THE CONTRACTOR SHALL PERFORM EARTHWORK GRADING IN ACCORDANCE WITH THESE PLANS AND SPECIFICATIONS. THE CONTRACTOR SHALL BE RESPONSIBLE FOR REMOVING ANY UNSUITABLE MATERIALS AND REPLACING WITH SUITABLE MATERIALS. UNLESS OTHERWISE SPECIFIED IN THE PLANS OR SPECIFICATIONS, THE SITE GRADING, EXCAVATION, AND

SPECIFICATIONS

WETLAND PRESERVATION

THE CONTRACTOR SHALL BE RESPONSIBLE TO TAKE THE NECESSARY PRECAUTIONS TO MINIMIZE WETLAND DISTURBANCE WITHIN THE DESIGNATED CONSTRUCTION LIMITS, AS WELL AS MAINTAINING ALL MEASURES THROUGHOUT THE DURATION OF THE PROJECT. NO SITE PREPARATION WORK, INCLUDING DELIVERY OF MATERIALS, SHALL BEGIN IN ANY WETLAND AREAS UNTIL PROTECTION AND TREATMENT [I.E. TIMBER MATS] MEASURES HAVE BEEN AGREED UPON AND COMPLETED. DURING DRY PERIODS, THE CONTRACTOR SHALL KEEP ALL TRAVELED AREAS WATERED REGULARLY OR APPLY OTHER APPROVED DUST CONTROL METHODS TO PREVENT EXCESSIVE DUST ACCUMULATION ON WETLANDS TO BE PRESERVED. THE CONTRACTOR SHALL BE RESPONSIBLE FOR DAMAGE TO WETLANDS RESULTING FROM EQUIPMENT, INCLUDING FLUID LEAKAGE OR DAMAGE RESULTING FROM EQUIPMENT FAILURE. ANY INCIDENTS OF THIS TYPE SHALL BE REPORTED IMMEDIATELY TO THE OWNER. UPON PROJECT COMPLETION, THE CONTRACTOR SHALL REMOVE ALL EXCESS MATERIALS, SOIL, DEBRIS, AND EQUIPMENT DIRECTLY RELATED TO WETLAND PRESERVATION ACTIVITIES.

CLEARING AND GRUBBING

THE CONTRACTOR SHALL CLEAR AREAS REQUIRED FOR ACCESS TO SITE AND EXECUTION OF WORK. THE CONTRACTOR SHALL REMOVE TREES, SHRUBS, CLEAR UNDERGROWTH, DEADWOOD, AND SURFACE DEBRIS WITHOUT DISTURBING SUBSOIL. ANY EXISTING AREA THAT WILL BE DISTURBED SHALL HAVE THE TOPSOIL STRIPPED AND STOCKPILED ON SITE FOR REUSE. TREES DEEMED SUITABLE FOR FUTURE RESTORATION USE SHALL BE HARVESTED AND STOCKPILED AT AN APPROVED AREA. ALL OTHER MATERIALS SHALL BE DISPOSED OF AND REMOVED OFF-SITE.

GRADING

THE CONTRACTOR SHALL BE RESPONSIBLE TO VERIFY SUBGRADE IS CONTOURED AND COMPACTED AS WELL AS VERIFY BACKFILL HAS BEEN INSPECTED. THE CONTRACTOR SHALL FINE GRADE TO ELIMINATE UNEVEN AREAS AND DEPRESSION BY FOLLOWING CONTOURS, PROFILES, AND CROSS SECTIONS PROVIDED IN THE DESIGN PLANS.

THE CONTRACTOR SHALL REMOVE UNUSED STOCKPILES, GRADE AREA TO PREVENT STANDING WATER, PROTECT FROM EROSION, AND STABILIZE. SITE SHALL BE LEFT CLEAN AND RAKED, READY TO RECEIVE LANDSCAPING. UNSUITABLE MATERIALS SHALL BE REMOVED FROM THE PROJECT SITE AND DISPOSED OF AT AN APPROVED AREA. REFER TO THE 'EXCAVATION AND FILL' SPECIFICATION (THIS SHEET) FOR APPROPRIATE COMPACTION REQUIREMENTS.

EROSION CONTROL BLANKET

THIS WORK SHALL CONSIST OF FURNISHING AND INSTALLING EROSION CONTROL BLANKETS FOR EXPOSED RIVER EMBANKMENTS. MATERIAL SHALL BE 700 SERIES COIR BLANKETS, OR APPROVED EQUAL BY THE OWNER. EROSION CONTROL BLANKETS SHALL BE INSTALLED IN ACCORDANCE WITH THE MANUFACTURER'S REQUIREMENTS AND WITH ODOT CONSTRUCTION STANDARDS. BLANKETS SHALL BE INSTALLED IMMEDIATELY AFTER SEEDING OPERATIONS HAVE BEEN COMPLETED.

EXCAVATION AND FILL

PRIOR TO SITE EXCAVATIONS AND FILL PLACEMENT, EXISTING TOPSOIL, TREES, SHRUBS, AND OTHER DELETERIOUS MATERIALS SHALL BE STRIPPED AND GRUBBED. THESE MATERIALS SHALL BE EITHER REMOVED FROM THE SITE OR STOCKPILED IN A DESIGNATED AND APPROVED AREA OF THE SITE. EXCAVATION CONSISTS OF THE REMOVAL OF MATERIAL ENCOUNTERED TO SUBGRADE ELEVATIONS AND, WHERE APPLICABLE, THE REUSE OF DISPOSAL OF MATERIALS REMOVED.

THE CONTRACTOR IS RESPONSIBLE TO CONSTRUCT THE PROPOSED GRADES WITH SUITABLE MATERIALS. SUITABLE MATERIALS SHALL BE APPROVED BY A SOILS TECHNICIAN OR SOILS ENGINEER.

ON-SITE/IMPORTED FILL, BACKFILL, AND EMBANKMENT MATERIALS SHOULD MEET THE FOLLOWING REQUIREMENTS:

- UNLESS OTHERWISE SHOWN OR SPECIFIED, FILL, BACKFILL, AND EMBANKMENT MATERIALS SHALL BE EXISTING EXCAVATED SOILS FREE OF DEBRIS LARGER THAN 6-INCHES IN ANY DIMENSION, GRASS, ROOTS, VEGETATION, AND OTHER LARGE DEBRIS FRAGMENTS.
- MAXIMUM PARTICLE SIZE OF 6 INCHES
- PLACED IN MAXIMUM 8 INCH LIFTS
- ON-SITE FILL MATERIALS SHALL BE CAPABLE OF SPECIFIED COMPACTION REQUIREMENTS
- SOILS IDENTIFIED AS BEING CLASSIFIED AS SILT "ML" PER USCS ASTM D 2487 OR EXHIBITING PLASTIC LIMIT VALUES IN EXCESS OF 25 PERCENT MAY NOT BE SUITABLE FOR PROPER COMPACTION AND SLOPE CONSTRUCTION

THE CONTRACTOR SHALL PROTECT NEWLY GRADED AREAS FROM TRAFFIC, FREEZING, AND EROSION. IN THE EVENT FILL MATERIALS BECOME ERODED, RUTTED, SETTLED, OR LOSE COMPACTION DUE TO SUBSEQUENT CONSTRUCTION OPERATIONS OR WEATHER CONDITIONS, THE CONTRACTOR SHALL REPAIR AND RE-ESTABLISH GRADES TO THE SPECIFIED TOLERANCES. THE CONTRACTOR SHALL SCARIFY OR REMOVE AND REPLACE MATERIAL TO DEPTH DIRECTED BY THE ENGINEER AND RESHAPE AND RE-COMPACT AT OPTIMUM MOISTURE CONTENT TO THE REQUIRED DENSITY. CONTRACTOR SHALL RESTORE APPEARANCE, QUALITY, AND CONDITION OF FINISHED SURFACING TO MATCH ADJACENT WORK, AND ELIMINATE EVIDENCE OF RESTORATION TO THE GREATEST EXTENT POSSIBLE.

RIPRAP

THIS WORK CONSISTS OF FURNISHING ROCK TO BE USED FOR RIVERBANK PROTECTION. THE FOLLOWING SPECIFICATIONS SHALL BE CONSIDERED SUPPLEMENTAL TO THE ODOT CMS FOR MATERIAL SPECIFICATIONS AND CONSTRUCTION STANDARD PROCEDURES UNLESS OTHER SPECIFIED ON THE CONTRACT DRAWINGS. RIPRAP IS DEFINED AS ANGULAR IN SHAPE AND COMPRISED OF SANDSTONE, GRANITE, LIMESTONE OR SIMILAR HARD MATERIAL. FRIABLE MATERIAL OR LOW QUALITY SANDSTONE IS NOT ACCEPTABLE. ANGULAR MATERIAL IS PREFERRED AS IT INCREASES THE INTERLOCKING ABILITY OF THE STONE AND IS LESS LIKELY TO ROLL OR MOVE.

RIPRAP SIZING IS DEFINED AS FOLLOWS:

RIPRAP SPECIFICATIONS [ODOT PARAMETERS]

TYPE	SIZE (INCHES)	SIZE (FEET)
A	18-30+ IN	1.5-2.5+ FT
B	12-24 IN	1.0-2.0 FT
C	6-18 IN	0.5-1.5 FT
D	3-12 IN	0.25-1.0 FT

ODOT TYPE A RIPRAP:

- ODOT TYPE A RIPRAP SHALL BE TYPE A DUMPED ROCK FILL AND ROCK CHANNEL PROTECTION AS SPECIFIED IN SECTION 703.19 OF THE ODOT CMS.
- HARD AND DURABLE QUARRY STONE FREE FROM FRACTURES, BEDDING PLANES, PRONOUNCED WEATHERING, CALCITE INTRUSIONS, EARTH, OR OTHER ADHERENT COATINGS.
- FREE OF FINES, ROOTS, ORGANIC MATTER, OIL, GREASE, DEBRIS, WOOD, REFUSE, PLASTER, BROKEN CONCRETE WITH EXPOSED REBAR, ASPHALT, TOXIC CONTAMINANTS IN ANYTHING OTHER THAN TRACE QUANTITIES, AND OTHER DELETERIOUS MATTER.
- AT LEAST 85 PERCENT OF THE TOTAL MATERIAL BY WEIGHT SHALL BE LARGER THAN AN 18-INCH (0.5 M BUT LESS THAN A 30-INCH (0.8 M) SQUARE OPENING AND AT LEAST 50 PERCENT OF THE TOTAL MATERIAL BY WEIGHT LARGER THAN A 24-INCH (0.6 M) SQUARE OPENING. FURNISH MATERIAL SMALLER THAN AN 18-INCH (0.5 M) SQUARE OPENING THAT CONSISTS PREDOMINANTLY OF ROCK SPALLS AND ROCK FINES, AND THAT IS FREE OF SOIL.
- MINIMUM DIMENSION OF INDIVIDUAL PIECES: NOT LESS THAN 2/3 MAXIMUM DIMENSION.

ODOT TYPE B RIPRAP:

- ODOT TYPE B RIPRAP SHALL BE TYPE B DUMPED ROCK FILL AND ROCK CHANNEL PROTECTION AS SPECIFIED IN SECTION 703.19 OF THE ODOT CMS.
- HARD AND DURABLE QUARRY STONE FREE FROM FRACTURES, BEDDING PLANES, PRONOUNCED WEATHERING, CALCITE INTRUSIONS, EARTH, OR OTHER ADHERENT COATINGS.
- FREE OF FINES, ROOTS, ORGANIC MATTER, OIL, GREASE, DEBRIS, WOOD, REFUSE, PLASTER, BROKEN CONCRETE WITH EXPOSED REBAR, ASPHALT, TOXIC CONTAMINANTS IN ANYTHING OTHER THAN TRACE QUANTITIES, AND OTHER DELETERIOUS MATTER.
- AT LEAST 85 PERCENT OF THE TOTAL MATERIAL BY WEIGHT SHALL BE LARGER THAN A 12-INCH (0.3 M BUT LESS THAN A 24-INCH (0.6 M) SQUARE OPENING AND AT LEAST 50 PERCENT OF THE TOTAL MATERIAL BY WEIGHT LARGER THAN AN 18-INCH (0.5 M) SQUARE OPENING. FURNISH MATERIAL SMALLER THAN A 12-INCH (0.3 M) SQUARE OPENING THAT CONSISTS PREDOMINANTLY OF ROCK SPALLS AND ROCK FINES, AND THAT IS FREE OF SOIL.
- MINIMUM DIMENSION OF INDIVIDUAL PIECES: NOT LESS THAN 1/3 MAXIMUM DIMENSION.

ODOT TYPE C RIPRAP:

- ODOT TYPE C RIPRAP SHALL BE TYPE C DUMPED ROCK FILL AND ROCK CHANNEL PROTECTION AS SPECIFIED IN SECTION 703.19 OF THE ODOT CMS.
- HARD AND DURABLE QUARRY STONE FREE FROM FRACTURES, BEDDING PLANES, PRONOUNCED WEATHERING, CALCITE INTRUSIONS, EARTH, OR OTHER ADHERENT COATINGS.
- FREE OF FINES, ROOTS, ORGANIC MATTER, OIL, GREASE, DEBRIS, WOOD, REFUSE, PLASTER, BROKEN CONCRETE WITH EXPOSED REBAR, ASPHALT, TOXIC CONTAMINANTS IN ANYTHING OTHER THAN TRACE QUANTITIES, AND OTHER DELETERIOUS MATTER.
- AT LEAST 85 PERCENT OF THE TOTAL MATERIAL BY WEIGHT SHALL BE LARGER THAN A 6-INCH (150 MM) BUT LESS THAN AN 18-INCH (0.5 M) SQUARE OPENING AND AT LEAST 50 PERCENT OF THE TOTAL MATERIAL BY WEIGHT LARGER THAN A 12-INCH (0.3 M) SQUARE OPENING. FURNISH MATERIAL SMALLER THAN A 6-INCH (150 MM) SQUARE OPENING THAT CONSISTS PREDOMINANTLY OF ROCK SPALLS AND ROCK FINES, AND THAT IS FREE OF SOIL.
- MINIMUM DIMENSION OF INDIVIDUAL PIECES: NOT LESS THAN 1/3 MAXIMUM DIMENSION.

ODOT TYPE D RIPRAP:

- ODOT TYPE D RIPRAP SHALL BE TYPE D DUMPED ROCK FILL AND ROCK CHANNEL PROTECTION AS SPECIFIED IN SECTION 703.19 OF THE ODOT CMS.
- HARD AND DURABLE QUARRY STONE FREE FROM FRACTURES, BEDDING PLANES, PRONOUNCED WEATHERING, CALCITE INTRUSIONS, EARTH, OR OTHER ADHERENT COATINGS.
- FREE OF FINES, ROOTS, ORGANIC MATTER, OIL, GREASE, DEBRIS, WOOD, REFUSE, PLASTER, BROKEN CONCRETE WITH EXPOSED REBAR, ASPHALT, TOXIC CONTAMINANTS IN ANYTHING OTHER THAN TRACE QUANTITIES, AND OTHER DELETERIOUS MATTER.
- AT LEAST 85 PERCENT OF THE TOTAL MATERIAL BY WEIGHT SHALL BE LARGER THAN A 3-INCH (75 MM) BUT LESS THAN A 12-INCH (0.3 M) SQUARE OPENING AND AT LEAST 50 PERCENT OF THE TOTAL MATERIAL BY WEIGHT LARGER THAN A 6-INCH (150 MM) SQUARE OPENING. FURNISH MATERIAL SMALLER THAN A 3-INCH (75 MM) SQUARE OPENING THAT CONSISTS PREDOMINANTLY OF ROCK SPALLS AND ROCK FINES, AND THAT IS FREE OF SOIL.
- MINIMUM DIMENSION OF INDIVIDUAL PIECES: NOT LESS THAN 1/3 MAXIMUM DIMENSION.

SEE SHEET 16 FOR MIX DESIGN AND PLACEMENT LOCATIONS.

SEEDING

SEEDING SHALL CONFORM WITH THE INFORMATION PROVIDED ON THE SEEDING NOTES AND DETAILS SHEET, LOCATED WITHIN THE CONTRACT DRAWINGS.

LIVE STAKES

LIVE STAKES SHALL CONFORM WITH THE INFORMATION PROVIDED ON THE SEEDING NOTES AND DETAILS SHEET, LOCATED WITHIN THE CONTRACT DRAWINGS.

UTILITIES

THROUGH FIELD INVESTIGATION AND COORDINATION WITH THE OHIO UTILITIES PROTECTION SERVICE (OUPS), THE FOLLOWING UTILITIES WERE FOUND WITHIN THE PROJECT LIMITS AND HAVE BEEN IDENTIFIED WITHIN THE CONTRACT DRAWINGS:

FIBER OPTIC LINE-UTILITY OWNER UNKNOWN

OHIO811.org Before You Dig

DESIGNED: JM	SUB SHEET NO.	TITLE OF DRAWING	DRAWING NO.
DRAWN BY: TG	G2	GENERAL NOTES & LEGEND	644 / 176923
TECH REVIEW: JB		LOCATION WITHIN PARK: MM20 SOUTH	PMIS/PKG NO. 224822
DATE: Aug 16, 2023		NAME OF PARK: CUYAHOGA VALLEY NATIONAL PARK	02 OF 18
		REGION: MIDWEST; COUNTY: SUMMIT/CUYAHOGA; STATE: OHIO	

P:\PIL_PROJECTS\2018\8\CHECHACHA\2018188_CVNP BANK STABILIZATION DESIGN\MMXD DESIGN 30\SHEETS\GENERAL NOTES AND LEGEND\GNL-GENERAL NOTES & LEGEND-DESIGN REVIEW\CTB - PLOTTED MAY 2021
PORTS: JWARGACHEET BORDER.dwg

EX. TOWPATH TRAIL

APPROXIMATE LOCATION FOR CONSTRUCTION AHEAD SIGN, SEE DETAIL THIS SHEET.

APPROXIMATE LOCATION FOR RIVER CONSTRUCTION ZONE SIGN, SEE DETAIL THIS SHEET.

APPROXIMATE RIVERBANK ENTRANCE LOCATION

PROPOSED RIVER CROSSING LOCATION

CUYAHOGA RIVER

EX. WETLANDS LIKELY PRESENT

EX. FIBER OPTIC [DND]

PROP. ACCESS ROUTE TO BE CONSTRUCTED WITH TIMBERMATS (MIN. 16' WIDTH)

PROP. STAGING AREA

PROP. ACCESS ROUTE

APPROXIMATE LOCATION FOR HEAVY EQUIPMENT CROSSING SIGN, SEE DETAIL THIS SHEET.

PROP. GRADING LIMITS

EX. WETLAND

EX. WETLAND

APPROXIMATE LOCATION FOR CONSTRUCTION ENTRANCE SIGN, SEE DETAIL THIS SHEET.

EX. WETLANDS LIKELY PRESENT

EX. WETLANDS LIKELY PRESENT

APPROXIMATE LOCATION FOR CONSTRUCTION AHEAD SIGN, SEE DETAIL THIS SHEET.

EX. TOWPATH TRAIL

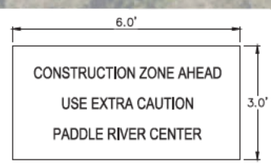
ABANDONED STANFORD RD.

PROP. ACCESS ROUTE

FOR GENERAL LEGEND, SEE SHEET 2

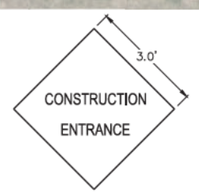
LEGEND

- P/L — PROPERTY LINE
- EXISTING WETLAND
- PROPOSED MAINTENANCE OF TRAFFIC SIGN
- PROPOSED GRADING LIMITS
- PROPOSED ACCESS ROUTE
- PROPOSED STAGING AREA



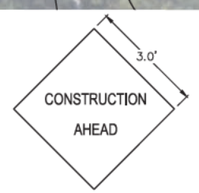
RIVER CONSTRUCTION ZONE SIGN NOTES
- SIGN TO BE ATTACHED TO 4" POSTS.
- SIGN TO BE WHITE WITH RED BOLD LETTERING.
- FACING UPSTREAM

RIVER CONSTRUCTION ZONE SIGN
SCALE: NTS



CONSTRUCTION ENTRANCE SIGN NOTES
- SIGN TO BE PLACED ON STAND.
- SIGN TO BE ORANGE WITH BLACK BOLD LETTERING

CONSTRUCTION ENTRANCE SIGN
SCALE: NTS



CONSTRUCTION AHEAD SIGN NOTES
- SIGN TO BE PLACED ON STAND.
- SIGN TO BE ORANGE WITH BLACK BOLD LETTERING

CONSTRUCTION AHEAD SIGN
SCALE: NTS

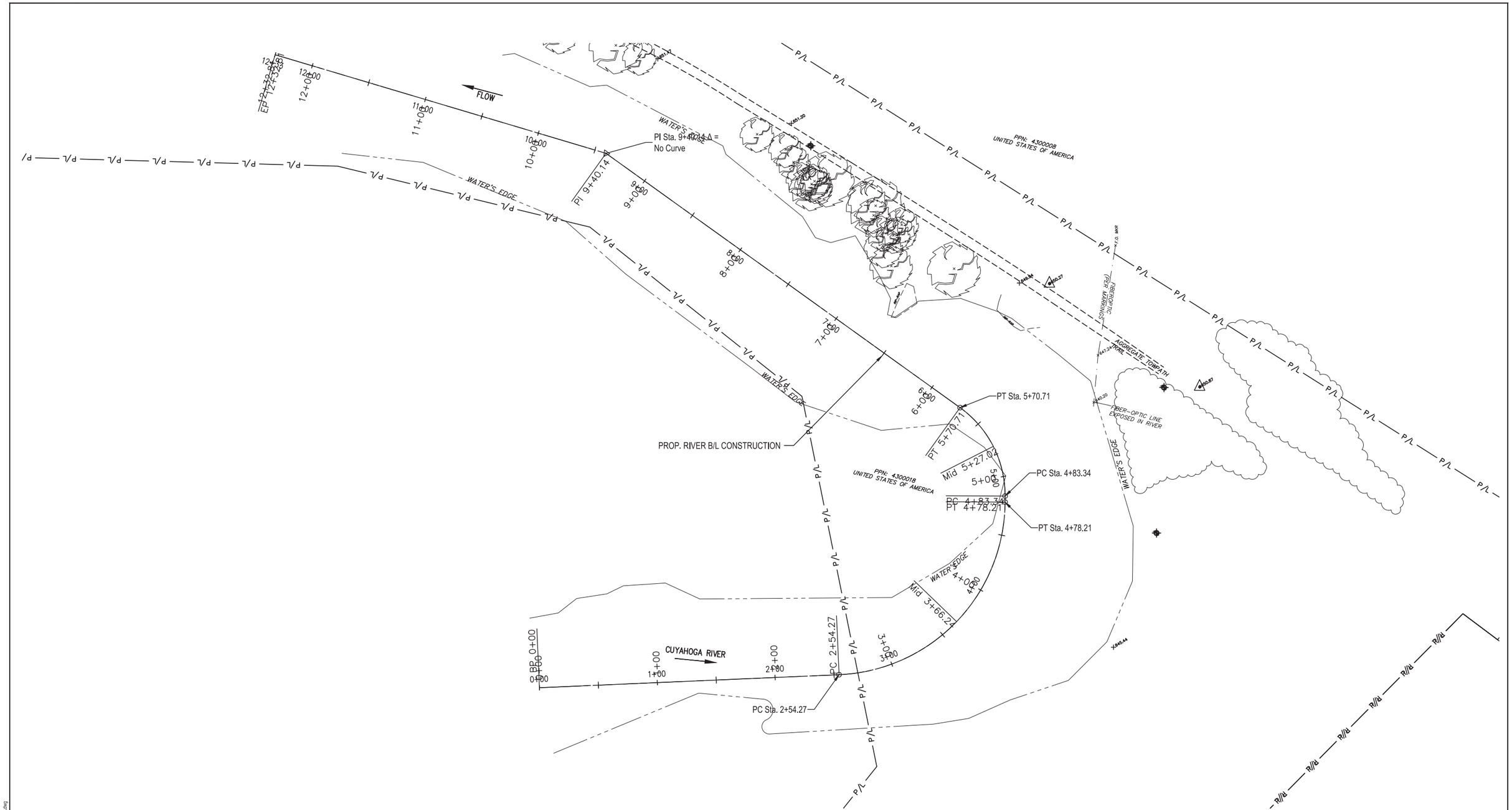
CAUTION HEAVY EQUIPMENT CROSSING NOTES
- SIGN TO BE PLACED ON STAND.
- SIGN TO BE ORANGE WITH BLACK BOLD LETTERING

HEAVY EQUIPMENT CROSSING SIGN
SCALE: NTS

0 100 200
GRAPHIC SCALE IN FEET

DESIGNED: JM	SUB SHEET NO.	TITLE OF DRAWING	DRAWING NO.
DRAWN BY: TG	G-3	ACCESS & MAINTENENCE OF TRAFFIC PLAN	644
TECH REVIEW: JB		LOCATION WITHIN PARK: MM20 SOUTH	176923
DATE: August 2023		NAME OF PARK: CUYAHOGA VALLEY NATIONAL PARK	PMIS/PKG NO. 224822
		REGION: MIDWEST; COUNTY: SUMMIT/CUYAHOGA; STATE: OHIO	03 OF 18

P:\15_PROJECTS\RIVER\RIVERSCAPE\ARRR\1996_CUNP BANK STABILIZATION\VEGETATION\1_DESIGN\MOD DESIGN SHEETS\MAINTENANCE OF TRAFFIC PLANS\MOD - NOT - DESIGN REVIEW\ACTIB - PLOTTED MAY 2021
PRED_JOHNSON\SHEET 02\MOD2.dwg | JOHNSON\MOD2-CNP.dwg | JOHNSON\MOD2-CNP.dwg | JOHNSON\MOD2-CNP.dwg



SURVEYING PARAMETERS

USE THE FOLLOWING VERTICAL AND HORIZONTAL POSITIONING PARAMETERS FOR ALL SURVEYING:

PROJECT CONTROL
- POSITIONING METHOD: ODOT VRS
- MONUMENT TYPE: B

VERTICAL POSITIONING
- ORTHOMETRIC HEIGHT
  DATUM: NAVD88
- GEOID: GEOID 12B

HORIZONTAL POSITIONING
- REFERENCE FRAME: NAD83 (2011)
- ELLIPSOID: GRS80
- MAP PROJECTION: LAMBERT CONFORMAL CONIC
- COORDINATE SYSTEM: OHIO STATE PLANE – NORTH

COMBINED SCALE FACTOR, TO GO FROM GRID TO GROUND: 1.0000000000
[UNITS ARE IN U.S. SURVEY FEET]

LEGEND

- P/L — PROPERTY LINE
- STREAM – EDGE OF WATER
- PROPOSED CREEK BASELINE CONSTRUCTION

FOR GENERAL LEGEND, SEE SHEET 2

0 40 80
GRAPHIC SCALE IN FEET

DESIGNED: JM	SUB SHEET NO.	TITLE OF DRAWING	DRAWING NO.
DRAWN BY: TG	C1	SURVEY CONTROL PLAN	644 / 176923
TECH REVIEW: JB		LOCATION WITHIN PARK: MM20 SOUTH	PMIS/PKG NO. 224822
DATE: August 2023		NAME OF PARK: CUYAHOGA VALLEY NATIONAL PARK	04 OF 18
		REGION: MIDWEST / COUNTY: SUMMIT/CUYAHOGA / STATE: OHIO	

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XREFS: 0_NVDTC-SHEET BORDER.dwg | J:\NDT\1-BASE-SYM.dwg | J:\NDT\C-01-LABEL.dwg

NOTES:

1. EX. WETLANDS WILL BE FLAGGED PRIOR TO THE START OF CONSTRUCTION.

LEGEND

- P/L — PROPERTY LINE
- 685 — EX. CONTOURS
- EX. THALWEG
- EX. TOP OF BANK
- EX. TOE OF SLOPE
- EX. WOODED AREA
- DISTURBANCE LIMITS
- EX. SPOIL AREA
- EX. TEMP. STOCKPILE STAGING AREA
- EX. DELINEATED WETLAND
- EX. CULVERT TO BE REMOVED
- EX. PAVEMENT TO BE REMOVED
- EX. TREE TO REMAIN
- EX. TREE TO BE REMOVED (REUSE)
- STREAM – EDGE OF WATER
- PROPOSED CREEK BASELINE CONSTRUCTION

0 60 120
GRAPHIC SCALE IN FEET

DESIGNED: JM	SUB SHEET NO.	TITLE OF DRAWING EX. CONDITIONS PLAN LOCATION WITHIN PARK MM20 SOUTH NAME OF PARK CUYAHOGA VALLEY NATIONAL PARK	DRAWING NO. 644 / 176923
DRAWN BY: TG	C2		PMIS/PKG NO. 224822
TECH REVIEW: JB		REGION: MIDWEST / COUNTY: SUMMIT/CUYAHOGA / STATE: OHIO	05 OF 18
DATE: August 2023			

P:\10_PROJECTS\RIVERS\CHA\SR\1996_CVNP BANK STABILIZATION\WESTORATION\DESIGN\MM20 DESIGN 30\SHEETS\MM20_EXCONDITIONSDEMO.DWG - C-01 - DESIGN REVIEW.CTB - PLOTTED MAY 2021
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CONSTRUCTION SITE POLLUTION – EROSION CONTROL NOTES

1. THESE CONTRACT DRAWINGS SHALL BE MADE AVAILABLE ON SITE AT ALL TIMES AND PRESENTED UPON REQUEST. IF UNFORESEEN STORM WATER POLLUTION IS ENCOUNTERED, ADDITIONAL EROSION CONTROL MEASURES SHALL BE IMPLEMENTED TO MANAGE THE CURRENT SITE CONDITIONS WHICH MAY BE REQUESTED BY THE CONTRACTING OFFICER OR PROJECT ENGINEER AT ANYTIME. SUCH REQUESTS AND CHANGE IN SITE CONDITIONS SHALL BE IMPLEMENTED IMMEDIATELY.
2. ALL EROSION CONTROL MEASURES WILL BE INSTALLED BEFORE ANY OTHER EARTH MOVING OCCURS.
3. ALL EROSION CONTROL MEASURES SHALL BE INSTALLED AS SHOWN OR NOTED IN THESE PLANS.
4. EROSION CONTROL MEASURES SHALL BE INSTALLED AROUND ALL DIRT OR TOPSOIL STOCKPILES AND OTHER TEMPORARILY DISTURBED AREAS AS SHOWN ON THESE PLANS AND AS DIRECTED BY THE ENGINEER OR CONTRACTING OFFICER.
5. CONSTRUCTION ENTRANCES, AND SILT PERIMETER CONTROLS SHALL REMAIN IN PLACE UNTIL A GOOD STAND OF PERMANENT NATIVE SEED HAS BEEN OBTAINED AND/OR OPERATIONS ARE COMPLETE. CONTRACTOR SHALL KEEP SILT FROM ENTERING ANY STORM DRAINAGE SYSTEM. ONCE SITE HAS BEEN COMPLETELY STABILIZED, ANY SILT IN PIPES AND DRAINAGE SWALES SHALL BE REMOVED WITHIN 10 DAYS.
6. UTILITY COMPANIES MUST COMPLY WITH ALL EROSION CONTROL MEASURES AS DEFINED ON THE EROSION CONTROL PLANS, DETAILS AND NOTES.
7. ALL EXISTING WATER COURSES WITHIN THE PROJECT LIMITS SHALL BE TEMPORARILY PROTECTED DURING LAND CLEARING AND GRADING OPERATIONS. SOILS WITHIN 50 FEET OF SAID WATER COURSES SHALL BE STABILIZED WITHIN 2 DAYS OF THE INITIAL CLEARING / GRADING OPERATION AS SHOWN ON PLANS.
8. IT IS THE CONTRACTOR'S RESPONSIBILITY TO MAINTAIN ALL SEDIMENTATION AND EROSION CONTROL ITEMS AT ALL TIMES.
9. DUST CONTROL SHALL BE MAINTAINED THROUGHOUT CONSTRUCTION. IF POSSIBLE GRADING SHALL BE DONE BY PHASING. IF PHASING IS NOT AN OPTION, DUST SHALL BE CONTROLLED WITH WATER DURING EARTHWORK.
10. ANY DISCHARGE OF HAZARDOUS MATERIALS / REGULATED SUBSTANCES ONTO A PERVIOUS SURFACE SHALL BE LEGALLY REMOVED AND PROPERLY TREATED OR PROPERLY DISPOSED OF, OR OTHERWISE REMEDIATED, SO THAT NO CONTAMINATION FROM THE DISCHARGE REMAINS ON-SITE.
11. IN THE EVENT OF HAZARDOUS MATERIALS / REGULATED SUBSTANCES SPILLS (25 OR MORE GALLONS OR ENOUGH TO CAUSE A SHEEN), THE CONTRACTOR MUST CONTACT THE OHIO EPA (1-800-282-9378), THE LOCAL FIRE DEPARTMENT, SUMMIT COUNTY LOCAL EMERGENCY PLANNING COMMITTEE (330-643-2522), THE CONTRACTING OFFICER, AND CUYAHOGA VALLEY NATIONAL PARK EMERGENCY SERVICES (440-546-5945) WITHIN 30 MINUTES. CONTACT INFORMATION BELOW:

    CUYAHOGA VALLEY NATIONAL PARK EMERGENCY SERVICES
    440-546-5945
    10340 RIVERVIEW ROAD
    BRECKSVILLE, OH 44141

    SUMMIT COUNTY LOCAL EMERGENCY PLANNING COMMITTEE
    (330) 643-2522
    175 S. MAIN ST.
    AKRON, OH 44308

    SAGAMORE HILLS TWP FIRE DEPARTMENT
    (330) 468-1234
    11550 VALLEY VIEW RD.
    SAGAMORE HILLS, OH 44067

12. IF CONDITIONS ARE SUCH THAT MUD IS COLLECTING ON VEHICLE TIRES, THE TIRES MUST BE CLEANED BEFORE THE VEHICLES ENTER THE PUBLIC ROADWAY. THE SITE ENTRANCE SHALL BE MAINTAINED IN A CONDITION THAT WILL PREVENT THE TRACKING OR FLOW OF MUD ONTO THE PUBLIC RIGHT-OF-WAY. ALL MATERIALS SPILLED, DROPPED, WASHED OR TRACKED FROM VEHICLES ONTO THE ROADWAY MUST BE REMOVED PROMPTLY.
13. IF NECESSARY, THE CONTRACTOR SHALL COORDINATE WITH RESPECTIVE UTILITY COMPANIES PRIOR TO THE REMOVAL AND/OR RELOCATION OF UTILITIES. THE CONTRACTOR SHALL COORDINATE WITH THE UTILITY COMPANY CONCERNING PORTIONS OF WORK WHICH MAY BE PERFORMED BY THE UTILITY COMPANY'S FORCES AND ANY FEES WHICH ARE TO BE PAID TO THE UTILITY COMPANY FOR THEIR SERVICES. THE CONTRACTOR IS RESPONSIBLE FOR PAYING ALL FEES AND CHARGES.
14. IF NECESSARY, ELECTRICAL, TELEPHONE, CABLE, WATER, FIBER OPTIC CABLE AND/OR GAS LINES NEEDING TO BE REMOVED OR RELOCATED SHALL BE COORDINATED WITH THE AFFECTED UTILITY COMPANY. ADEQUATE TIME SHALL BE PROVIDED FOR RELOCATION AND CLOSE COORDINATION WITH THE UTILITY COMPANY IS NECESSARY TO PROVIDE A SMOOTH TRANSITION IN UTILITY SERVICE. CONTRACTOR SHALL PAY CLOSE ATTENTION TO EXISTING UTILITIES WITHIN ANY ROAD RIGHT OF WAY DURING CONSTRUCTION.
15. CONTRACTOR IS RESPONSIBLE FOR PLACING AND MAINTAINING CONSTRUCTION FENCE, SIGNS, ETC. TO WARN AND KEEP PEOPLE OFF SITE FOR THE DURATION OF THE PROJECT. IF AN EXISTING FENCE IS PARTIALLY AROUND THE PERIMETER OF THE SITE IT COULD BE UTILIZED AS A CONSTRUCTION FENCE DURING INFRASTRUCTURE WORK.
16. IF, FOR ANY REASON, THE PROJECT IS SUSPENDED, THE CONTRACTOR SHALL ENSURE THAT ALL INSTALLED EROSION MEASURES ARE FUNCTIONING AND PROPERLY MAINTAINED DURING THIS PERIOD, AND THAT ALL BARE SOILS ARE SEEDED AND MULCHED WITH TEMPORARY SEED MIXTURE.
17. PERIMETER CONTROLS SHALL BE INSTALLED/IMPLEMENTED PER THE CONSTRUCTION SEQUENCE IN THIS PLAN SET (AS REQUIRED). IN AREAS WHERE THE PLANS DO NOT SPECIFY, OR AREAS WHICH ARE IN ADDITION TO PLAN SPECIFICATIONS, PERIMETER CONTROLS SHALL BE INSTALLED/IMPLEMENTED WITHIN 7 DAYS OF GRUBBING ACTIVITIES AND PRIOR TO GRADING OF THE AREA THEY WILL CONTROL.
18. SPILL REPORTING REQUIREMENTS: SPILLS ON PAVEMENT SHALL BE ABSORBED WITH SAWDUST OR KITTY LITTER AND DISPOSED OF WITH THE TRASH AT A LICENSED SANITARY LAND FILL. HAZARDOUS MATERIALS / REGULATED SUBSTANCES OR INDUSTRIAL WASTES SUCH AS MOST SOLVENTS, GASOLINE, OIL-BASED PAINTS, AND CEMENT CURING COMPOUNDS REQUIRE SPECIAL HANDLING. SPILLS SHALL BE REPORTED TO OHIO EPA (1-800-282-9378). SPILLS OF 25 GALLONS OR MORE OR ENOUGH TO CAUSE A SHEEN SHALL BE REPORTED TO OHIO EPA, THE LOCAL FIRE DEPARTMENT (330-655-2257), THE LOCAL EMERGENCY PLANNING COMMITTEE (330-643-2522), THE CONTRACTING OFFICER, AND CUYAHOGA VALLEY NATIONAL PARK SERVICES (440-546-5945) WITHIN 30 MINUTES OF THE DISCOVERY OF THE RELEASE. ALL SPILLS WHICH CONTACT WATERS OF THE STATE MUST BE REPORTED TO OHIO EPA.
19. HAZARDOUS MATERIALS/REGULATED SUBSTANCES. IF SUBSTANCES SUCH AS OIL, DIESEL FUEL, HYDRAULIC FLUID, ANTIFREEZE, ETC. ARE SPILLED, LEAKED, OR RELEASED ONTO THE SOIL, THE SOIL SHOULD BE DUG UP AND DISPOSED OF AT A LICENSED SANITARY LAND FILL OR OTHER APPROVED PETROLEUM CONTAMINATED SOIL REMEDIATION FACILITY (NOT A CONSTRUCTION/DEMOLITION DEBRIS LAND FILL). NOTE THOSE STORM WATER RUNOFFS ASSOCIATED WITH CONTAMINATED SOILS ARE NOT AUTHORIZED UNDER OHIO EPA'S GENERAL STORM WATER PERMIT ASSOCIATED WITH CONSTRUCTION ACTIVITIES.
20. OPEN BURNING, NO MATERIALS CONTAINING RUBBER, GREASE, ASPHALT, OR PETROLEUM PRODUCTS, SUCH AS TIRES, AUTO PARTS, PLASTICS OR PLASTIC COATED WIRE MAY BE BURNED (OAC 3745-19). OPEN BURNING IS NOT ALLOWED IN RESTRICTED AREAS, AS FOLLOWS:
    1) WITHIN CORPORATION LIMITS
    2) WITHIN 1000 FEET OUTSIDE A MUNICIPAL CORPORATION HAVING A POPULATION OF 1,000 TO 10,000
    3) A ONE MILE ZONE OUTSIDE OF A CORPORATION OF 10, 000 OR MORE. OUTSIDE OF RESTRICTED AREAS.

    NO OPEN BURNING IS ALLOWED WITHIN 1000 FEET OF AN INHABITED BUILDING ON ANOTHER PROPERTY. OPEN BURNING IS PERMISSIBLE IN A RESTRICTED AREA FOR: HEATING TAR, WELDING, SMUDGE POTS AND SIMILAR OCCUPATIONAL NEEDS, AND HEATING FOR WARMTH OR OUTDOOR BARBEQUES. OUTSIDE OF RESTRICTED AREAS, OPEN BURNING IS PERMISSIBLE FOR LANDSCAPE OR LAND-CLEARING WASTES (PLANT MATERIAL, WITH PRIOR WRITTEN PERMISSION FROM OHIO EPA), AND AGRICULTURAL WASTES, EXCLUDING BUILDINGS.
26. DUST CONTROL OR DUST SUPPRESSANTS SHALL BE USED TO PREVENT NUISANCE CONDITIONS, IN ACCORDANCE WITH THE MANUFACTURER'S SPECIFICATIONS AND IN A MANNER, WHICH PREVENT A DISCHARGE TO WATERS OF THE STATE. SUFFICIENT DISTANCE MUST BE PROVIDED BETWEEN APPLICATIONS AND NEARBY BRIDGES, CATCH BASINS, AND OTHER WATERWAYS. APPLICATION (EXCLUDING WATER) MAY NOT OCCUR WHEN RAIN IS IMMINENT AS NOTED IN THE SHORT TERM FORECAST. USED OIL MAY NOT BE APPLIED FOR DUST CONTROL.
27. PROCESS WASTE WATER/LEACHATE MANAGEMENT. OHIO EPA'S CONSTRUCTION GENERAL PERMIT ONLY ALLOWS THE DISCHARGE OF STORM WATER AND DOES NOT INCLUDE OTHER WASTE STREAMS/DISCHARGES SUCH AS VEHICLE AND/OR EQUIPMENT WASHING, ON-SITE SEPTIC LEACHATE CONCRETE WASH OUTS, WHICH ARE CONSIDERED PROCESS WASTEWATERS. ALL PROCESS WASTEWATERS MUST BE COLLECTED AND PROPERLY DISPOSED AT AN APPROVED DISPOSAL FACILITY. IN THE EVENT, LEACHATE OR SEPTAGE IS DISCHARGED; IT MUST BE ISOLATED FOR COLLECTION AND PROPER DISPOSAL AND CORRECTIVE ACTIONS TAKEN TO ELIMINATE THE SOURCE OF WASTE WATER.
28. PLEASE REFER TO THE OHIO RAINWATER AND LAND DEVELOPMENT MANUAL, OHIOS STANDARDS FOR STORMWATER MANAGEMENT LAND DEVELOPMENT AND URBAN STREAM PROTECTION, CURRENT EDITION, FOR ADDITIONAL INFORMATION.

STORMWATER MANAGEMENT BMPS

BMP 1 TEMPORARY SEEDING:
- PLANT TEMPORARY SEEDING AND MULCHING IN ALL AREAS THAT SHALL BE INACTIVE FOR 14 DAYS OR MORE.
- ALL DISTURBED AND ERODED EARTH SHALL BE REGRADED AND SEEDED WITHIN 7 DAYS WITH SEEDING, AS DEFINED ABOVE AND AS SHOWN ON THE TABLE BELOW, TO ESTABLISH STABILITY AND PROVIDE SEDIMENT CONTROL.
- WHERE POSSIBLE, TEMPORARY SEEDING GROWTH SHALL NOT BE MOWED UNTIL IT HAS GONE TO SEED FOR 1 YEAR.

TEMPORARY SEEDING SPECIFICATIONS:

SEEDING DATES	SEED TYPE	APPLICATION RATE
MARCH 1 – NOVEMBER 1	OATS	50#
AFTER NOVEMBER 1	STRAW OR HAY MULCH	80 – 120 BALES
SEED BED PREPARATION	LIME	4300#
	10-10-10 OR 12-12-12 FERTILIZER	516 – 645#

PER ACRE

BMP 2 PERMANENT SEEDING:
- EMBANKMENT AND FLOODPLAIN SEED MIXES
- SEE SHEET 18 FOR LOCATIONS.
- SEE SHEET 17 FOR NOTES.

BMP 3 SILT FENCE:
- SEE SHEET 07 FOR NOTES AND DETAILS.

BMP 4 CONSTRUCTION ENTRANCE:
- SEE SHEET 07 FOR NOTES AND DETAILS.

BMP 5 WASTE DISPOSAL, SOLID WASTE MATERIALS, HAZARDOUS WASTES, AND SANITARY WASTE:
- CONSTRUCTION PERSONNEL, INCLUDING SUBCONTRACTORS WHO MAY USE OR HANDLE HAZARDOUS OR TOXIC MATERIALS, SHALL BE MADE AWARE OF THE FOLLOWING GENERAL GUIDELINES REGARDING DISPOSAL AND HANDLING OF HAZARDOUS AND CONSTRUCTION WASTES:

  A. PREVENT SPILLS
  B. USE PRODUCTS UP
  C. FOLLOW LABEL DIRECTIONS FOR DISPOSAL
  D. REMOVE LIDS FROM EMPTY BOTTLES AND CANS WHEN DISPOSING IN TRASH
  E. RECYCLE WASTES WHENEVER POSSIBLE
  F. DON'T POUR INTO WATERWAYS, STORM DRAINS OR ONTO THE GROUND
  G. DON'T POUR DOWN THE SINK, DOOR DRAIN OR SEPTIC TANKS
  H. DON'T BURY CHEMICALS OR CONTAINERS
  I. DON'T BURN CHEMICALS OR CONTAINERS
  J. DON'T MIX CHEMICALS TOGETHER

- CONTAINERS SHALL BE PROVIDED FOR THE PROPER COLLECTION OF ALL WASTE MATERIAL INCLUDING CONSTRUCTION DEBRIS, TRASH, PETROLEUM PRODUCTS AND ANY HAZARDOUS MATERIALS USED ON-SITE. CONTAINERS SHALL BE COVERED AND NOT LEAKING.
- ALL WASTE MATERIAL SHALL BE DISPOSED OF AT FACILITIES APPROVED FOR THAT MATERIAL. CONSTRUCTION DEMOLITION AND DEBRIS (CD&D) WASTE MUST BE DISPOSED OF AT AN OHIO EPA APPROVED CD&D LAND FILL.
- NO CONSTRUCTION RELATED WASTE MATERIALS ARE TO BE BURIED ON-SITE. BY EXCEPTION, CLEAN FILL (BRICKS, HARDENED CONCRETE, SOIL) MAY BE UTILIZED IN A WAY WHICH DOES NOT ENCROACH UPON NATURAL WETLANDS, STREAMS OR PLAINS OR RESULT IN THE CONTAMINATION OF WATERS OF THE STATE.
- WASTES GENERATED BY CONSTRUCTION ACTIVITIES (i.e. CONSTRUCTION MATERIALS SUCH AS PAINTS, SOLVENTS, FUELS, CONCRETE, WOOD, ETC) MUST BE DISPOSED OF IN ACCORDANCE WITH ORC 3734 AND OR5C 3714.

BMP 6 MATERIAL HANDLING:
- STOCKPILED MATERIALS (STONE, TOPSOIL, ETC.) SHALL BE SURROUNDED WITH SILT FENCE. SILT FENCE SHALL BE INSPECTED AS SPECIFIED ON THIS SHEET.
- ALL PETROLEUM PRODUCTS SHALL BE KEPT IN SEALED TANKS/CONTAINERS. TANKS/CONTAINERS AND VEHICLES SHALL BE INSPECTED REGULARLY FOR LEAKS. SPILLS SHALL BE REPORTED AS SPECIFIED ON THIS SHEET.
- MIXING, PUMPING, TRANSFERRING OR OTHER HANDLING OF CONSTRUCTION CHEMICALS SUCH AS FERTILIZER, LIME, ASPHALT, CONCRETE DRYING COMPOUNDS, AND ALL OTHER POTENTIALLY HAZARDOUS MATERIALS SHALL BE PERFORMED IN AN AREA AWAY FROM ANY WATERCOURSE, DITCH OR STORM DRAIN.

BMP 7 EQUIPMENT FUELING AND MAINTENANCE:
- EQUIPMENT FUELING AND MAINTENANCE, OIL CHANGING, ETC., SHALL BE PERFORMED AWAY FROM WATERCOURSES, DITCHES OR STORM DRAINS, IN AN AREA DESIGNATED FOR THAT PURPOSE. THE DESIGNATED AREA SHALL BE EQUIPPED FOR RECYCLING OIL AND CATCHING SPILLS. SECONDARY CONTAINMENT SHALL BE PROVIDED FOR ALL FUEL OIL STORAGE TANKS. THESE AREAS MUST BE INSPECTED EVERY SEVEN DAYS AND WITHIN 24 HRS. OF A 0.5 INCH OR GREATER RAIN EVENT TO ENSURE THERE ARE NO EXPOSED MATERIALS WHICH WOULD CONTAMINATE STORM WATER.
- SITE OPERATORS MUST BE AWARE THAT SPILL PREVENTION CONTROL AND COUNTERMEASURES (SPCC) REQUIREMENTS MAY APPLY. A SPCC PLAN IS REQUIRED FOR SITES WITH ONE SINGLE ABOVE GROUND TANK OF 660 GALLONS OR MORE, ACCUMULATIVE ABOVE GROUND STORAGE OF 1330 GALLONS OR MORE, OR 42,000 GALLONS OF UNDERGROUND STORAGE.
- CONTAMINATED SOILS MUST BE DISPOSED OF AS SPECIFIED ON THIS SHEET.

BMP 8 TIMBER MAT WETLAND CROSSING (OR APPROVED EQUAL):
- SEE SHEET 07 FOR NOTES AND DETAILS
- USE WHEN NECESSARY
- RESTORE ALL TEMPORARY IMPACTS UPON PROJECT COMPLETION.

BMP 9 EROSION CONTROL MATTING – STREAM BANKS
- TO BE INSTALLED PER MANUFACTURERS SPECS.
- SEE SHEET 07 FOR NOTES AND DETAILS

FOR PERMANENT SEEDING AND MULCHING NOTES, SEE SHEET 17
FOR COMPLETE LEGEND, SEE SHEET 02

SITE INSPECTIONS SHALL BE DONE WEEKLY AND AFTER EVERY RAINFALL EVENT EXCEEDING 1/2" OF RAINFALL. ALL NECESSARY REPAIRS SHOULD BE IMPLEMENTED IMMEDIATELY AFTER SUCH INSPECTIONS.

ONLY A QUALIFIED INSPECTION PERSONNEL IS TO PERFORM INSPECTIONS.

INSPECTOR SHALL BE RESPONSIBLE FOR PREPARING AND SIGNING WEEKLY AND ALL INTERMEDIATE EROSION CONTROL INSPECTION REPORTS AFTER EVERY INSPECTION. SUCH REPORTS SHALL BE MADE AVAILABLE TO CONTRACTING OFFICER, ENGINEER, AND CITY / STATE OFFICIALS UPON THEIR REQUEST.

SUCH REPORTS SHALL BE KEPT FOR 3 YEARS AFTER TERMINATION OF CONSTRUCTION ACTIVITIES.

** REVISIONS TO THESE PLANS MUST BE AUTHORIZED BY THE CONTRACTING OFFICER AND/OR GPD GROUP PRIOR TO IMPLEMENTATION.

DESIGNED: JM	SUB SHEET NO.	TITLE OF DRAWING	DRAWING NO.
DRAWN BY: TG	C-3	EROSION CONTROL NOTES	644 / 176923
TECH REVIEW: JB		LOCATION WITHIN PARK: MM20 SOUTH	PMIS/PKG NO. 224822
DATE: August 2023		NAME OF PARK: CUYAHOGA VALLEY NATIONAL PARK	06 OF 18
		REGION: MIDWEST / COUNTY: SUMMIT/CUYAHOGA / STATE: OHIO	

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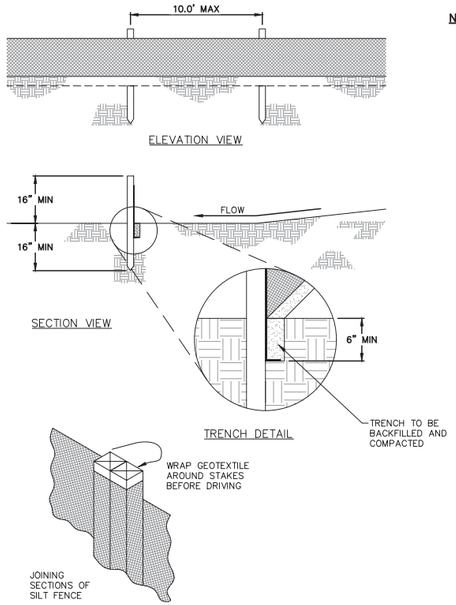


NOTES:

1. SILT FENCE SHALL BE CONSTRUCTED BEFORE UPSLOPE LAND DISTURBANCE BEGINS.
2. ALL SILT FENCES SHALL BE PLACED AS CLOSE TO THE CONTOUR AS POSSIBLE SO THAT WATER WILL NOT CONCENTRATE AT LOW POINTS IN THE FENCE AND SO THAT SMALL SWALES OR DEPRESSIONS THAT MAY CARRY SMALL CONCENTRATED FLOWS TO THE SILT FENCE ARE DISSIPATED ALONG ITS LENGTH.
3. ENDS OF THE SILT FENCES SHALL BE BROUGHT UPSLOPE SLIGHTLY SO THAT WATER PONDED BY THE SILT FENCE WILL BE PREVENTED FROM FLOWING AROUND THE ENDS.
4. SILT FENCE SHALL BE PLACED ON THE FLATTEST AREA AVAILABLE.
5. WHERE POSSIBLE, VEGETATION SHALL BE PRESERVED FOR 5 FEET (OR AS MUCH AS POSSIBLE) UPSLOPE FROM THE SILT FENCE. IF VEGETATION IS REMOVED, IT SHALL BE REESTABLISHED WITHIN 7 DAYS FROM THE INSTALLATION OF THE SILT FENCE.
6. THE HEIGHT OF THE SILT FENCE SHALL BE A MINIMUM OF 16 INCHES ABOVE THE GROUND SURFACE.
7. THE SILT FENCE SHALL BE PLACED IN AN EXCAVATED OR SLICED TRENCH CUT A MINIMUM OF 6 INCHES DEEP. THE TRENCH SHALL BE MADE WITH A TRENCHER, CABLE LAYING MACHINE, SLICING MACHINE OR OTHER SUITABLE DEVICE THAT WILL ENSURE AN ADEQUATELY UNIFORM TRENCH DEPTH.
8. THE SILT FENCE SHALL BE PLACED WITH THE STAKES ON THE DOWNSLOPE SIDE OF THE GEOTEXTILE. A MINIMUM OF 8 INCHES OF GEOTEXTILE MUST BE BELOW THE GROUND SURFACE. EXCESS MATERIAL SHALL LAY ON THE BOTTOM OF THE 6-INCH DEEP TRENCH. THE TRENCH SHALL BE BACKFILLED AND COMPACTED ON BOTH SIDES OF THE FABRIC.
9. SEAMS BETWEEN SECTIONS OF SILT FENCE SHALL BE SPLICED TOGETHER ONLY AT A SUPPORT POST WITH A MINIMUM 6-IN. OVERLAP PRIOR TO DRIVING INTO THE GROUND, (SEE DETAILS).
10. MAINTENANCE – SILT FENCE SHALL ALLOW RUNOFF TO PASS ONLY AS DIFFUSE FLOW THROUGH THE GEOTEXTILE. IF RUNOFF OVERTOPS THE SILT FENCE, FLOWS UNDER THE FABRIC OR AROUND THE FENCE ENDS, OR IN ANY OTHER WAY ALLOWS A CONCENTRATED FLOW DISCHARGE, ONE OF THE FOLLOWING SHALL BE PERFORMED, AS APPROPRIATE:

    1) THE LAYOUT OF THE SILT FENCE SHALL BE CHANGED
    2) ACCUMULATED SEDIMENT SHALL BE REMOVED
    3) OTHER PRACTICES SHALL BE INSTALLED

    SEDIMENT DEPOSITS SHALL BE ROUTINELY REMOVED WHEN THE DEPOSIT REACHES APPROXIMATELY ONE-HALF OF THE HEIGHT OF THE SILT FENCE.

    SILT FENCES SHALL BE INSPECTED AFTER EACH RAINFALL AND AT LEAST DAILY DURING A PROLONGED RAINFALL. THE LOCATION OF EXISTING SILT FENCE SHALL BE REVIEWED DAILY TO ENSURE ITS PROPER LOCATION AND EFFECTIVENESS. IF DAMAGED, THE SILT FENCE SHALL BE REPAIRED IMMEDIATELY.

CRITERIA FOR SILT FENCE MATERIALS

1. FENCE POST – THE LENGTH SHALL BE A MINIMUM OF 32 INCHES. WOOD POSTS SHALL BE 2-BY-2-IN. NOMINAL DIMENSIONED HARDWOOD OF SOUND QUALITY. THEY SHALL BE FREE OF KNOTS, SPLITS AND OTHER VISIBLE IMPERFECTIONS, THAT WILL WEAKEN THE POSTS. THE MAXIMUM SPACING BETWEEN POSTS SHALL BE 10 FT. POSTS SHALL BE DRIVEN A MINIMUM 16 INCHES INTO THE GROUND, WHERE POSSIBLE. IF NOT POSSIBLE, THE POSTS SHALL BE ADEQUATELY SECURED TO PREVENT OVERTURNING OF THE FENCE DUE TO SEDIMENT/WATER LOADING.
2. SILT FENCE FABRIC – SEE CHART IN THIS DETAIL.

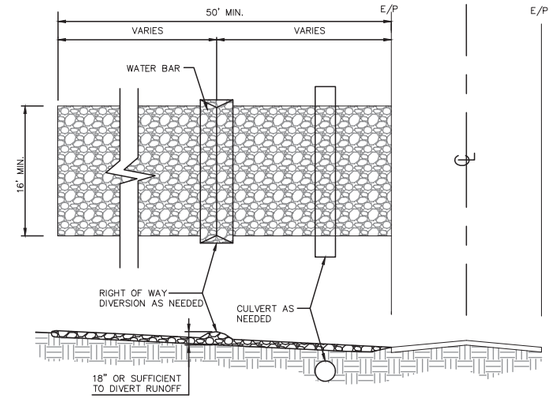
TABLE 6.3.2 MINIMUM CRITERIA FOR SILT FENCE FABRIC (ODOT, 2013)

FABRIC PROPERTIES	VALUES	TEST METHOD
Minimum Tensile Strength	120 lbs. (535 N)	ASTM D 4632
Maximum Elongation at 60 lbs	50%	ASTM D 4632
Minimum Puncture Strength	50 lbs. (220 N)	ASTM D 4833
Minimum Tear Strength	40 lbs. (180 N)	ASTM D 4533
Apparent Opening Size	≤ 0.84 mm	ASTM D 4751
Minimum Permittivity	1X10-2 sec.-1	ASTM D 4491
UV Exposure Strength Retention	70%	ASTM D 4355

SILT FENCE DETAIL
(BMP 3)
SCALE: NTS

NOTES:

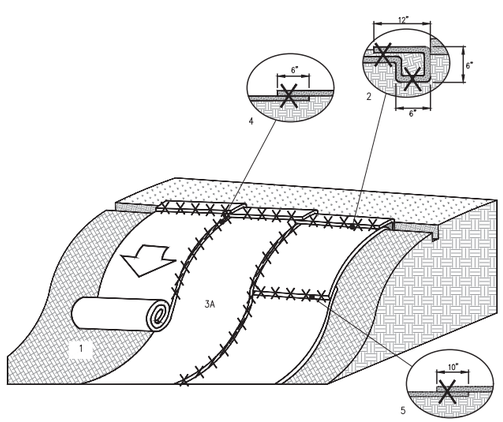
1. THE EXISTING GRAVEL DRIVE SHALL BE UTILIZED FOR CONSTRUCTION ENTRANCE. IF NECESSARY, INSTALL CONSTRUCTION ENTRANCE AS NOTED BELOW.
2. STONE SIZE – NO. 2 STONE SHALL BE USED, OR RECYCLED CONCRETE EQUIVALENT.
3. THICKNESS – STONE LAYER SHALL BE 6" THICK FOR STANDARD DUTY ACTIVITY AND 10" THICK FOR HEAVY DUTY ACTIVITY.
4. DRIVEWAY WIDTH – THE ENTRANCE SHALL BE AT LEAST 16' WIDE. CONTRACTOR SHALL ENSURE ALL VEHICLES UTILIZE THE CONSTRUCTION ENTRANCE UNTIL PAVEMENT IS IN PLACE.
5. BEDDING-A GEOTEXTILE SHALL BE PLACED OVER THE ENTIRE AREA PRIOR TO PLACING STONE. IT SHALL HAVE A GRAB TENSILE STRENGTH OF AT LEAST 200 LBS. AND A MULLEN BURST STRENGTH OF AT LEAST 190 LBS.
6. CULVERT-A PIPE OR CULVERT SHALL BE CONSTRUCTED UNDER THE ENTRANCE IF NEEDED TO PREVENT SURFACE WATER FLOWING ACROSS THE ENTRANCE FROM BEING DIRECTED OUT ONTO PAVED SURFACES.
7. WATER BAR – A WATER BAR SHALL BE CONSTRUCTED AS PART OF THE CONSTRUCTION ENTRANCE IF NEEDED TO PREVENT SURFACE RUNOFF FROM FLOWING THE LENGTH OF THE CONSTRUCTION ENTRANCE AND OUT ONTO PAVED SURFACES.
8. MAINTENANCE – TOP DRESSING OF ADDITIONAL STONE SHALL BE APPLIED AS CONDITIONS DEMAND. MUD SPILLED, DROPPED, WASHED OR TRACKED ONTO PUBLIC ROADS, OR ANY SURFACE WHERE RUNOFF IS NOT CHECKED BY SEDIMENT CONTROLS, SHALL BE REMOVED IMMEDIATELY. REMOVAL SHALL BE ACCOMPLISHED BY SCRAPING OR SWEEPING.
9. CONSTRUCTION ENTRANCES SHALL NOT BE RELIED UPON TO REMOVE MUD FROM VEHICLES AND PREVENT OFF SITE TRACKING. VEHICLES THAT ENTER AND LEAVE THE CONSTRUCTION SHALL BE RESTRICTED FROM MUDDY AREAS.
10. THE ENTRANCE SHALL REMAIN IN PLACE UNTIL THE DISTURBED AREA IS STABILIZED OR REPLACED WITH A PERMANENT ROADWAY OR ENTRANCE.



TEMPORARY CONSTRUCTION DRIVE ACCESS
(BMP 4)
SCALE: NTS

EROSION FABRIC NOTES:

- EMBANKMENT: 700 SEMES COIR BLANKET OR APPROVED EQUAL, INSTALLED PER MANUFACTURER SPECIFICATIONS
- DISTURBED AREA ABOVE THE PROPOSED EMBANKMENT AREA [I.E. STAGING AREAS AND TREE LAWNS]: STRAW BLANKET



1. PREPARE SOIL BEFORE INSTALLING ROLLED EROSION CONTROL PRODUCTS (RECPS), INCLUDING ANY NECESSARY APPLICATION OF LIME, FERTILIZER, AND SEED.

2. BEGIN AT THE TOP OF THE SLOPE BY ANCHORING THE RECPS IN A 6" DEEP BY 6" WIDE TRENCH WITH APPROXIMATELY 12" OF RECPS EXTENDED BEYOND THE UP-SLOPE PORTION OF THE TRENCH. ANCHOR THE RECPS WITH A ROW OF WOODY STAKES APPROXIMATELY 12" APART IN THE BOTTOM OF THE TRENCH. BACKFILL AND COMPACT THE TRENCH AFTER STAPLING. APPLY SEED TO THE COMPACTED SOIL AND FOLD THE REMAINING 12" PORTION OF RECPS BACK OVER THE SEED AND COMPACTED SOIL. SECURE RECPS OVER COMPACTED SOIL WITH A ROW OF WOODY STAKES SPACED APPROXIMATELY 12" APART ACROSS THE WIDTH OF THE RECPS.

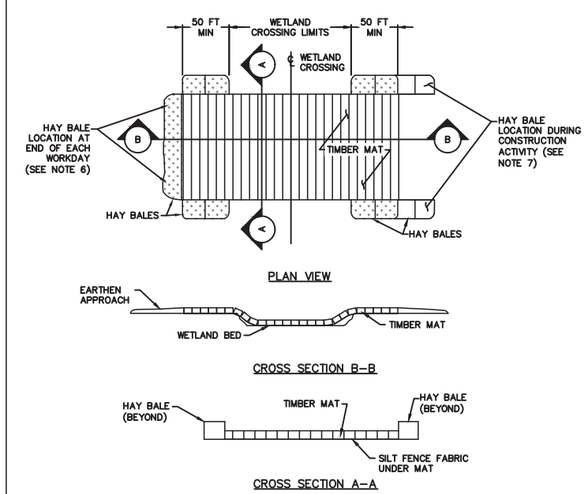
3. ROLL THE RECPS (A) DOWN OR (B) HORIZONTALLY ACROSS THE SLOPE. RECPS WILL UNROLL WITH APPROPRIATE SIDE AGAINST THE SOIL SURFACE. ALL RECPS MUST BE SECURELY FASTENED TO SOIL SURFACE BY PLACING WOODY STAKES IN APPROPRIATE LOCATIONS AS SHOWN IN THE STAPLE PATTERN GUIDE.

4. THE EDGES OF PARALLEL RECPS MUST BE STAPLED WITH APPROXIMATELY 6" OVERLAP DEPENDING ON THE RECPS TYPE.

5. CONSECUTIVE RECPS SPLICED DOWN THE SLOPE MUST BE END OVER END (SHINGLE STYLE) WITH AN APPROXIMATE 10" OVERLAP. SECURED THROUGH OVERLAPPED AREA, APPROXIMATELY 12" APART ACROSS ENTIRE RECPS WIDTH.

NOTE: IN LOOSE SOIL CONDITIONS, THE USE OF STAKE LENGTHS GREATER THAN 6" MAY BE NECESSARY TO PROPERLY SECURE THE RECP'S

EROSION CONTROL FABRIC DETAIL
(BMP 9)
SCALE: NTS
[DETAIL PER NORTH AMERICAN GREEN – EROSION CONTROL PRODUCTS]



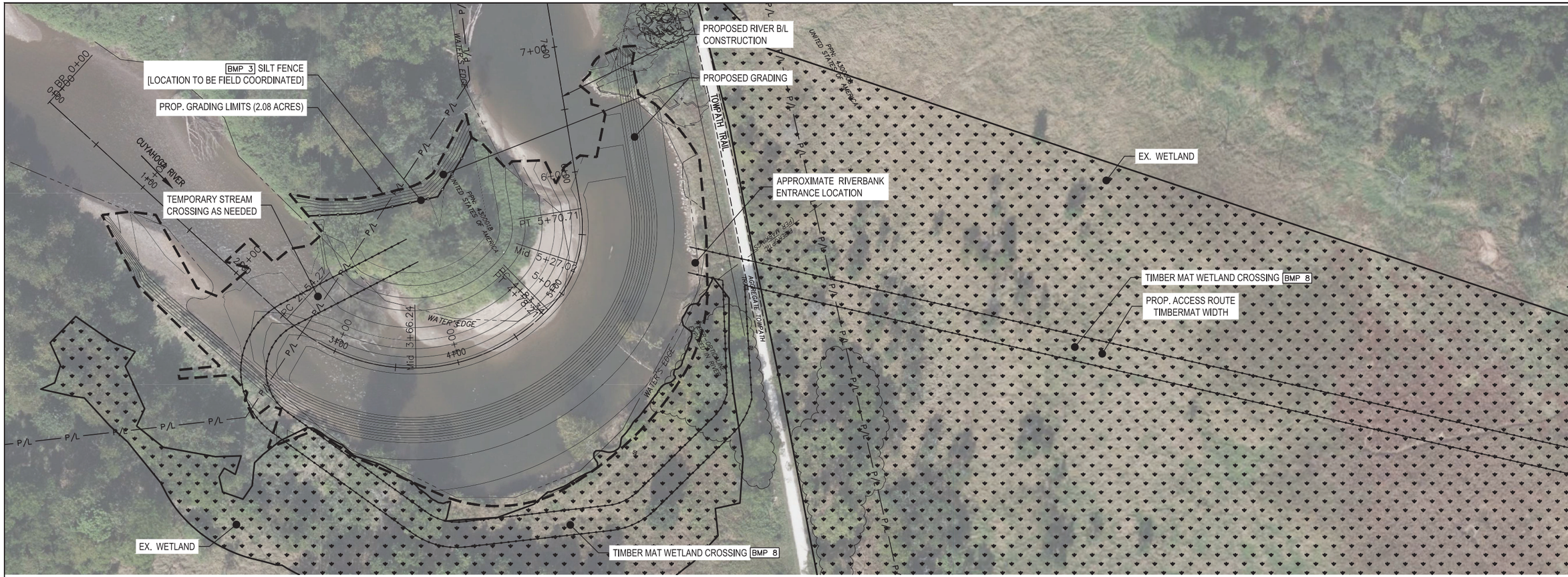
NOTES:

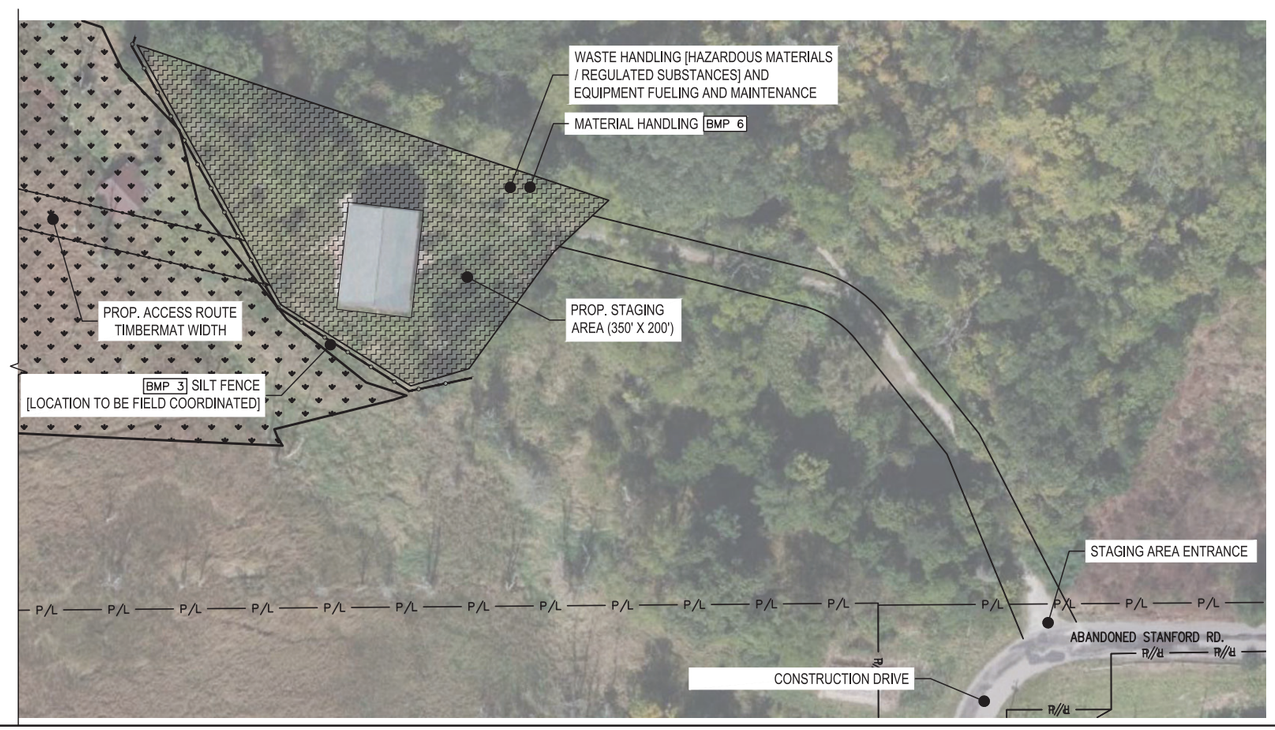
1. THIS TYPE OF CROSSING IS GENERALLY USED FOR SMALL STREAM CROSSINGS LESS THAN 30 FEET IN WIDTH AND A PROPER STREAM BANK CONFIGURATION.
2. TIMBER MAT SHALL BE TEMPORARILY REMOVED IF HIGH WATER RENDERS IT UNSAFE FOR CROSSING.
3. TIMBER MAT TO REMAIN IN PLACE UNTIL COMPLETION OF FINAL RESTORATION.
4. A SKIRT FORMED OF SILT FENCE, GEOTEXTILE FABRIC, OR EQUIVALENT SHALL BE PLACED ON THE BOTTOM OF THE BRIDGE TO TRAP SEDIMENT AS NECESSARY.
5. INDIVIDUAL MATS SHALL BE ANCHORED AND BUTTED TIGHTLY TO MINIMIZE THE INTRODUCTION OF SEDIMENT TO THE WATERBODY.
6. IF NECESSARY, HAY BALES WILL BE PLACED AT THE EDGE OF THE TIMBER MAT AT THE END OF EACH WORK DAY TO PREVENT EROSION, BUT WILL BE REMOVED DURING CONSTRUCTION ACTIVITY.
7. TEMPORARY WETLAND CROSSING SHALL BE INSPECTED ON A DAILY BASIS.
8. DAMAGED CROSSING SHALL BE REPAIRED WITHIN 24 HOURS OF THE INSPECTION, AND BEFORE ANY SUBSEQUENT USE.
9. SEDIMENT DEPOSITS ON THE CROSSING OR ITS APPROACHES SHALL BE REMOVED WITHIN 24 HOURS OF INSPECTION.

TIMBER MAT EQUIPMENT CROSSING OVER WETLAND
(BMP 8)
SCALE: NTS

DESIGNED: JM	SUB SHEET NO.	TITLE OF DRAWING: EROSION CONTROL DETAILS	DRAWING NO. 644 / 176923
DRAWN BY: TG	C4	LOCATION WITHIN PARK: MM20 SOUTH	PMIS/PKG NO. 224822
TECH REVIEW: JB		NAME OF PARK: CUYAHOGA VALLEY NATIONAL PARK	
DATE: August 2023		REGION: MIDWEST; COUNTY: SUMMIT/CUYAHOGA; STATE: OHIO	07 OF 18

P:\15_PROJECTS\RIVERREACH\ASR\1996_CVNP BANK STABILIZATION\RESTORATION DESIGN\MM20 DESIGN\10\SHEETS\ACCESS & SWPP PLAN\DWG - SWPP DETAILS - DESIGN REVIEW\CTB - PLOTTED MAY 2021
PREPD: J.WARFS-SHEET: BORDER.dwg | J.WARFS-HDRSEC-VRS.dwg | J.WARFS-base-MM20.dwg | J.WARFS-CATL-MM20.dwg





FOR GENERAL LEGEND, SEE SHEET 2
FOR PERMANENT SEEDING LOCATIONS AND QUANTITIES, SEE SHEET 18 AND 17

LEGEND

- P/L — PROPERTY LINE
- 685 — EX. CONTOUR
- 685 — PROP. CONTOUR
- PROPOSED GRADING LIMITS
- PROPOSED ACCESS ROUTE
- PROPOSED SILT FENCE
- PROPOSED STAGING AREA
- EXISTING WETLAND
- STREAM – EDGE OF WATER
- PROPOSED CREEK BASELINE CONSTRUCTION

0 100 200
GRAPHIC SCALE IN FEET

DESIGNED: JM	SUB SHEET NO.	TITLE OF DRAWING	DRAWING NO.
DRAWN BY: TG	C5	EROSION CONTROL PLAN	644 / 176923
TECH REVIEW: JB		LOCATION WITHIN PARK: MM20 SOUTH	PMIS/PKG NO. 224822
DATE: August 2023		NAME OF PARK: CUYAHOGA VALLEY NATIONAL PARK	08 OF 18
		REGION: MIDWEST / COUNTY: SUMMIT/CUYAHOGA / STATE: OHIO	

P:\1_PROJECTS\RIVERREACH\RR1996_CVNP BANK STABILIZATION\RESTORATION DESIGN\MM20 DESIGN 30\SHEETS\ACCESS & SWPP PLAN.DWG - ES PLAN - DESIGN REVIEW,CTB - PLOTTED MAY 2021
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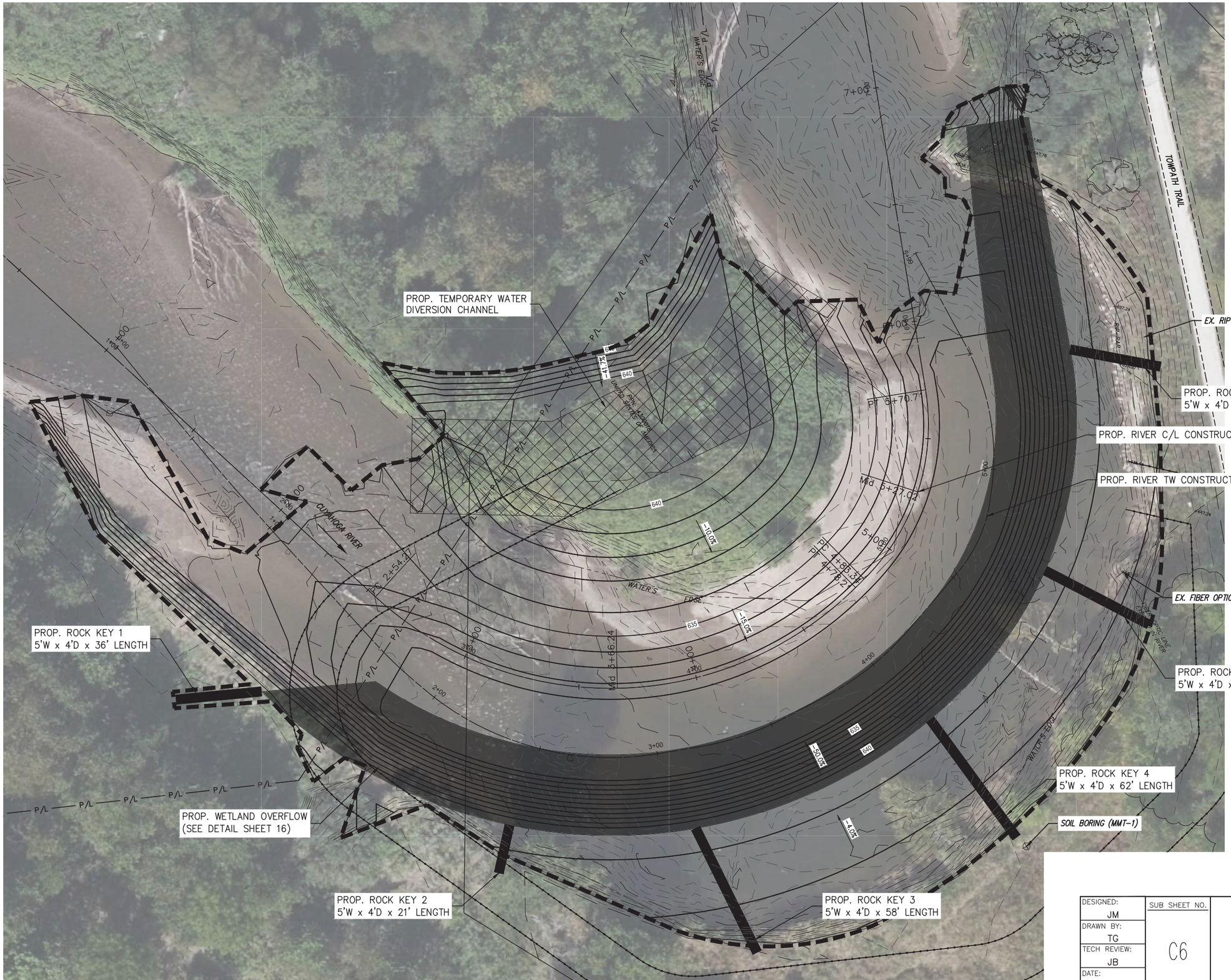

LEGEND

- P/L — PROPERTY LINE
- 685 — EX. CONTOURS
- 685 — PROP. CONTOURS
- PROP. ROCK KEY
- PROP. BANK STABILIZATION
- PROPOSED GRADING LIMITS
- PROPOSED ACCESS ROUTE
- PROPOSED WATER DIVERSION CHANNEL

0 20 40
GRAPHIC SCALE IN FEET

DESIGNED: JM DRAWN BY: TG TECH REVIEW: JB DATE: August 2023	SUB SHEET NO. C6	TITLE OF DRAWING PROP. GRADING PLAN LOCATION WITHIN PARK MM20 SOUTH NAME OF PARK CUYAHOGA VALLEY NATIONAL PARK REGION MIDWEST · COUNTY SUMMIT/CUYAHOGA · STATE OHIO	DRAWING NO. 644 / 176923 PMIS/PKG NO. 224822 09 OF 18

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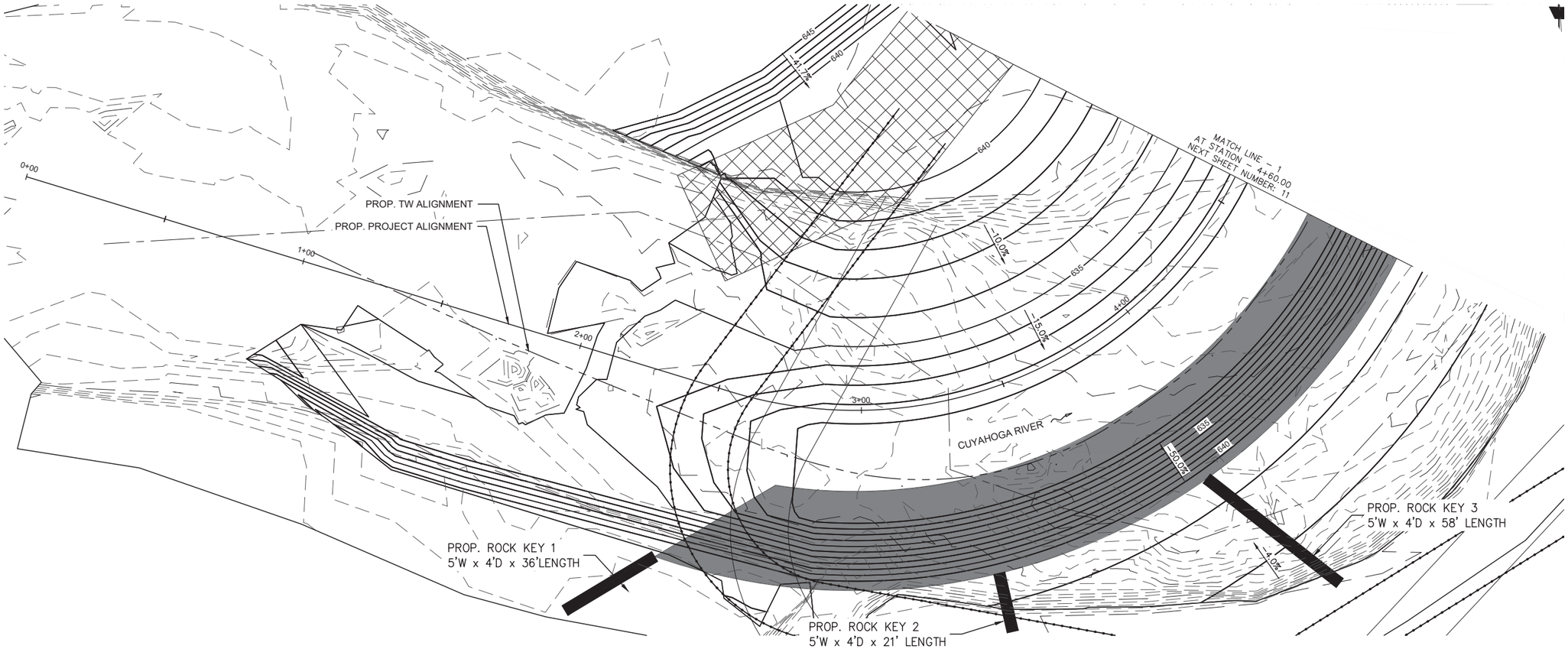

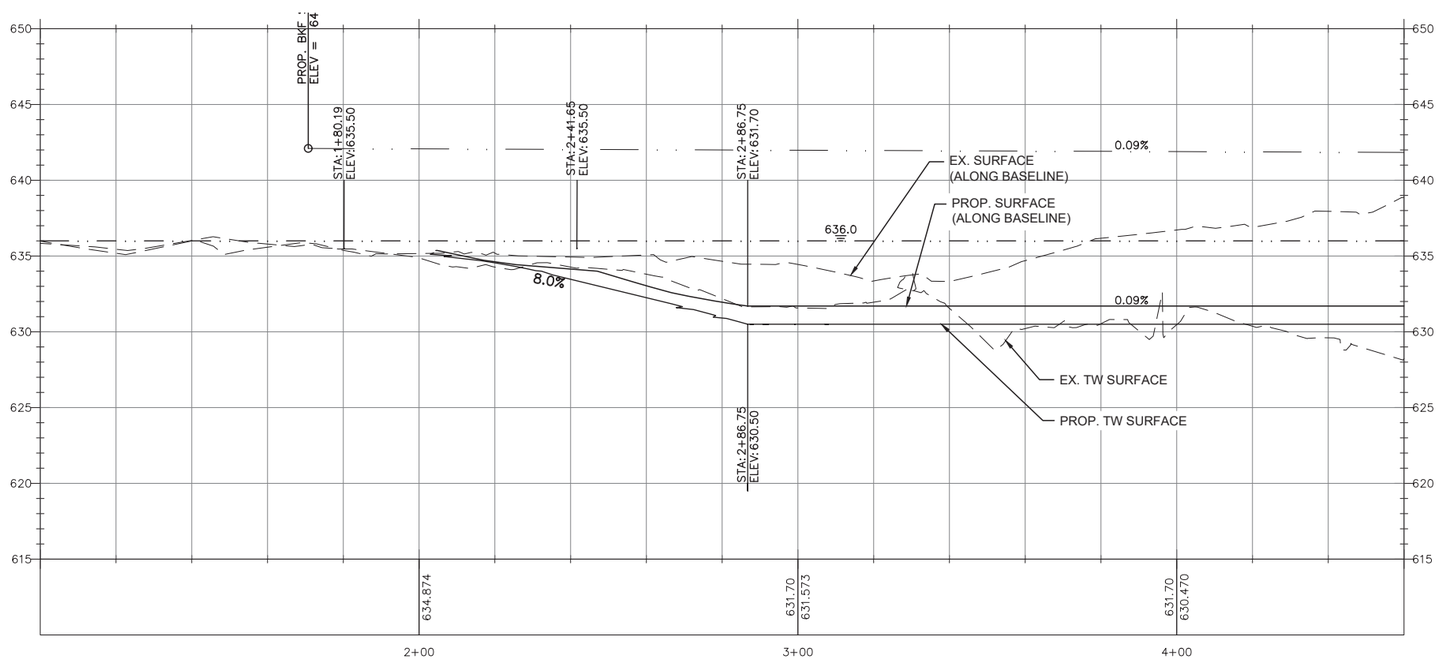

LEGEND

- P/L — PROPERTY LINE
- 685 — EX. CONTOURS
- 685 — PROP. CONTOURS
- PROPOSED ACCESS ROUTE
- PROPOSED GRADING LIMITS
- PROP. ROCK KEY
- PROP. BANK STABILIZATION
- PROPOSED WATER DIVERSION CHANNEL

PROFILE LEGEND

- EX. SURFACE
- PROP. THALWEG
- PROP. BANKFULL
- APPROX. LOW FLOW WATER SURFACE

0 5 10
GRAPHIC SCALE IN FEET
VERTICAL SCALE

0 20 40
GRAPHIC SCALE IN FEET
HORIZONTAL SCALE

DESIGNED: JM	SUB SHEET NO.	TITLE OF DRAWING	DRAWING NO.
DRAWN BY: TG	C7	PROP. PLAN AND PROFILE	644 / 176923
TECH REVIEW: JB		LOCATION WITHIN PARK: MM20 SOUTH	PMIS/PKG NO. 224822
DATE: August 2023		NAME OF PARK: CUYAHOGA VALLEY NATIONAL PARK	10 OF 18
		REGION: MIDWEST / COUNTY: SUMMIT/CUYAHOGA / STATE: OHIO	

P:\10_PROJECTS\RIVERREACH4\ER\1996_CVNP BANK STABILIZATION\RESTORATION DESIGN\MM20 DESIGN 30\SHEETS\MM20_PLAN & PROFILE.DWG - PR-01 - DESIGN REVIEW,CTB - PLOTTED:MAY 2021
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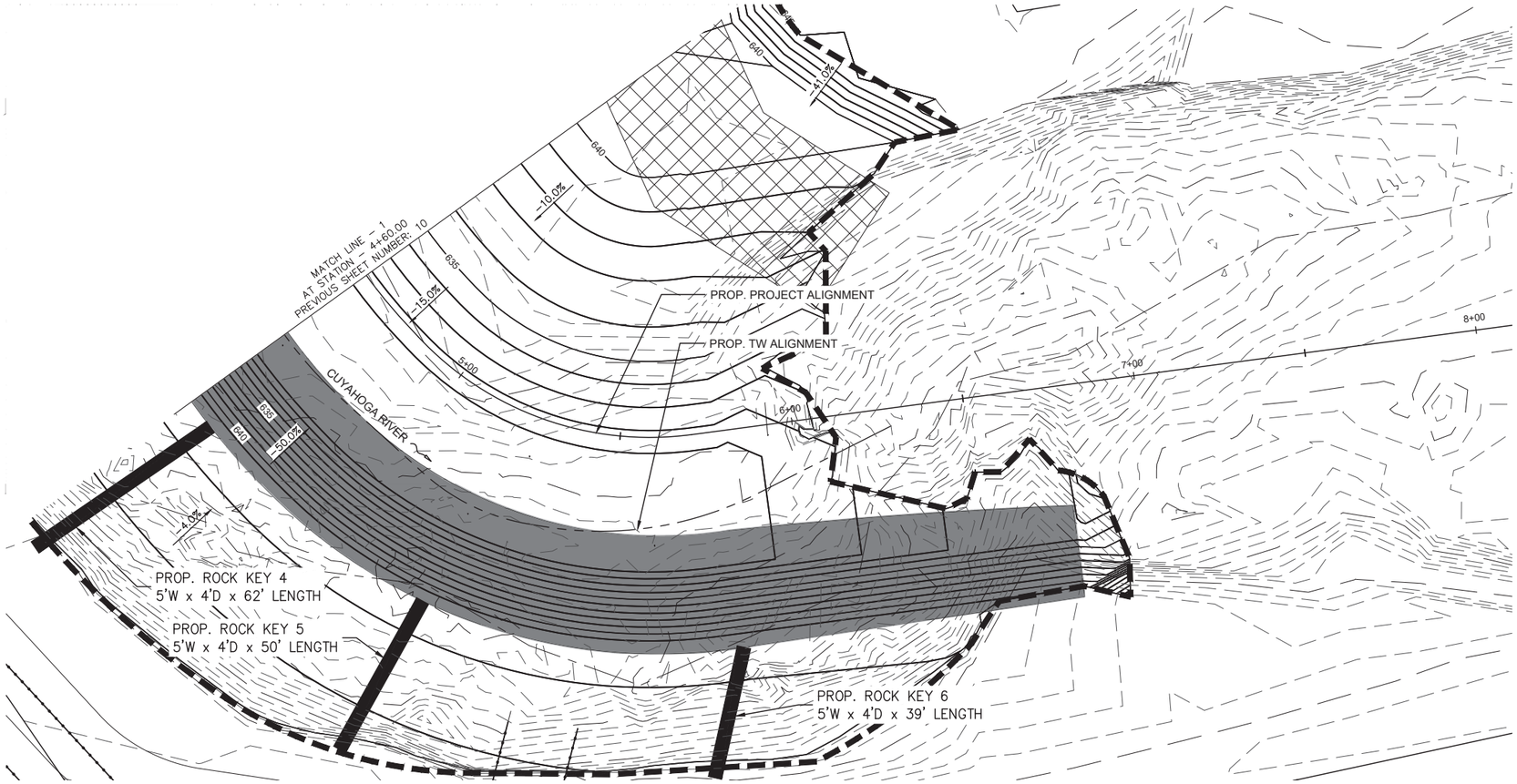

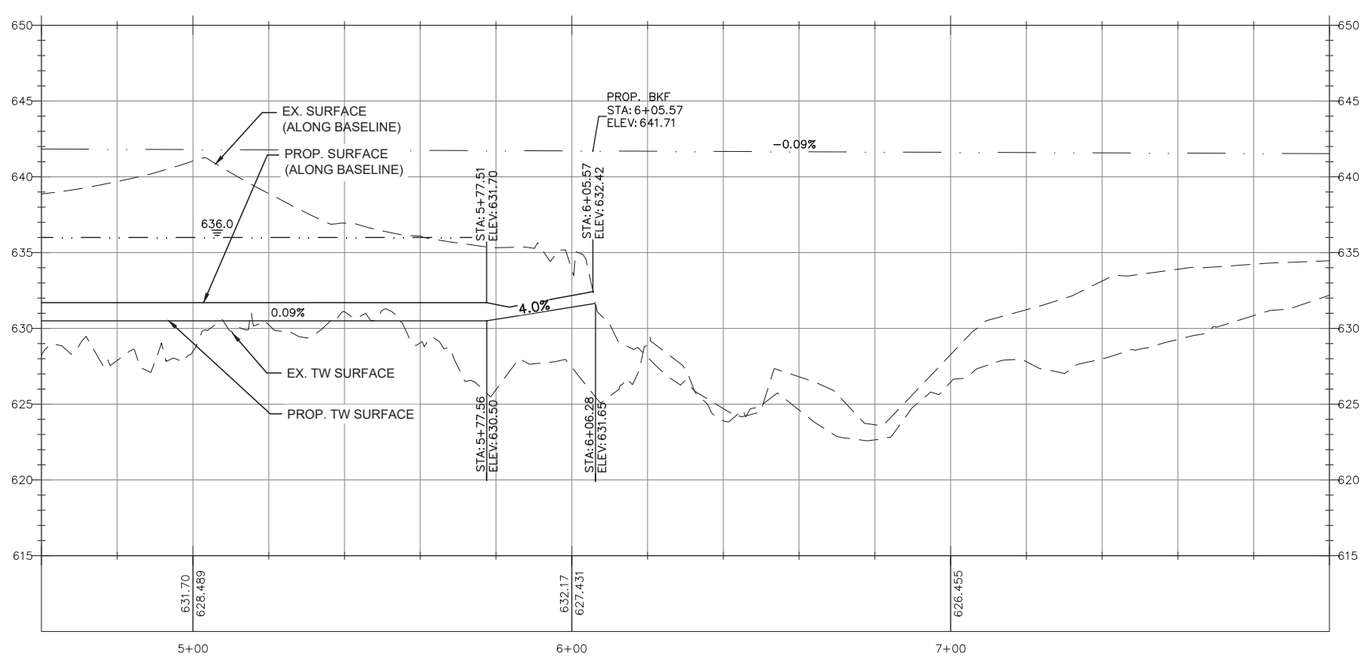

LEGEND

- P/L — PROPERTY LINE
- 685 — EX. CONTOURS
- 685 — PROP. CONTOURS
- PROPOSED ACCESS ROUTE
- PROPOSED GRADING LIMITS
- PROP. ROCK KEY
- PROP. BANK STABILIZATION
- PROPOSED WATER DIVERSION CHANNEL

PROFILE LEGEND

- EX. SURFACE
- PROP. THALWEG
- PROP. BANKFULL
- APPROX. LOW FLOW WATER SURFACE

0 5 10
GRAPHIC SCALE IN FEET
VERTICAL SCALE

0 20 40
GRAPHIC SCALE IN FEET
HORIZONTAL SCALE

DESIGNED: JM	SUB SHEET NO.	TITLE OF DRAWING	DRAWING NO.
DRAWN BY: TG	C8	PROP. PLAN AND PROFILE	644
TECH REVIEW: JB		LOCATION WITHIN PARK: MM20 SOUTH	176923
DATE: August 2023		NAME OF PARK: CUYAHOGA VALLEY NATIONAL PARK	PMIS/PKG NO. 224822
		REGION: MIDWEST · COUNTY: SUMMIT/CUYAHOGA · STATE: OHIO	11 OF 18

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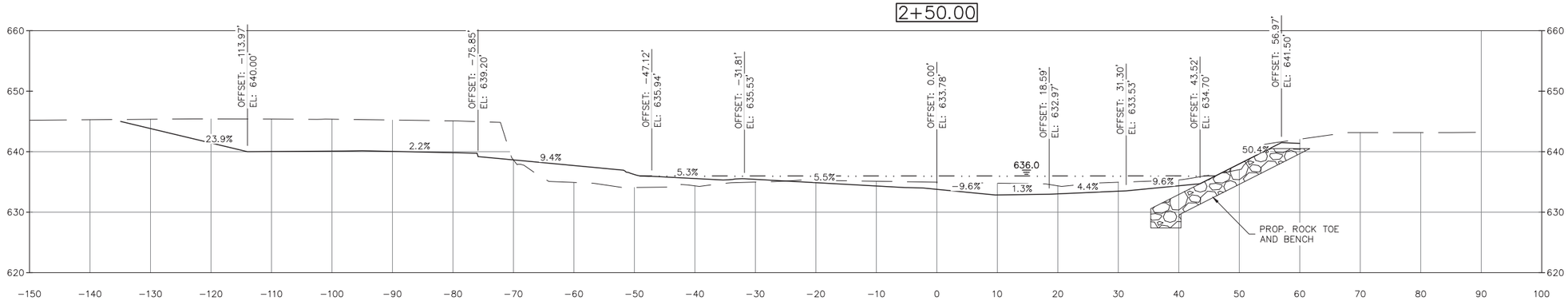

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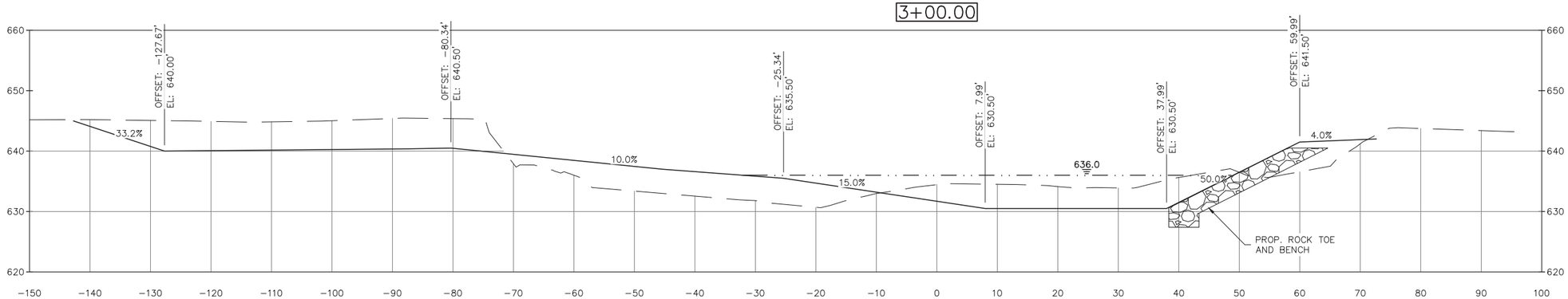

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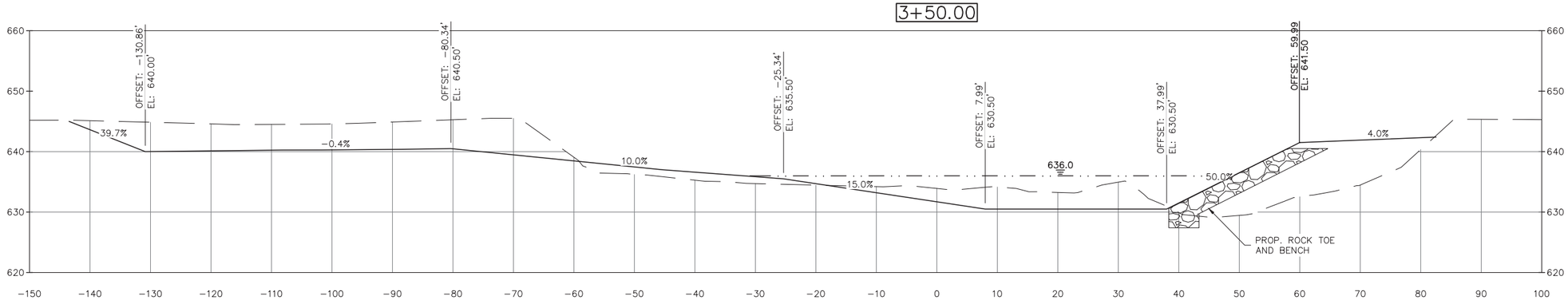

NOTES:

1. ELEVATIONS PROVIDED IN CROSS SECTIONS REPRESENT FINISHED GRADE.
2. FINAL GRADES AND SLOPES WILL BE ADJUSTED IN THE FIELD AS NECESSARY AT THE DIRECTION OF THE ENVIROSCIENCE CONSTRUCTION REPRESENTATIVE. SLOPES WILL BE GRADED TO CREATE A NATURAL APPEARANCE.

LEGEND

- EX GROUND
- PROP. GRADE
- 636.0 APPROX. LOW FLOW WATER SURFACE

0 10 20
GRAPHIC SCALE IN FEET

DESIGNED: JM	SUB SHEET NO.	TITLE OF DRAWING	DRAWING NO.
DRAWN BY: TG	C9	RIVER CROSS SECTIONS	644
TECH REVIEW: JB		LOCATION WITHIN PARK: MM20 SOUTH	176923
DATE: August 2023		NAME OF PARK: CUYAHOGA VALLEY NATIONAL PARK	PMIS/PKG NO. 224822
		REGION: MIDWEST · COUNTY: SUMMIT/CUYAHOGA · STATE: OHIO	12 OF 18

P:\10_PROJECTS\RIVER\REACH4\RIR\16986_CVNP BANK STABILIZATION\RESTORATION DESIGN\MM20 DESIGN 30\SHEETS\MM20_CROSSSECTIONS.DWG - XS-01 - 8/14/2023 3:43:58 PM - JIM MOYER
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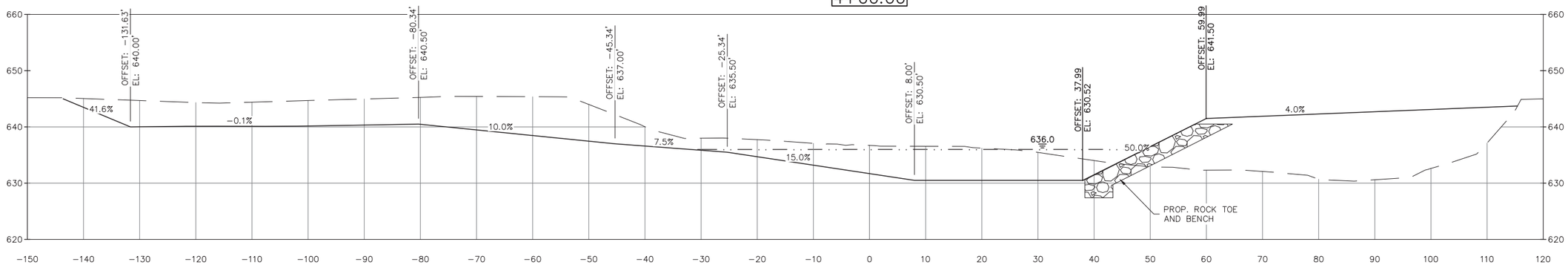

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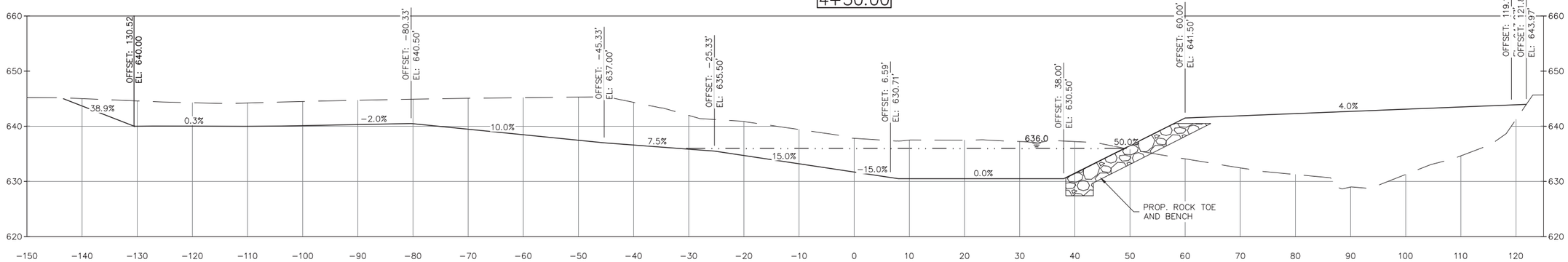

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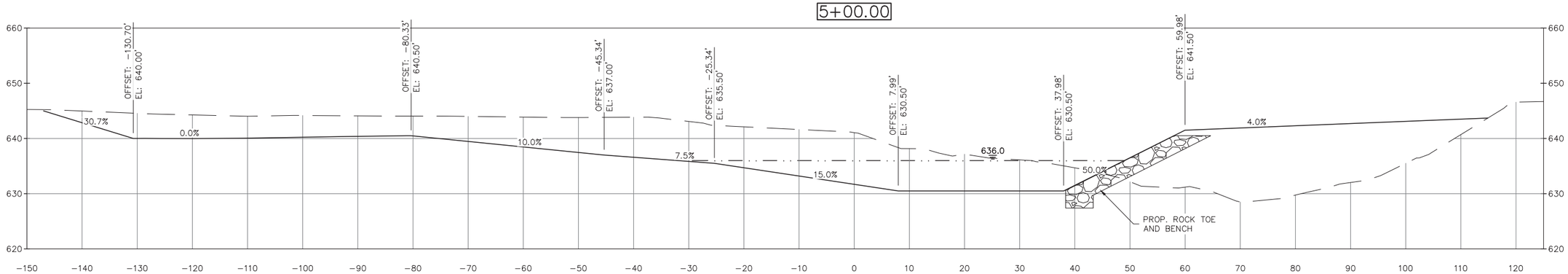

NOTES:

1. ELEVATIONS PROVIDED IN CROSS SECTIONS REPRESENT FINISHED GRADE.
2. FINAL GRADES AND SLOPES WILL BE ADJUSTED IN THE FIELD AS NECESSARY AT THE DIRECTION OF THE ENVIROSCIENCE CONSTRUCTION REPRESENTATIVE. SLOPES WILL BE GRADED TO CREATE A NATURAL APPEARANCE.

LEGEND

- EX GROUND
- PROP. GRADE
- 636.0 APPROX. LOW FLOW WATER SURFACE

0 10 20
GRAPHIC SCALE IN FEET

DESIGNED: JM	SUB SHEET NO.	TITLE OF DRAWING
DRAWN BY: TG	C10	RIVER CROSS SECTIONS
TECH REVIEW: JB		LOCATION WITHIN PARK: MM20 SOUTH
DATE: August 2023		NAME OF PARK: CUYAHOGA VALLEY NATIONAL PARK
		REGION: MIDWEST; COUNTY: SUMMIT/CUYAHOGA; STATE: OHIO

DRAWING NO. 644 / 176923

PMIS/PKG NO. 224822

13 OF 18

P:\10_PROJECTS\RIVER\REACH4\RIV6986_CVNP BANK STABILIZATION\RESTORATION DESIGN\MM20 DESIGN 30\SHEETS\MM20_CROSSSECTIONS.DWG - XS-02 - 8/14/2023 3:43:59 PM - JIM MOYER
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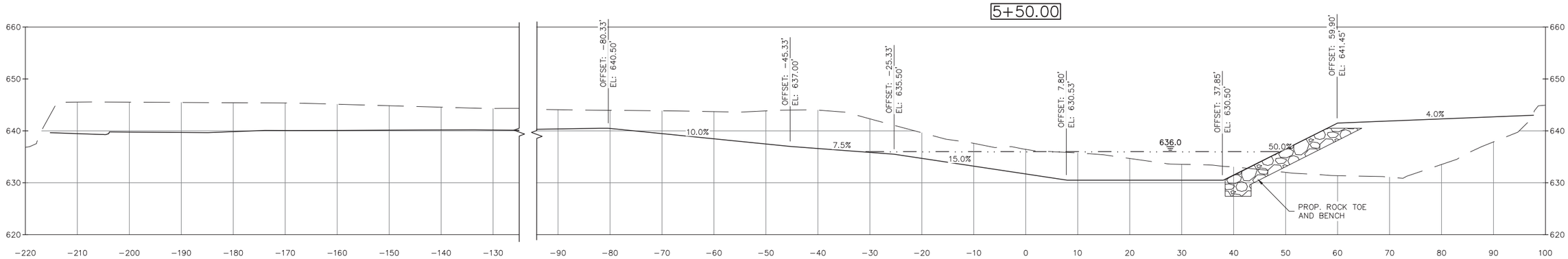

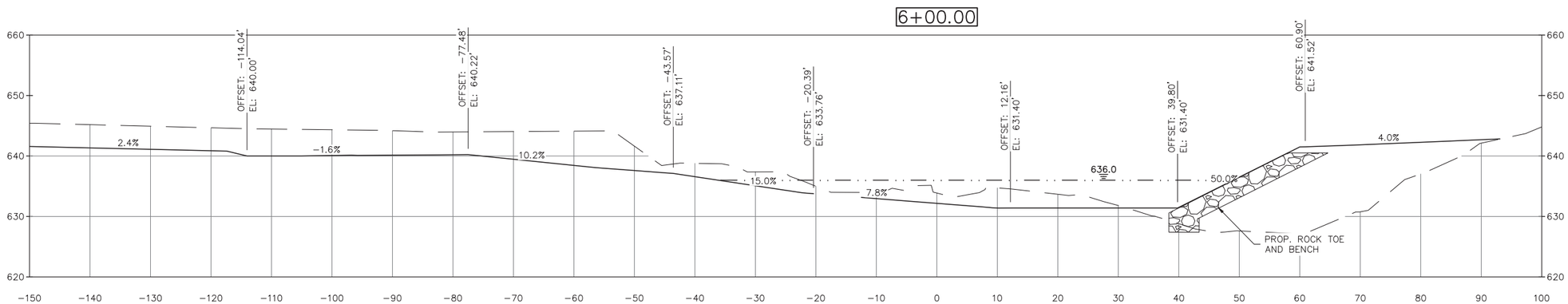

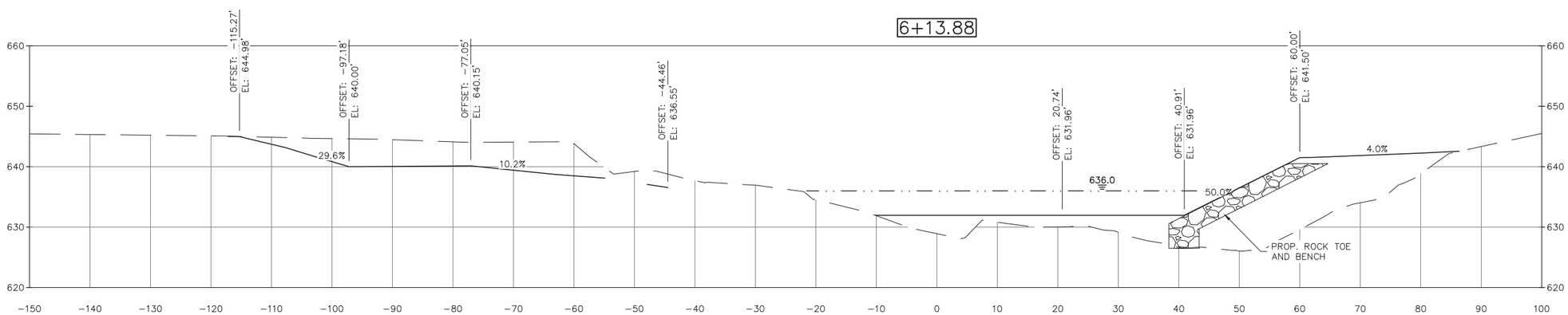

NOTES:

1. ELEVATIONS PROVIDED IN CROSS SECTIONS REPRESENT FINISHED GRADE.
2. FINAL GRADES AND SLOPES WILL BE ADJUSTED IN THE FIELD AS NECESSARY AT THE DIRECTION OF THE ENVIROSCIENCE CONSTRUCTION REPRESENTATIVE. SLOPES WILL BE GRADED TO CREATE A NATURAL APPEARANCE.

LEGEND

- EX GROUND
- PROP. GRADE
- 636.0 APPROX. LOW FLOW WATER SURFACE

0 10 20
GRAPHIC SCALE IN FEET

DESIGNED: JM	SUB SHEET NO.	TITLE OF DRAWING
DRAWN BY: TG	C11	RIVER CROSS SECTIONS
TECH REVIEW: JB		LOCATION WITHIN PARK: MM20 SOUTH
DATE: August 2023		NAME OF PARK: CUYAHOGA VALLEY NATIONAL PARK
		REGION: MIDWEST; COUNTY: SUMMIT/CUYAHOGA; STATE: OHIO

DRAWING NO. 644 / 176923

PMIS/PKG NO. 224822

14 OF 18

P:\10_PROJECTS\RIVER\ERIE&CH-&SR\16986_CVNP BANK STABILIZATION\RESTORATION DESIGN\MM20 DESIGN 30\SHEETS\MM20_CROSSSECTIONS.DWG - XS-03 - 8/14/2023 3:43:58 PM - JIM MOYER
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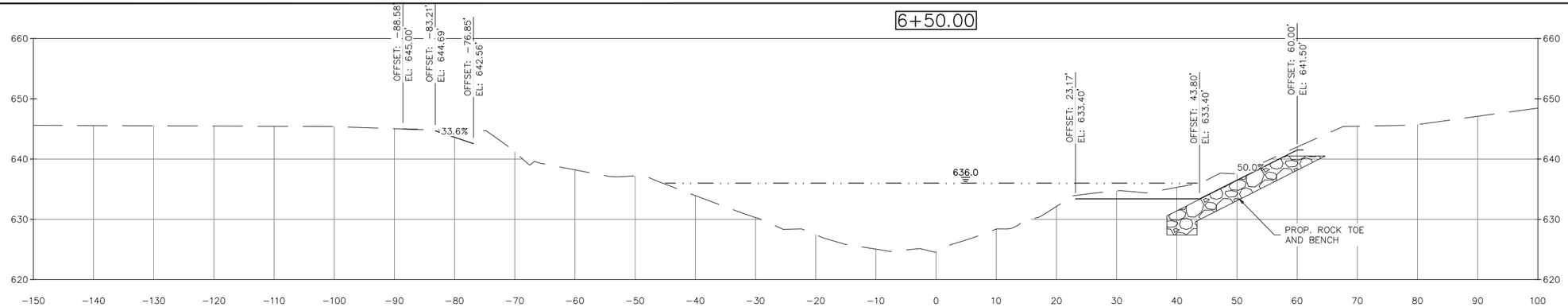

NOTES:

1. ELEVATIONS PROVIDED IN CROSS SECTIONS REPRESENT FINISHED GRADE.
2. FINAL GRADES AND SLOPES WILL BE ADJUSTED IN THE FIELD AS NECESSARY AT THE DIRECTION OF THE ENVIROSCIENCE CONSTRUCTION REPRESENTATIVE. SLOPES WILL BE GRADED TO CREATE A NATURAL APPEARANCE.

LEGEND

- EX GROUND
- PROP. GRADE
- 636.0 — APPROX. LOW FLOW WATER SURFACE

0 10 20
GRAPHIC SCALE IN FEET

DESIGNED: JM	SUB SHEET NO.	TITLE OF DRAWING	DRAWING NO.
DRAWN BY: TG	C12	RIVER CROSS SECTIONS	644
TECH REVIEW: JB		LOCATION WITHIN PARK: MM20 SOUTH	176923
DATE: August 2023		NAME OF PARK: CUYAHOGA VALLEY NATIONAL PARK	PMIS/PKG NO. 224822
		REGION: MIDWEST / COUNTY: SUMMIT/CUYAHOGA / STATE: OHIO	15 OF 18

P:\10_PROJECTS\RIVER\RIVERBEACH430R\16896_CVNP BANK STABILIZATION\RESTORATION DESIGN\MM20 DESIGN 30\SHEETS\MM20_CROSSSECTIONS.DWG - XS-44 - 8/14/2023 3:43:59 PM - JIM MOYER
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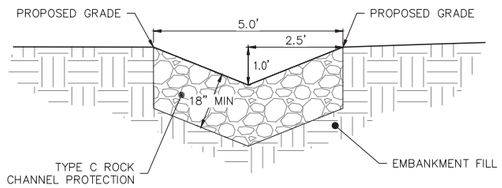
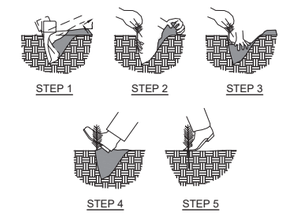


NOTE:
1. ROCK FOR WETLAND OVERFLOW TO EXTEND FROM TOP OF BANK TO ELEVATION 636, TOP OF ROCK CHANNEL PROTECTION.

WETLAND OVERFLOW DETAIL

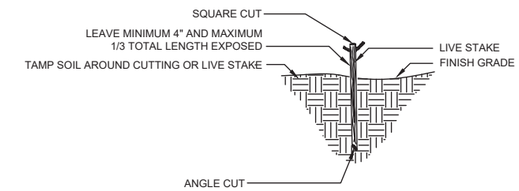
SCALE: NTS



INSTALLATION STEPS

1. DRIVE GRAB HOE INTO THE GROUND, LIFT HANDLE, AND PULL HOE BACK.
2. PLACE SEEDLING AGAINST STRAIGHT SIDE AT CORRECT DEPTH.
3. FILL BORROW OF HOLE AND PACK SOIL AGAINST ROOTS.
4. FINISH FILLING IN SOIL AND PACK IT WITH HEEL.
5. FIRM AROUND SEEDLING WITH THE FOOT.

BARE ROOT SEEDLING INSTALLATION

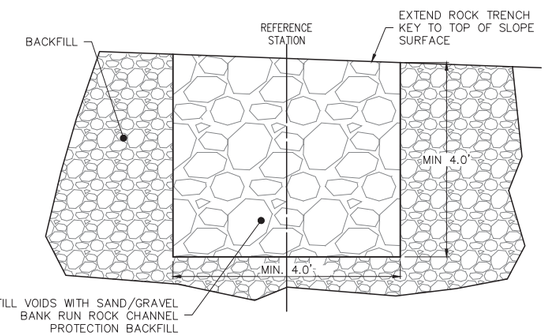


LIVE STAKE CROSS SECTION

INSTALLATION SPECIFICATIONS

1. LIVE STAKES SHALL RANGE FROM 1/2" TO 1" IN DIAMETER AND BE FROM 2 TO 3 FT IN LENGTH
2. CARE SHALL BE TAKEN NOT TO DAMAGE THE LIVE STAKES DURING INSTALLATION.
3. A PILOT HOLE WILL BE REQUIRED TO ENSURE THAT THE LIVE STAKE IS NOT DAMAGED WHEN DRIVEN THROUGH THE SUBSOIL. PILOT HOLE SHALL BE MADE THROUGH THE USE OF A STEEL SPIKE, REBAR, OR SIMILAR TOOL TO WORK AN OPENING THROUGH THE SUBSOIL.
4. LIVE STAKES SHALL BE CUT TO A POINT ON THE BASAL END FOR INSERTION IN THE GROUND.
5. SEE CONTRACT DOCUMENTS FOR SPECIES, SIZE, SPACING, LOCATION, AND FINAL DETERMINATION ON USE OF LIVE STAKES.
6. USE A DEAD BLOW HAMMER TO DRIVE LIVE STAKES INTO THE PILOT HOLE.
7. LEAVE BETWEEN 4" AND 8" OF LIVE STAKE EXPOSED ABOVE FINISH GRADE.
8. TAMP SOIL AROUND LIVE STAKES.

LIVE STAKE PLANTING



NOTE:
1. FILL VOIDS WITH BANK RUN MIX.
2. VOIDS ARE FILLED IN LIFTS.
3. ROCK TRENCH KEY TO EXTEND A MIN. 10.0' INTO THE NATIVE SOIL ALONG THE EXISTING BANK OR AS FIELD DIRECTED.

TYPICAL ROCK TRENCH KEY MIX		NO CONCRETE OR RECYCLED CONCRETE ALLOWED. NATURAL STONE ONLY.
ROCK SIZES: A	40%	
B	50%	
C	10%	
FILL VOIDS WITH SAND/GRAVEL BANK RUN ROCK CHANNEL PROTECTION BACKFILL		

EXCAVATED SEDIMENT BAR MATERIAL MAY BE USED AS BANK RUN

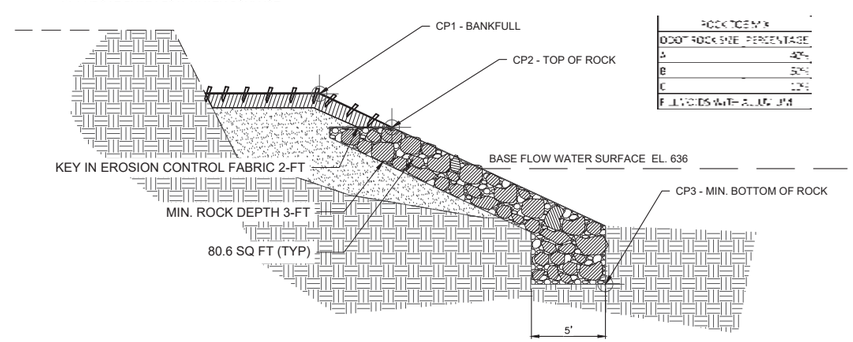
ROCK TRENCH KEY LOCATIONS			
ROCK KEY NO.	SIDE*	B/L CONST. STATION**	LENGTH
1	RT.	2+46	36'
2	RT.	3+33	21'
3	RT.	3+89	58'
4	RT.	4+66	62'
5	RT.	5+18	50'
6	RT.	5+77	39'

SAND/GRAVEL (BANK RUN) ROCK CHANNEL PROTECTION BACKFILL
AGGREGATE FOR THIS MIX SHALL BE A NATURAL MATERIAL COMPOSED OF A MIXTURE OF HARD, DURABLE PARTICLES OR FRAGMENTS OF STONE OR GRAVEL AND SAND, AND SMALL AMOUNTS OF SILT, CLAY OR OTHER SIMILAR BINDING MATERIAL. BANK RUN IS DEFINED AS A NON-CRUSHED SAND/GRAVEL SUBSTRATE MATERIAL AND SHALL BE UNWASHED/UNSORTED RAW MATERIAL. MATERIAL SHALL BE BIASED TOWARD LESS FINES AND MORE COARSE MATERIAL. LIMESTONE SHALL NOT BE USED FOR THIS MIX.

ROCK TRENCH KEY DETAIL

SCALE: NTS

POTENTIAL LIVE STAKE LOCATIONS ON BANK STABILIZATION AREAS*
BETWEEN CP1 AND CP2 (BANKFULL)
1-FT ABOVE BASE FLOW WATER SURFACE



ROCK TOE MIX	
ODOT ROCK SIZE	PERCENTAGE
A	40%
B	50%
C	10%
FILL VOIDS WITH SAND/GRAVEL	

ROCK TOE AND BENCH DETAIL

SCALE: NTS

ROCK TOE STRUCTURE TABLE							
STRUCTURE NUMBER	BANK	BEGIN STA	END STA	TOTAL LENGTH	CP 1	CP 2	CP 3
RT-1	RIGHT	2+87	6+77	527 LF	641.5	640.5	627.42

DESIGNED: JM	SUB SHEET NO.	TITLE OF DRAWING	DRAWING NO.
DRAWN BY: TG	C13	STABILIZATION DETAILS	644 / 176923
TECH REVIEW: JB		LOCATION WITHIN PARK: MM20 SOUTH	PMIS/PKG NO. 224822
DATE: August 2023		NAME OF PARK: CUYAHOGA VALLEY NATIONAL PARK	16 OF 18
		REGION: MIDWEST / COUNTY: SUMMIT/CUYAHOGA / STATE: OHIO	

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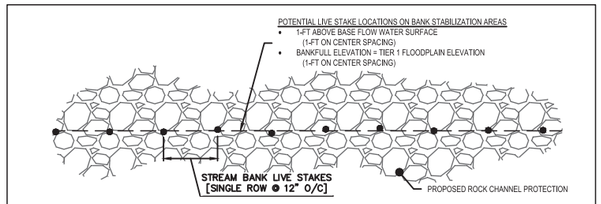
XREFS: LIMITDESHEET EXHRZB.dwg

LANDSCAPE PLANT QUANTITIES AND SCHEDULES

STREAM BANK LIVE STAKES PLANT LIST

Botanical Name	Common Name	Percent	Quantity	Min. Size	Spacing
Cornus amomum	Silky Dogwood	20	158	3–4'	12" o/c, 1 Row
Cornus sericea	Redosier Dogwood	–	–	3–4'	12" o/c, 1 Row
Salix Exigua	Sand Bar Willow	40	315	3–4'	12" o/c, 1 Row
Salix lucida	Shining Willow	–	–	3–4'	12" o/c, 1 Row
Salix nigra	Black Willow	–	–	3–4'	12" o/c, 1 Row
Salix sericea	Silky Willow	40	315	3–4'	12" o/c, 1 Row

FOR PLANTINGS AND SEEDING, SEE SHEET 17,



LIVE STAKE SPACING DETAIL
SCALE: NTS

SEED MIX AREAS

Seed Mix Type	Total AC
Floodplain Mix	0.54
Upland Mix	N/A
Lawn Mix	N/A

FLOODPLAIN – SEED MIX

APPLICATION RATE: 15 LBS/ACRE, 1.7 ACRES

PERCENT	SPECIES	SCIENTIFIC NAME
16.90%	BLUE SPIKE	Agastache foeniculum
10.50%	SWAMP MILKWEED	Asclepias incarnata
10.10%	WILD BERGAMOT	Monarda fistulosa
10.00%	PURPLEHEAD SNEEZEWEED	Helenium flexuosum
8.30%	BLACKEYED SUSAN	Rudbeckia hirta
7.00%	GREY HEADED CONEFLOWER	Ratibida pinnata
6.30%	PLAINS COREOPSIS	Coreopsis tinctoria
5.40%	MARSH BLAZING STAR	Liatris spicata
5.10%	LANCELEAF COREOPSIS	Coreopsis lanceolata
5.10%	PURPLE CONEFLOWER	Echinacea purpurea
5.10%	OXEYE SUNFLOWER	Heliopsis helianthoides
3.00%	GIANT IRONWEED	Vernonia gigantea
2.80%	PRAIRIE BLAZING STAR	Liatris pycnostachya
2.50%	HAIRY BEARDTONGUE	Penstemon hirsutus
1.70%	SPOTTED BEEBALM	Monarda punctata
0.20%	GREAT BLUE LOBELIA	Lobelia siphilitica

LIVESTAKE NOTES

LIVE STAKE PLANTING SHALL BE OF THE SPECIES AS INDICATED IN THE PLANT LIST. LIVE STAKES SHOULD BE HARVESTED OR PURCHASED CLOSE TO INSTALLATION DATE, KEPT MOIST AND OUT OF DIRECT SUNLIGHT. STAKES MUST BE KEPT COVERED AND MOIST DURING STORAGE AND TRANSPORT. THE LOWER ½ OF THE STAKES SHALL BE PRE-SOAKED IN WATER FOR 24 HOURS PRIOR TO INSTALLATION. LIVE STAKES SHALL BE ½ INCH OR LARGER IN DIAMETER, AND THREE TO FOUR FEET IN LENGTH, HAVE SIDE BRANCHES REMOVED AND BARK INTACT.

THE DEPTH OF PLANTING THAT WILL BE ACHIEVED INSTALLING THE LIVE STAKES AFTER CONSTRUCTION ACTIVITIES MAY BE SOMEWHAT VARIABLE AND DICTATED BY WHAT CAN BE ACHIEVED IN THE FIELD BY A HAND EFFORT TO INSTALL THE INDIVIDUAL STAKES. THE EXPECTED DEPTH THAT WILL BE ACHIEVED USING THIS METHOD SHOULD BE BETWEEN 16 TO 24 ON AVERAGE. CONTRACTOR SHALL INSTALL THE LIVE STAKE INTO THE GROUND AND FIRMLY PACK THE SOIL / BANK RUN / SAND AND GRAVEL AROUND THE STAKE. CONTRACTOR SHALL TAMP LIVE STAKES INTO OPENINGS OF THE ROCK DURING OR AFTER PLACEMENT OF THE ROCK. A STEEL ROD OR HYDRAULIC PROBE MAY BE USED TO PREPARE A HOLE THROUGH THE ROCK. ADDITIONALLY, ANY LIVES TAKES BEING INSTALLED FOR WARRANTY PURPOSES WILL BE INSTALLED WITH THE SAME METHOD DESCRIBED. REMOVE AND REPLACE ANY STAKES THAT SPLIT DURING INSTALLATION.

LIVE STAKES WILL BE PLANTED DURING THE APPROPRIATE SEASON IF POSSIBLE, FEBRUARY 15TH THROUGH APRIL 15TH. SEE BANK STABILIZATION DETAIL ON SHEET 16 FOR LIVE STAKE PLANTING ELEVATION. LIVE STAKES SHALL BE ORIENTED PERPENDICULAR TO THE SLOPE WITH GROWING TIPS PROTRUDING SLIGHTLY FROM THE FINISHED FACE OF THE ROCK, INSTALLED AT AN ANGLE SLIGHTLY DOWNSTREAM AND SHALL BE PLACED PER PLAN.

LIVE STAKE SOURCE
ERNST CONSERVATION SEEDS
8884 MERCER PIKE
MEADVILLE, PA 16335
800-873-3321

FOLLOWING A WARRANTY INSPECTION PERFORMED BY THE OWNER, REMOVE AND REPLACE UP TO 80% OF WARRANTED LIVE STAKES FOUND TO BE DEAD OR IN UNHEALTHY CONDITION DURING WARRANTY PERIOD. MAKE LIVE STAKE REPLACEMENTS DURING DORMANT SEASON OF WARRANTY PERIOD. ANY LIVE STAKES REQUIRING REPLACEMENT WITHIN THE ORIGINAL WARRANTY PERIOD SHALL BE WARRANTED FOR AN EXTENDED PERIOD OF ONE ADDITIONAL YEAR BEYOND THE ORIGINAL WARRANTY. A SECOND WARRANTY INSPECTION SHALL BE CONDUCTED AT THE END OF THE EXTENDED WARRANTY PERIOD. REMOVE AND REPLACED WARRANTED LIVE STAKES FOUND TO BE DEAD OR UNHEALTHY CONDITION DURING THE EXTENDED WARRANTY PERIOD.

LANDSCAPE NOTES

GENERAL:

1. CONTRACTOR SHALL GET APPROVAL FROM ECOLOGIST (ENVIROSCIENCE) OR LANDSCAPE ARCHITECT (GPD GROUP) FOR ANY PLANT VARIATIONS FROM ALL PLANT LISTS AND SEED MIXES.
2. TOPSOIL FOR PLANTING OPERATIONS SHALL BE FURNISHED BY THE CONTRACTOR, AND APPROVED BY ECOLOGIST OR LANDSCAPE ARCHITECT.
3. THE DEPTH OF PLANTING AREAS IS THE DEPTH BELOW THE FINISHED GRADE. NO PLANT MATERIAL SUBSTITUTIONS WILL BE ACCEPTED UNLESS APPROVED BY OTHERS.
4. PLANT MATERIAL LOCATIONS MAY BE SUBJECT TO CHANGE AS DIRECTED BY LANDSCAPE ARCHITECT OR ECOLOGIST.
5. PLANT SIZING: MEASURE TREES AND SHRUBS ACCORDING TO ANSI Z60.1 STANDARDS.
6. ALL PLANTS SHALL BE DELIVERED ON TRUCKS WITH THE ENTIRE LOAD COMPLETELY COVERED WITH TARPS MANUFACTURED FOR PLANT PROTECTION. THE FOLLOWING IS A LIST OF REASONS FOR PLANT REJECTION: WIND BURNED PLANS, WOUNDS ON TREE TRUNKS, IMPROPER LOADING, UNLOADING, OR HANDLING PRIOR TO, DURING, OR SUBSEQUENT TO SHIPPING, RESULTING IN DROPPED OR DAMAGED ROOT BALLS, CONTAINERIZED MATERIAL BEING THROWN, KICKED, TOSSED, HANDLED BY THE PLANT AND NOT BY THE CONTAINER ITSELF, IMPROPER WATERING IN THE HOLDING YARD RESULTING IN LEAF DROP NOT GREATER THAN 10 PERCENT OF THE TOTAL PLANT FOLIAGE. THIS IS NOT INTENDED AS A COMPREHENSIVE LIST TO THE EXCLUSION OTHER DAMAGE CAUSED BY IGNORING COMMON HORTICULTURE PRACTICE.
7. PLANTS SHALL NOT REMAIN IN A STORAGE AREA FOR A PERIOD LONGER THAN 4 WEEKS FROM THE TIME OF DELIVERY.
8. DO NOT HANDLE, MOVE, BIND, TIE OR OTHERWISE TREAT PLANTS SO AS TO DAMAGE THE ROOT BALL, ROOTS, TRUNK, OR BRANCHES IN ANY WAY.
9. WHILE PLANTS ARE IN THE STORAGE AREA, ALL TREES AND SHRUBS WILL BE HEELED IN WITH BARK MULCH IMMEDIATELY UPON DELIVERY AND WATERED IN AT A RATE OF 1 INCH PER WEEK, OR ADEQUATE TO MAINTAIN ALL PLANTS IN A HEALTHY, THRIVING CONDITION. ALL BARE ROOT TREES AND SHRUBS WILL BE KEPT IN COLD STORAGE WITH MOIST STRAW COVERING THE ROOT SYSTEMS, UNTIL THEY ARE PLANTED. ALL CONTAINERIZED MATERIAL WILL BE KEPT MOIST, NOT ALLOWING THE SOIL TO DRY OUT RESULTING IN STRESSED PLANTS.

SEEDING AND MULCHING NOTES

SEEDING PERIOD

SEEDING SHALL BE INSTALLED WITHIN 48 HOURS OF COMPLETION OF GRADING OPERATIONS. ALL SEEDING SHALL BE DONE "IN THE DRY." SEEDING SHALL NOT NOT TAKE PLACE WHEN THE GROUND OR OVERLYING WATER IS FROZEN OR WHEN CONDITIONS ARE OTHERWISE UNSATISFACTORY FOR PLANTING. INUNDATED AREAS SHALL NOT BE SEEDED. NATIVE SEED SHALL BE SOWN BETWEEN MARCH 1 AND JUNE 15, OR SEPT. 1 TO NOV. 30.

SEEDING APPLICATION

THE NATIVE SEED MIX SHALL BE APPLIED IN CONFORMANCE WITH THE FOLLOWING: SEED SHALL BE APPLIED AT 15LBS/ACRE AND THE SEED SHALL BE BROADCAST IN AN EVEN COVERAGE BY HAND. THE SEED SHALL THEN BE PRESSED INTO GOOD CONTACT WITH THE SOIL. SCARIFY THE SOIL TO AVOID PLACING THE SEEDS DEEPER THAN ¼ INCH. FOR SMALL AREAS, HAND RAKING IS ACCEPTABLE.

MULCH SHALL BE APPLIED TO ALL SEEDED AREAS. MULCH SHALL BE AS PER ODOT CMS SECTION 659.06 AND SHALL BE APPLIED IN ACCORDANCE WITH ODOT CMS SECTION 659.09.

NATIVE SEED SOURCES

OHIO PRAIRIE NURSERY	CARDNO NATIVE PLANT NURSERY	ERNST SEED
P.O. BOX 174	128 SUNSET DRIVE	8884 MERCER PIKE
HIRAM, OH 44234	WALKERTON, INDIANA 46574	MEADVILLE, PA 16335
866-569-380	574-586-2412	800-873-3321

ALL PERMANENT SEEDED AREAS SHALL HAVE A ONE YEAR WARRANTY PERIOD. SURVIVABILITY AFTER ONE YEAR IS 95% COVERAGE WITH NO MORE THAN A 4 FOOT BARE AREA. CORRECT DEFECTIVE WORK WITHIN A ONE-YEAR PERIOD AFTER DATE OF SUBSTANTIAL COMPLETION, WITHIN THE SEEDING SCHEDULE OUTLINED IN THESE CONTRACT DRAWINGS.

DESIGNED: JM	SUB SHEET NO.	TITLE OF DRAWING	DRAWING NO.
DRAWN BY: TG	L1	LANDSCAPE NOTES & DETAILS	644
TECH REVIEW: JB		LOCATION WITHIN PARK: MM120 SOUTH	176923
DATE: August 2023		NAME OF PARK: CUYAHOGA VALLEY NATIONAL PARK	PMIS/PKG NO. 224822
		REGION: MIDWEST / COUNTY: SUMMIT/CUYAHOGA / STATE: OHIO	17 OF 18

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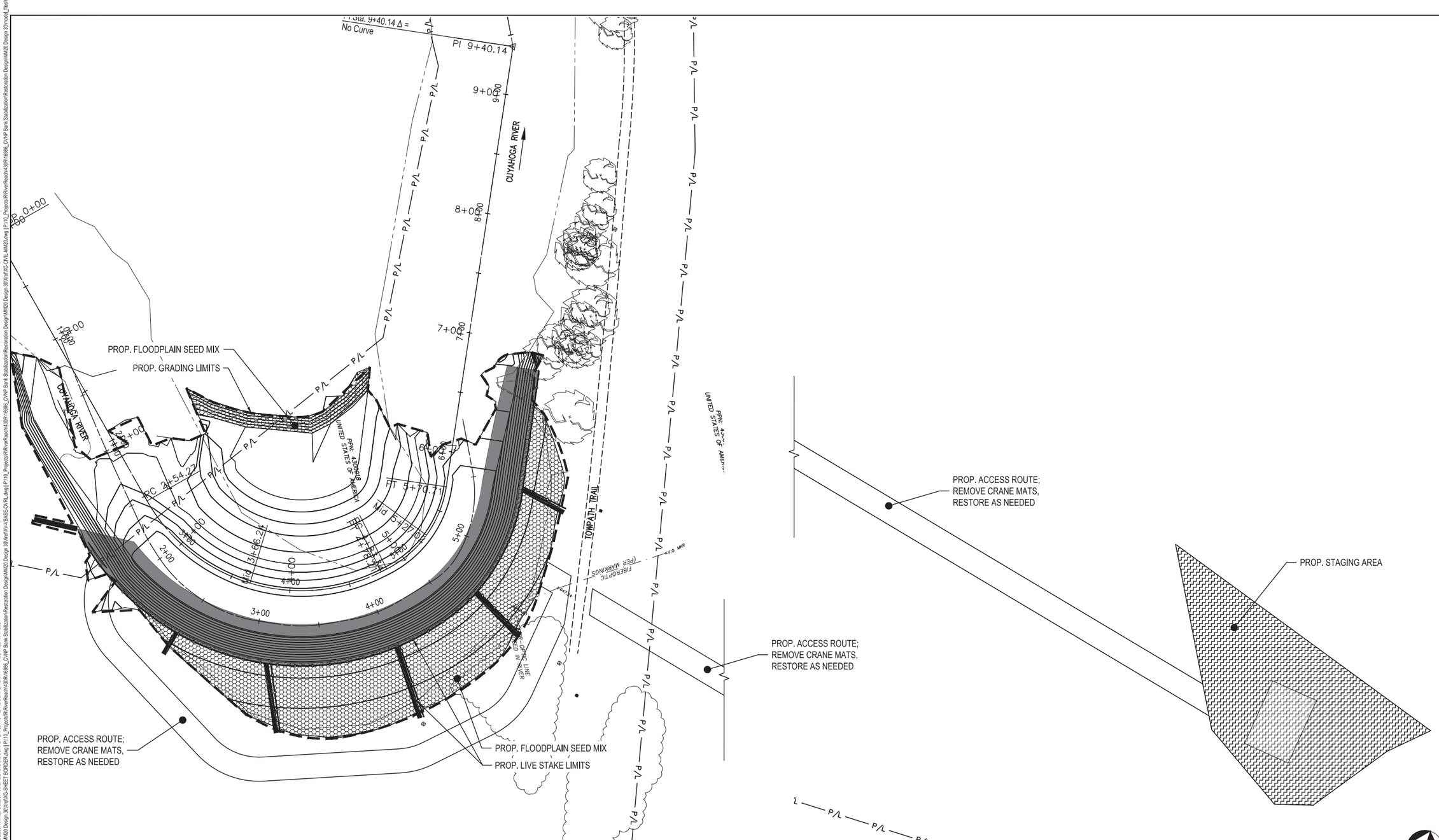

FOR GENERAL LEGEND, SEE SHEET 2
FOR SEED QUANTITIES, SEE SHEET 17
FOR LIVE STAKE TYPE AND QUANTITIES, SEE SHEET 17
FOR LIVE STAKE SPACING DETAIL, SEE SHEET 17

LEGEND

- P/L — PROPERTY LINE
- PROPOSED GRADING LIMITS
- PROPOSED STAGING AREA
- PROPOSED FLOODPLAIN SEED LIMITS 0.54 AC
- PROPOSED UPLAND SEED LIMITS
- PROPOSED LIVE STAKE LIMITS 791 LF
- EXISTING TREES

DESIGNED: JM	SUB SHEET NO.	TITLE OF DRAWING	DRAWING NO.
DRAWN BY: TG	L2	LANDSCAPE PLAN	644
TECH REVIEW: JB		LOCATION WITHIN PARK: MM20 SOUTH	176923
DATE: August 2023		NAME OF PARK: CUYAHOGA VALLEY NATIONAL PARK	PMIS/PKG NO. 224822
		REGION: MIDWEST; COUNTY: SUMMIT/CUYAHOGA; STATE: OHIO	18 OF 18

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APPENDIX III

GEOTECHNICAL ENGINEERING REPORT

GPD GROUP
Glaus, Pyle, Schomer, Burns & DeHaven, Inc.

GEOTECHNICAL ENGINEERING REPORT

CUYAHOGA VALLEY NATIONAL PARK
MILE MARKER 20 SOUTH - RIVERBANK STABILIZATION

INDEPENDENCE, OHIO

Prepared For:

RiverReach Construction

&

The National Park Service

GPD Project No. 2022281.00 Rev.0
August 09, 2023

STATE OF OHIO
Delbert James Channels
E-57295
REGISTERED
PROFESSIONAL ENGINEER

08/14/2023

520 South Main Street, Suite 2531 | Akron, OH 44311 | 330.572.2100 | **gpdgroup.com**

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APPENDIX I 10

Boring Location Plans and Cross-Sections

Supplemental Boring Logs (GPD)

Original Boring Logs (SME)

Soil Laboratory Analysis (SME)

Slope Stability Results

SECTION 1

1.0 Introduction

We are pleased to submit this Geotechnical Report for the aforementioned project. The purpose of this study was to obtain supplemental information on the subsurface conditions at the proposed project site and, based on this information, to provide geotechnical recommendations regarding the design and construction of embankment improvements. A total of three (3) dynamic cone penetrometers tests were conducted to supplement data previously obtained by others across the MM20 project site. Individual boring logs and Boring Location Plans are provided in Appendix I.

1.1 Project Description

The site for the proposed embankment improvements is located along the Cuyahoga River and Erie Canal Towpath Trail. This project will address the Mile Marker 20 South (MM20) site located approximately 1.25-miles north of the I-271 bridge spanning the Cuyahoga River in Brecksville, Ohio. This site is part of a larger initiative to protect valuable assets within the Cuyahoga Valley National Park at risk for failure due to bank erosion caused by frequent flooding and high-water events. Consultants hired through the National Park Service (NPS) conducted analyses and developed bioengineered Schematic Design (SD) solutions for a total of eight sites located along the Cuyahoga Valley Scenic Railroad (CVSR), which runs primarily along the left (west) bank of the Cuyahoga River, and along the Ohio & Erie Canal and Towpath Trail, which runs along the right (east) bank.

RiverReach and their Design-Build (D-B) Team were contracted to re-evaluate each site for necessary repairs, reconstruction, and stabilization requirements in relation to information provided from the previous studies. Documents included the SD Basis of Design Reports, SD Plans, hydraulic modeling files, and geotechnical data reports. Based on this document review and on-site observations, the eight sites were given priority ranking for implementation and construction. A full report of the initial evaluation can be found in the SD Evaluation report dated October 2022. Phase I included design and implementation of bank stabilization measures at MP-64.1, scheduled to start construction in May 2023. The "Four-Sites" project is Phase II and includes four of the seven remaining sites, based on proximity and scope of work. Phase III includes the Mile Marker 20 South site.

This supplemental investigation was conducted to aid in the re-evaluation of each project site for necessary repairs, reconstruction, and stabilization requirements in relation to information provided from the previous study. Previous study/documents included the SD Basis of Design Reports, SD Plans, hydraulic modeling files, and a geotechnical data reports. Three (3) proposed alternatives were put forward as part as the initial design study. It is our understanding the selected remediation option will align with "Alternative A: Hybrid Riprap/Live Staking" as outlined in HDR's Basis of Design Report, Section 4.3.2.1.

1.2 Purpose and Scope

The purposes of this report were to investigate subsurface conditions along the project length and to provide supplemental geotechnical engineering recommendations for earthwork and embankment improvements. Specifically, the scope of work included the following:

- Conducting a supplemental field exploration program consisting of site reconnaissance and drilling sample borings at selected locations along the project length to explore subsurface conditions and collect soil samples.
- Conduct slope stability analysis of existing conditions and evaluate alternate embankment stabilization options.
- Develop geotechnical engineering recommendations for the selected embankment stabilization and earthwork for site grading.

SECTION 2

2.0 Site Conditions

In general, the proposed embankment improvements are all located approximately 1.25-miles north of the I-271 bridge spanning the Cuyahoga River in Brecksville, Ohio. The towpath project lengths are located east of the Cuyahoga River and generally consist of a relatively flat northernly-to southernly walking trail surface ranging from about EL 648 to EL 650 (south-to-north). The site slopes westerly toward the Cuyahoga river with embankment toe elevations ranging from about EL 628 to EL 630. Shallow surficial soil sloughing was observed along the embankment near and directly above the waterline.

2.1 Subsurface Exploration Programs

2.1.1 Historical Subsurface Information

As part of this study, GPD reviewed previous subsurface information prepared by HDR, dated August 18, 2021. Information contained within the HDR report included three (3) borings performed at the top of slope at Mile Marker 20 South site. In addition, the boring logs (prepared by HDR) included description of the encountered soils, split-spoon samples, in-situ moisture contents, unconfined compression strengths, Atterberg Limit results, and grain size distributions.

2.1.2 Supplemental Subsurface Program

An additional three (3) Dynamic cone penetration tests were performed by GPD field crews utilizing a hand operated Wildcat Dynamic cone device. Dynamic cone testing operates by advancing a cone having a 10 square centimeter projected end area into the subsoils using a controlled dynamic energy produced by the drop of a 35 pound hammer through a height of 15 inches. The data was recorded as the number of blows required to advance the cone through each succeeding 10 centimeters of penetration.

The field cone penetration data was reduced by computation software, with the results as shown on the attached Wildcat Dynamic Cone Logs. Soil samples are not obtained during dynamic cone penetration testing. Thus, identification of soil type was not possible at this location. The logs show the relative density of the soil being penetrated for each 10-centimeter increment, if the soil being penetrated were sand or silt; and the stiffness of the soil being penetrated if it was clay. The value shown on the log as N' for each test interval is the approximate equivalent standard penetration blow count for the soil being tested, i.e., the equivalent blows per foot required to advance a standard split spoon sampler into that soil using a 140-pound hammer, freely falling from a height of 30 inches. This correlation between the two types of testing becomes inaccurate under high penetration resistance conditions, thus, the equivalent blow count is not given where such conditions exist.

Field logs of each boring were prepared by the drill crew. These logs included visual classifications of the materials encountered during drilling as well as the driller's interpretation of the subsurface conditions between samples. Final boring logs included with this report represent an interpretation of the field logs and include modifications based on observations made by a Geotechnical Engineer and the results of laboratory testing.

2.2 Subsurface Conditions

2.2.1 Historic Subsurface Conditions by Others

MM20 – *"The MM 20 site is approximately 700 feet long and located south of the Red Lock Trailhead off of W. Highland Road. The Towpath is comprised of a gravel/aggregate surface. Most of the riverbank is covered in trees, brush, or low-growing vegetation, giving way to open fields at the southwestern portion of the site, where the river bends away from the Towpath. Riprap had been placed at a couple of locations at the center of the site, near the end of the bend, where prior slope instability was visible on previous aerial photos of the site. At the time of our site reconnaissance, the top of the bank was encroaching to within about 5 feet of the Towpath, where erosion and a previous slope failure had occurred. The riverbank encroachment on the Towpath appeared to be due to erosion at the toe of the slope leading to progressive failure of the slope. Aerial photos from April 2006 through September 2019 are included in Appendix B showing the area of prior slope failure and repair."*

2.2.2 Supplemental Subsurface Conditions

As previously discussed, GPD conducted a series of three (3) Dynamic Cone Penetrometer (DCP) tests to supplement soil data at areas along the embankment that were inaccessible to conventional drilling equipment. In general, DCP's conducted along the lower sections of slope consisted of very loose to medium dense soils to the respective termination depth.

2.2.3 Groundwater Conditions

GPD utilized reported groundwater measurements provided in the Geotechnical information provided in HDR's Basis of Design Report. As reported by HDR, groundwater was encountered in the three (3) borings performed along the top of slope during drilling at 10 to 14 feet below grade (EL 635.7 to EL 639.0) and after completion from 10.5 to 16 feet (EL 629.7 to EL 639.0). It should be recognized that fluctuations of the groundwater table may occur due to seasonal variations in the amount of rainfall, runoff, River WSEL, and other factors not evident at the time the borings were performed. Therefore, groundwater levels during construction or at other times in the life of the embankment may be higher or lower than the levels indicated on the boring logs. The possibility of groundwater level fluctuations should be considered when developing the design and construction plans for the project.

2.3 Slope Stability Analysis

The existing and proposed slope conditions along each project length were analyzed using a numerical application of the slice method called Discontinuity Layout Optimization (DLO) within the modeling software. This is achieved by creating multidirectional soil geometry slices (free-body diagrams) from a nodal network. The interslice forces are analyzed to find the path of least energy, which indicates a failure mechanism for each set of slices selected from the network within the models. Rotational failure is determined using a combination of rotation and translational analyses based on moment forces exerted on each slice. These discrete moment forces on each slice were combined in the model to create logarithmic spiral analyses.

The parameters for the modeling included soil strata, effective cohesion, effective internal friction angle, slope profile, and soil weights based on field data collection. The slope profile was derived from available topographic survey data. Available geotechnical data from Others, in conjunction with the three (3) supplement soil test locations performed by GPD, were used to establish estimated soil strength parameters for the stability models. The results of the analysis were compared against collected field data, expected failure mechanisms, failure geometry, and minimum criteria established by GPD.

Slope failures were categorized into type, severity, and location. Failure was defined as wedge, rotational, sloughing, or a combination based on the movement pattern of soil material along the failure plan. Severity was defined as either minor (depth less than 3-feet), moderate (depth greater than 3-feet and less than 8-feet), or deep-seated (depth greater than 8-feet). Location was defined as top, middle, or bottom of slope.

Based on these variables, "direct impact to adjacent structures" was defined as a failure surface within a 10-foot lateral distance from the adjacent structures (i.e. trail pathway). Minimum Adequacy Factors for the MM20 toe path site of 1.3 was targeted for long-term global stability along with a 1.1 for a short-term rapid drawdown condition. Adequacy Factors below the minimum recommended levels are highlighted in the proposed condition results summarized in Section 2.3.2.

2.3.1 Slope Stability Results - Existing Conditions

As part of this effort, GPD reviewed the existing condition slope stability models performed by Others. Existing Condition models were performed by HDR and summarized in their Basis of Design Report dated, October 08, 2021. Based on the reported results, GPD understands the Factor of Safeties for analyzed cross-sections at MM20 site were below 1.3.

2.3.2 Slope Stability Results – Proposed Conditions

The proposed remedial design will include installation of a keyed rock toe along the outer bend of the new meander. The existing bank and pool will be filled with alluvial material and capped with topsoil, bioengineered soil fill with native plantings along the bankfull elevation will create a transition from the rock toe to the bankfull bench. The depth of the rock toe key is governed by the potential scour depth determined by hydraulic modeling of the proposed conditions.

The proposed model took into account remedial solutions consisting of rock bank armoring and toe key. Model results achieved an acceptable Adequacy Factor for long- and short-term global stability at all three cross-sectional locations. Based on the results, the proposed condition exceeds minimum Adequacy Factor requirements as summarized in Table 1. That said, scour related events should be analyzed to define the type and size of rock required to preclude loss of soil/rock mass along the slope face.

Table 1. MM20 - Slope Stability Summary Table – Proposed Conditions

Station ID	Modeled Adequacy Factor		Failure Type of Governing Scenario[1]
	Proposed LT Condition	Rapid Drawdown Condition	
640+50	1.548	1.535[1]	Minor Wedge Failure
641+05	1.652	1.639[1]	Moderate Rotational Failure
642+57	1.752	1.748[1]	Moderate Rotational Failure

Rotation Failure	Occurs by the rotation on the slip surface, usually by the outward and inward movement of soil, and the shape of the slip surface is curved. Rotational failure may occur in three cases, including face failure, toe failure and base failure.
Translational Failure	Occurs in an infinite slope (e.g. slope which has no boundaries) in which the movement of the soil is along the level surface. This failure type occurs mostly in the layered material.
Compound Failure	The combination of translation and rotational. In this condition, the failure surface is curved at two ends, and plain at the middle portion is called compound failure, and generally, this occurs when the hard stratum is below the toe at considerable depth.
Wedge Failure	Also referred to as block failure or plane slope failure, and it occurs along an infinite plane. It mostly happens when the wedges and distinct blocks of the soil mass become separated. It is also common when there is a soil layer that has the weak bearing capacity, joints, or fissures and the slope has two different materials.
Soil Sloughing	A relatively shallow phenomenon involving the uppermost layers of soil.
TOS	Top of Slope
BOS	Bottom of Slope
Minor	Failure Depth less than 3-ft
Moderate	Failure Depth less than 8-ft
Deep-Seated	Failure Depth greater than 8-ft

SECTION 3

3.0 Engineering Recommendations

The following engineering recommendations are based on the proposed embankment improvements identified by the design-build team, the field and laboratory testing performed on the soil/rock encountered at this site, and other information discussed in this report. This report does not reflect variations that may occur between borings, across the site, or due to the modifying effects of weather. The nature and extent of such variations may not become evident until during or after construction. If variations appear, GPD should be immediately notified so that further evaluation and supplemental recommendations can be provided.

3.1 Site Preparation

All vegetation, topsoil, tree roots, organic-containing soils, and any soft or otherwise unsuitable materials should be removed from the site. Based on our borings, we estimate stripping depths of about 6 to 12 inches would be typical. These stripping depths would not remove all dark colored soil but would remove the material containing the highest organic content. We recommend the actual removal depths required be determined by a representative of GPD during construction.

Subsequent to the removal of trees, vegetation/brush and root systems, the prepared surface should be evaluated by the Geotechnical Engineer of Record or personnel under their direct supervision. At this time, the prepared surface may be evaluated using dynamic cone penetrometers, hand probing or by observation of loading under construction equipment where applicable.

It should be noted that the encountered fine-grained soils are inherently moisture sensitive and highly susceptible to disturbance from construction activity, particularly if the soil has a high natural moisture content and/or is wetted by surface water or seepage. It is therefore recommended that construction activities be deferred to the drier seasons and/or during lower flow river stage. Given the silty and clayey nature of the soils at this site, it is anticipated that portions of the natural soils and existing fill will likely pump and rut under the weight of heavy construction equipment, especially rubber-tired equipment. Therefore, heavy equipment traffic directly on fine-grained soil surfaces should be avoided to the extent possible. A bridging lift of No. 1 or No. 2 size stone may be required prior to initial fill placement and compaction operations due to the loose/soft consistency of native fine-grained soils.

3.2 Fill Material

Soil embankment fill used along the riverbank should be select material, as approved by a qualified geotechnical engineer. Compaction equipment and techniques will be dependent on the type of material being used as fill. It is anticipated that rock fill used for the fill access road, fill slope and rock toe key will be placed in thin lifts with excavating equipment and/or track-mounted haul vehicles. Compaction may be accomplished using excavator bucket or repeated passage of tracked machinery and should be evaluated by the onsite Geotechnical Engineer to verify the stone is firm and non-yielding. A bridging lift of stone may be required prior to initial fill placement and compaction operations due to the loose/soft consistency of native soils.

The uppermost portion of embankment fill and embankment infill will consist of either imported well-graded gravel or otherwise suitable/approved on-site borrow material from the opposite bank. It is anticipated this material will consist of sandy or gravelly material placed in thin lifts with excavating equipment and compacted using excavator bucket based on the site constraints and slope geometry. It is recommended that the on-site engineer field verify the placement operations to establish suitable lift thickness and compaction effort during the initial operations phases. This criteria will be based on the lift thickness and compaction effort required to achieve an 70% relative density per ASTM D-4254 or 95% of the Proctor maximum density per ASTM D-698. Once confirmed, the on-site inspector should visually observe the subsequent fill placement and compaction operations follow the established pattern.

It is our understanding that the embankment will not be benched, besides establishing the access roadway, due to potential archaeological impacts. Our analysis therefore does not assume native soils will be benched prior to receiving fill stone and soil. In the event benching is acceptable, GPD recommends the vertical cut of any bench should not exceed about 3 feet. We recommend that excavations be sloped per the requirements of OSHA regulations. Based on the borings performed at this site, we recommend that the excavations within the upper stratum be designed using an OSHA Type "C" soil classification.

In the event the proposed borrow material consist of fine-grained soils, the material will likely require chemical modifications such as lime kiln dust or Portland cement before reuse as structural fill. Any fine-grained clay and/or silty material should be compacted to 95% of the Proctor maximum density per ASTM D-698 to preclude excess bank settlement.

3.3 Dewatering Recommendations

We do not expect shallow groundwater seepage to be encountered during earthwork operations. However, in the event groundwater or groundwater seeps are encountered, the contractor should implement proper BMP's in a manner that does not cause erosion and does not result in heavily silt-laden water flowing into any body of water or other areas that could be negatively impacted. The Contractor shall modify and update the erosion and sediment control plan if necessary during construction in accordance with Federal, State and local codes.

3.4 Excavations

The contractor is solely responsible for designing and constructing stable, temporary excavations and should shore, slope, or bench the sides of the excavations as required to maintain stability of both the excavation sides and bottom. The contractor's "responsible person" as defined in "CFR Part 1926," should evaluate the soil exposed in the excavations as part of the contractor's safety procedures. In no case should slope height, slope inclination, or excavation depth, including utility trench excavation depth, exceed those specified in local, state, and federal safety regulations.

Any excavations left open and exposed to the elements for a significant length of time, desiccation of the clays may create minute shrinkage cracks which could allow large pieces of clay to collapse or slide into the excavation. Materials removed from the excavation should not be stockpiled immediately adjacent to the excavation, as this load may cause a sudden collapse of the embankment.

We are providing this information solely as a service to our client. GPD is not assuming responsibility for construction site safety or the contractor's activities; No warranties, either express or implied, are intended or made. Site safety, excavation support, and dewatering requirements are the responsibility of others.

3.5 Cut and Fill Slopes

Soil slopes should be properly treated for protection from rain, and surface runoff should be diverted away from the slopes. For erosion protection, a rock armoring, mattings, and/or vegetative seeding should be established on permanent soil slopes as soon as possible.

3.6 General Comments

The analysis and recommendations presented in this report are based upon the data obtained from the borings performed at the indicated locations and from other information discussed in this report. This report does not reflect variations that may occur between borings, across the site, or due to the modifying effects of weather. The nature and extent of such variations may not become evident until during or after construction. If variations appear, GPD should be immediately notified so that further evaluation and supplemental recommendations can be provided.

The scope of services for this project does not include either specifically or by implication any environmental assessment of the site or identification of contaminated or hazardous materials or conditions. If the owner is concerned about the potential for such contamination, other studies should be undertaken.

This report has been prepared for the exclusive use of **RiverReach Construction and The National Park Service** for specific application to the project discussed and has been prepared in accordance with generally accepted geotechnical engineering practices. No warranties, either express or implied, are intended or made. Site safety, excavation support, and dewatering requirements are the responsibility of others. In the event that changes in the nature, design, or location of the project as outlined in this report are planned, the conclusions and recommendations contained in this report shall not be considered valid unless GPD reviews the changes and either verifies or modifies the conclusions of this report in writing.

APPENDIX I

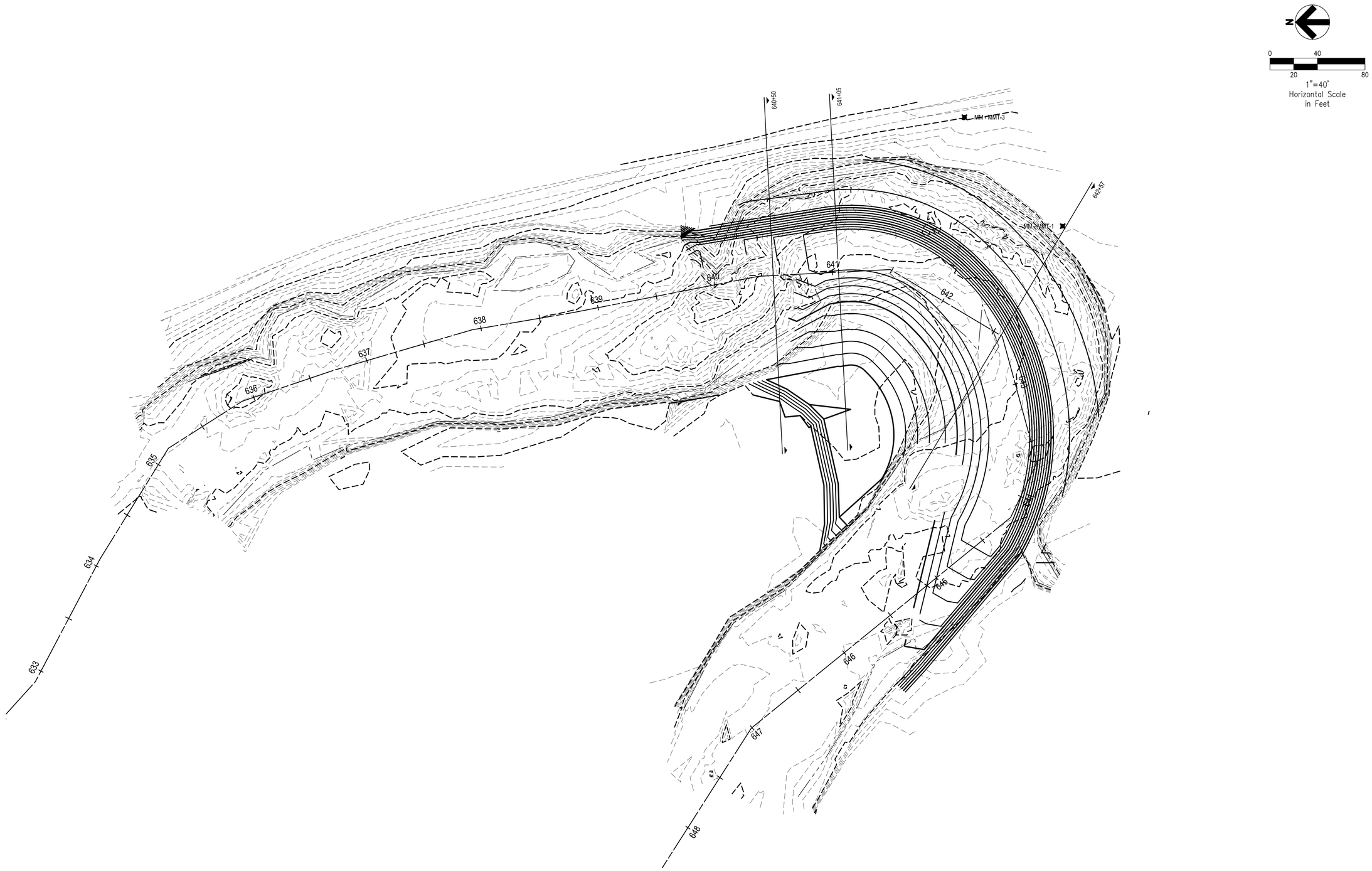
Boring Location Plans and Cross-Sections

Supplemental Boring Logs (GPD)

Original Boring Logs (SME)

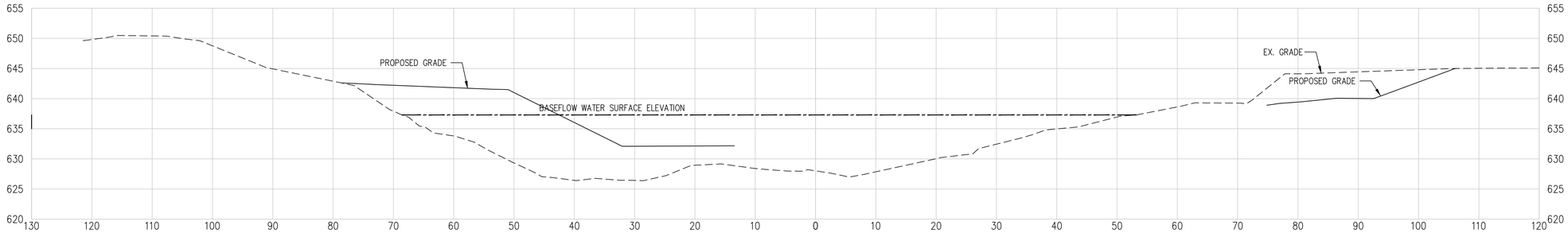
Soil Laboratory Analysis (SME)

Slope Stability Results – Proposed Conditions

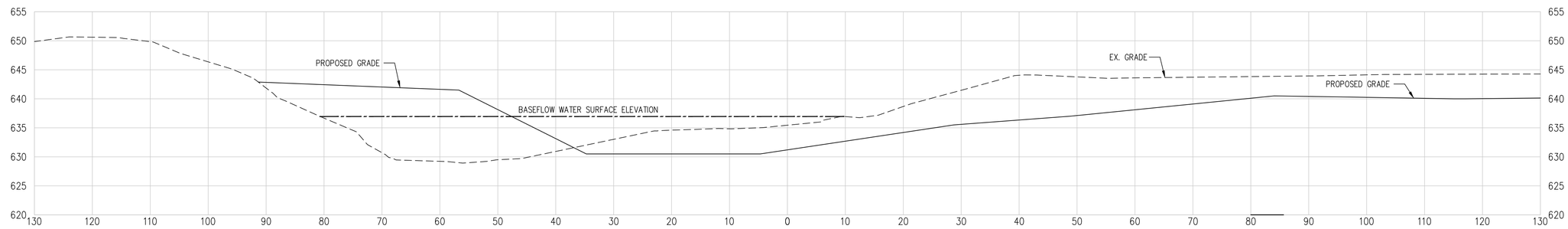


GEOTECH PLAN VIEW

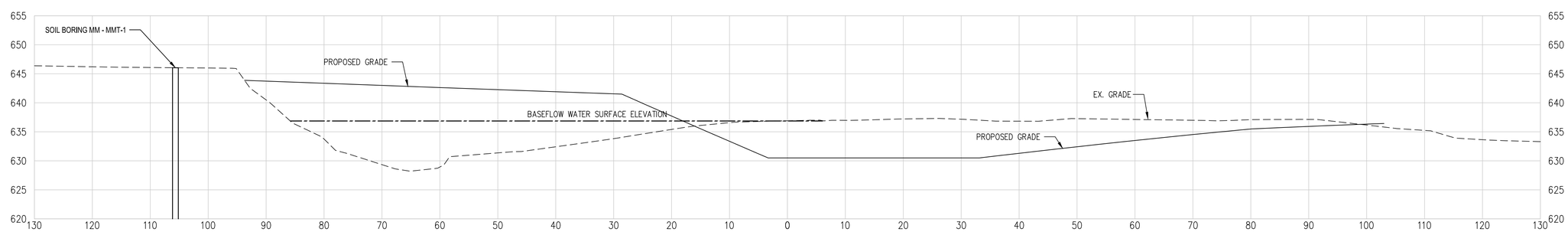
MM 20



CUYAHOGA RIVER MM 20 (SL-1) STA. 640+50



CUYAHOGA RIVER MM 20 (SL-2) STA. 641+05



CUYAHOGA RIVER MM 20 (SL-3) STA. 642+57

GEOTECHNICAL SECTIONS

MM 20

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Akron, Ohio 44311
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LOG NUMBER: MMT-B-1

DATE: 12/8/2022

WILDCAT DYNAMIC CONE LOG

PROJECT: Cuyahoga Valley National Park Bank Stabilization
PROJECT NUMBER: 2022281.00
LOCATION: Cuyahoga Valley National Park
GROUND ELEVATION: N/A
WEATHER: Overcast, 40°F
CREW: A. Sproat, S. Yoder, S. Wiley
REMARKS: The test began at existing grade and continued to the termination depth.

DEPTH FT	DEPTH M	BLOWS PER 10 CM	RESISTANCE KG/CM^2	CONE RESISTANCE 0 50 100 150	N'	TESTED DENSITY/CONSISTENCY NON-COHESIVE	COHESIVE
	0.1	2	8.9	**	2	VERY LOOSE	SOFT
	0.2	2	8.9	**	2	VERY LOOSE	SOFT
1	0.3	5	22.2	****	6	LOOSE	MEDIUM STIFF
	0.4	4	17.8	****	5	LOOSE	MEDIUM STIFF
	0.5	2	8.9	**	2	VERY LOOSE	SOFT
2	0.6	2	8.9	**	2	VERY LOOSE	SOFT
	0.7	2	8.9	**	2	VERY LOOSE	SOFT
	0.8	4	17.8	****	5	LOOSE	MEDIUM STIFF
3	0.9	5	22.2	****	6	LOOSE	MEDIUM STIFF
	1.0	5	22.2	****	6	LOOSE	MEDIUM STIFF
	1.1	4	15.4	***	4	LOOSE	MEDIUM STIFF
4	1.2	6	23.2	*****	6	LOOSE	MEDIUM STIFF
	1.3	7	27.0	*****	7	LOOSE	MEDIUM STIFF
	1.4	7	27.0	*****	7	LOOSE	MEDIUM STIFF
5	1.5	11	42.5	********	12	MEDIUM DENSE	STIFF
	1.6	20	77.2	**********	22	MEDIUM DENSE	VERY STIFF
	1.7	30	115.8	**********	-	DENSE	HARD
6	1.8	17	65.6	**********	18	MEDIUM DENSE	VERY STIFF
	1.9	18	69.5	**********	19	MEDIUM DENSE	VERY STIFF
	2.0	19	73.3	**********	20	MEDIUM DENSE	VERY STIFF
7	2.1	15	51.3	**********	14	MEDIUM DENSE	STIFF
	2.2	20	68.4	**********	19	MEDIUM DENSE	VERY STIFF
	2.3	12	41.0	********	11	MEDIUM DENSE	STIFF
8	2.4	11	37.6	********	10	MEDIUM DENSE	STIFF
	2.5	13	44.5	*********	12	MEDIUM DENSE	STIFF
	2.6	13	44.5	*********	12	MEDIUM DENSE	STIFF
9	2.7	9	30.8	******	8	LOOSE	STIFF
	2.8	7	23.9	*****	6	LOOSE	MEDIUM STIFF
	2.9	9	30.8	******	8	LOOSE	STIFF
10	3.0	9	30.8	******	8	LOOSE	STIFF
	3.1	5	15.3	***	4	LOOSE	MEDIUM STIFF
	3.2	4	12.2	**	3	VERY LOOSE	SOFT
	3.3	6	18.4	****	5	LOOSE	MEDIUM STIFF
11	3.4	6	18.4	****	5	LOOSE	MEDIUM STIFF
	3.5	6	18.4	****	5	LOOSE	MEDIUM STIFF
	3.6	4	12.2	**	3	VERY LOOSE	SOFT
12	3.7	6	18.4	****	5	LOOSE	MEDIUM STIFF
	3.8	8	24.5	*****	6	LOOSE	MEDIUM STIFF
	3.9	3	9.2	**	2	VERY LOOSE	SOFT
13	4.0	4	12.2	**	3	VERY LOOSE	SOFT
	4.1	3	8.3	**	2	VERY LOOSE	SOFT
	4.2	2	5.5	*	1	VERY LOOSE	VERY SOFT
14	4.3	3	8.3	**	2	VERY LOOSE	SOFT
	4.4	6	16.6	***	4	LOOSE	MEDIUM STIFF
	4.5	8	22.2	****	6	LOOSE	MEDIUM STIFF
15	4.6	5	13.9	***	3	VERY LOOSE	SOFT
	4.7	3	8.3	**	2	VERY LOOSE	SOFT
	4.8	3	8.3	**	2	VERY LOOSE	SOFT
16	4.9	3	8.3	**	2	VERY LOOSE	SOFT
	5.0	3	8.3	**	2	VERY LOOSE	SOFT
	5.1	4	10.2	**	2	VERY LOOSE	SOFT
17	5.2	5	12.7	***	3	VERY LOOSE	SOFT
	5.3	10	25.4	*****	7	LOOSE	MEDIUM STIFF
	5.4	8	20.3	****	5	LOOSE	MEDIUM STIFF
18	5.5	7	17.8	****	5	LOOSE	MEDIUM STIFF

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DATE: 12/8/2022

PROJECT: Cuyahoga Valley National Park Bank Stabilization

PROJECT NUMBER: 2022281.00

DEPTH FT	DEPTH M	BLOWS PER 10 CM	RESISTANCE KG/CM^2	CONE RESISTANCE 0 50 100 150	N'	TESTED DENSITY/CONSISTENCY NON-COHESIVE	TESTED DENSITY/CONSISTENCY COHESIVE
	5.6	4	9.3	**	2	VERY LOOSE	SOFT
	5.7	4	9.3	**	2	VERY LOOSE	SOFT
19	5.8	4	9.3	**	2	VERY LOOSE	SOFT
	5.9	4	8.6	**	2	VERY LOOSE	SOFT
	6.0	4	8.6	**	2	VERY LOOSE	SOFT
20	6.1	4	8.6	**	2	VERY LOOSE	SOFT
	6.2	5	10.8	**	3	VERY LOOSE	SOFT
	6.3	8	17.3	***	4	LOOSE	MEDIUM STIFF
21	6.4	5	10.8	**	3	VERY LOOSE	SOFT
	6.5	7	15.1	***	4	LOOSE	MEDIUM STIFF
	6.6	8	17.3	***	4	LOOSE	MEDIUM STIFF
22	6.7	10	21.6	****	6	LOOSE	MEDIUM STIFF
	6.8	13	28.1	******	8	LOOSE	STIFF
	6.9	16	32.2	******	9	LOOSE	STIFF
23	7.0	17	34.2	*******	9	LOOSE	STIFF
	7.1						
	7.2						
24	7.3						
	7.4						
	7.5						
25	7.6						
	7.7						
	7.8						
26	7.9						
	8.0						
	8.1						
27	8.2						
	8.3						
	8.4						
28	8.5						
	8.6						
	8.7						
29	8.8						
	8.9						
	9.0						
30	9.1						
	9.2						
	9.3						
31	9.4						
	9.5						
	9.6						
	9.7						
32	9.8						
	9.9						
	10.0						
33	10.1						
	10.2						
	10.3						
34	10.4						
	10.5						
	10.6						
35	10.7						
	10.8						
	10.9						
36	11.0						
	11.1						
	11.2						
37	11.3						
	11.4						
	11.5						
38	11.6						
	11.7						
	11.8						
39	11.9						

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Phone: 330.572.2100
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LOG NUMBER: MMT-WC-1

DATE: 12/8/2022

WILDCAT DYNAMIC CONE LOG

PROJECT: Cuyahoga Valley National Park Bank Stabilization
PROJECT NUMBER: 2022281.00
LOCATION: Cuyahoga Valley National Park
GROUND ELEVATION: N/A
WEATHER: Overcast, 40°F
CREW: A. Sproat, S. Yoder, S. Wiley
REMARKS: The test began at existing grade and continued to the termination depth.

DEPTH FT	DEPTH M	BLOWS PER 10 CM	RESISTANCE KG/CM^2	CONE RESISTANCE 0 50 100 150	N'	TESTED DENSITY/CONSISTENCY NON-COHESIVE	COHESIVE
	0.1	1	4.4	*	1	VERY LOOSE	VERY SOFT
	0.2	1	4.4	*	1	VERY LOOSE	VERY SOFT
1	0.3	1	4.4	*	1	VERY LOOSE	VERY SOFT
	0.4	2	8.9	**	2	VERY LOOSE	SOFT
	0.5	1	4.4	*	1	VERY LOOSE	VERY SOFT
2	0.6	2	8.9	**	2	VERY LOOSE	SOFT
	0.7	2	8.9	**	2	VERY LOOSE	SOFT
	0.8	2	8.9	**	2	VERY LOOSE	SOFT
3	0.9	5	22.2	****	6	LOOSE	MEDIUM STIFF
	1.0	5	22.2	****	6	LOOSE	MEDIUM STIFF
	1.1	8	30.9	******	8	LOOSE	STIFF
4	1.2	6	23.2	*****	6	LOOSE	MEDIUM STIFF
	1.3	3	11.6	**	3	VERY LOOSE	SOFT
	1.4	3	11.6	**	3	VERY LOOSE	SOFT
5	1.5	3	11.6	**	3	VERY LOOSE	SOFT
	1.6	2	7.7	**	2	VERY LOOSE	SOFT
	1.7	2	7.7	**	2	VERY LOOSE	SOFT
6	1.8	2	7.7	**	2	VERY LOOSE	SOFT
	1.9	2	7.7	**	2	VERY LOOSE	SOFT
	2.0	6	23.2	*****	6	LOOSE	MEDIUM STIFF
7	2.1	4	13.7	***	3	VERY LOOSE	SOFT
	2.2	5	17.1	***	4	LOOSE	MEDIUM STIFF
	2.3	2	6.8	*	1	VERY LOOSE	VERY SOFT
8	2.4	5	17.1	***	4	LOOSE	MEDIUM STIFF
	2.5	5	17.1	***	4	LOOSE	MEDIUM STIFF
	2.6	7	23.9	*****	6	LOOSE	MEDIUM STIFF
9	2.7	6	20.5	****	5	LOOSE	MEDIUM STIFF
	2.8	5	17.1	***	4	LOOSE	MEDIUM STIFF
	2.9	3	10.3	**	2	VERY LOOSE	SOFT
10	3.0	4	13.7	***	3	VERY LOOSE	SOFT
	3.1	3	9.2	**	2	VERY LOOSE	SOFT
	3.2	1	3.1	*	0	VERY LOOSE	VERY SOFT
	3.3	1	3.1	*	0	VERY LOOSE	VERY SOFT
11	3.4	2	6.1	*	1	VERY LOOSE	VERY SOFT
	3.5	4	12.2	**	3	VERY LOOSE	SOFT
	3.6	4	12.2	**	3	VERY LOOSE	SOFT
12	3.7	13	39.8	********	11	MEDIUM DENSE	STIFF
	3.8	21	64.3	**********	18	MEDIUM DENSE	VERY STIFF
	3.9	17	52.0	**********	14	MEDIUM DENSE	STIFF
13	4.0	11	33.7	*******	9	LOOSE	STIFF
	4.1	7	19.4	****	5	LOOSE	MEDIUM STIFF
	4.2	7	19.4	****	5	LOOSE	MEDIUM STIFF
14	4.3	9	24.9	*****	7	LOOSE	MEDIUM STIFF
	4.4	4	11.1	**	3	VERY LOOSE	SOFT
	4.5	3	8.3	**	2	VERY LOOSE	SOFT
15	4.6	4	11.1	**	3	VERY LOOSE	SOFT
	4.7	6	16.6	***	4	LOOSE	MEDIUM STIFF
	4.8	7	19.4	****	5	LOOSE	MEDIUM STIFF
16	4.9	7	19.4	****	5	LOOSE	MEDIUM STIFF
	5.0	9	24.9	*****	7	LOOSE	MEDIUM STIFF
	5.1	18	45.7	*********	13	MEDIUM DENSE	STIFF
17	5.2	19	48.3	**********	13	MEDIUM DENSE	STIFF
	5.3	31	78.7	**********	22	MEDIUM DENSE	VERY STIFF
	5.4	12	30.5	******	8	LOOSE	STIFF
18	5.5	15	38.1	********	10	MEDIUM DENSE	STIFF

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PROJECT: Cuyahoga Valley National Park Bank Stabilization

PROJECT NUMBER: 2022281.00

DEPTH FT	DEPTH M	BLOWS PER 10 CM	RESISTANCE KG/CM^2	CONE RESISTANCE 0 50 100 150	N'	TESTED DENSITY/CONSISTENCY NON-COHESIVE	COHESIVE
	5.6	16	37.3	*******	10	MEDIUM DENSE	STIFF
	5.7	21	48.9	**********	13	MEDIUM DENSE	STIFF
19	5.8	24	55.9	**********	15	MEDIUM DENSE	VERY STIFF
	5.9	20	43.2	*********	12	MEDIUM DENSE	STIFF
	6.0						
20	6.1						
	6.2						
	6.3						
21	6.4						
	6.5						
	6.6						
22	6.7						
	6.8						
	6.9						
23	7.0						
	7.1						
	7.2						
24	7.3						
	7.4						
	7.5						
25	7.6						
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	7.8						
26	7.9						
	8.0						
	8.1						
27	8.2						
	8.3						
	8.4						
28	8.5						
	8.6						
	8.7						
29	8.8						
	8.9						
	9.0						
30	9.1						
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32	9.8						
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	10.0						
33	10.1						
	10.2						
	10.3						
34	10.4						
	10.5						
	10.6						
35	10.7						
	10.8						
	10.9						
36	11.0						
	11.1						
	11.2						
37	11.3						
	11.4						
	11.5						
38	11.6						
	11.7						
	11.8						
39	11.9						

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LOG NUMBER: MMT-WC-2

DATE: 12/8/2022

WILDCAT DYNAMIC CONE LOG

PROJECT: Cuyahoga Valley National Park Bank Stabilization
PROJECT NUMBER: 2022281.00
LOCATION: Cuyahoga Valley National Park
GROUND ELEVATION: N/A
WEATHER: Overcast, 40°F
CREW: A. Sproat, S. Yoder, S. Wiley
REMARKS: The test began at existing grade and continued to the termination depth.

DEPTH FT	DEPTH M	BLOWS PER 10 CM	RESISTANCE KG/CM^2	CONE RESISTANCE 0 50 100 150	N'	TESTED DENSITY/CONSISTENCY NON-COHESIVE	TESTED DENSITY/CONSISTENCY COHESIVE
	0.1	0	0.0		0	VERY LOOSE	VERY SOFT
	0.2	1	4.4	*	1	VERY LOOSE	VERY SOFT
1	0.3	2	8.9	**	2	VERY LOOSE	SOFT
	0.4	1	4.4	*	1	VERY LOOSE	VERY SOFT
	0.5	2	8.9	**	2	VERY LOOSE	SOFT
2	0.6	5	22.2	****	6	LOOSE	MEDIUM STIFF
	0.7	6	26.6	*****	7	LOOSE	MEDIUM STIFF
	0.8	13	57.7	**********	16	MEDIUM DENSE	VERY STIFF
3	0.9	13	57.7	**********	16	MEDIUM DENSE	VERY STIFF
	1.0	29	128.8	**********	-	DENSE	HARD
	1.1	17	65.6	**********	18	MEDIUM DENSE	VERY STIFF
4	1.2	21	81.1	**********	23	MEDIUM DENSE	VERY STIFF
	1.3	18	69.5	**********	19	MEDIUM DENSE	VERY STIFF
	1.4	16	61.8	**********	17	MEDIUM DENSE	VERY STIFF
5	1.5	12	46.3	*********	13	MEDIUM DENSE	STIFF
	1.6	15	57.9	**********	16	MEDIUM DENSE	VERY STIFF
	1.7	7	27.0	*****	7	LOOSE	MEDIUM STIFF
6	1.8	6	23.2	*****	6	LOOSE	MEDIUM STIFF
	1.9	7	27.0	*****	7	LOOSE	MEDIUM STIFF
	2.0	20	77.2	**********	22	MEDIUM DENSE	VERY STIFF
7	2.1	24	82.1	**********	23	MEDIUM DENSE	VERY STIFF
	2.2	30	102.6	**********	-	MEDIUM DENSE	VERY STIFF
	2.3	37	126.5	**********	-	DENSE	HARD
8	2.4						
	2.5						
	2.6						
9	2.7						
	2.8						
	2.9						
10	3.0						
	3.1						
	3.2						
	3.3						
11	3.4						
	3.5						
	3.6						
12	3.7						
	3.8						
	3.9						
13	4.0						
	4.1						
	4.2						
14	4.3						
	4.4						
	4.5						
15	4.6						
	4.7						
	4.8						
16	4.9						
	5.0						
	5.1						
17	5.2						
	5.3						
	5.4						
18	5.5						

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BORING MMT-1

BORING DEPTH: 45 FEET

PROJECT NAME: NPS Cuyahoga Valley Stream Bank Stabilizations **PROJECT NUMBER:** 086138.00

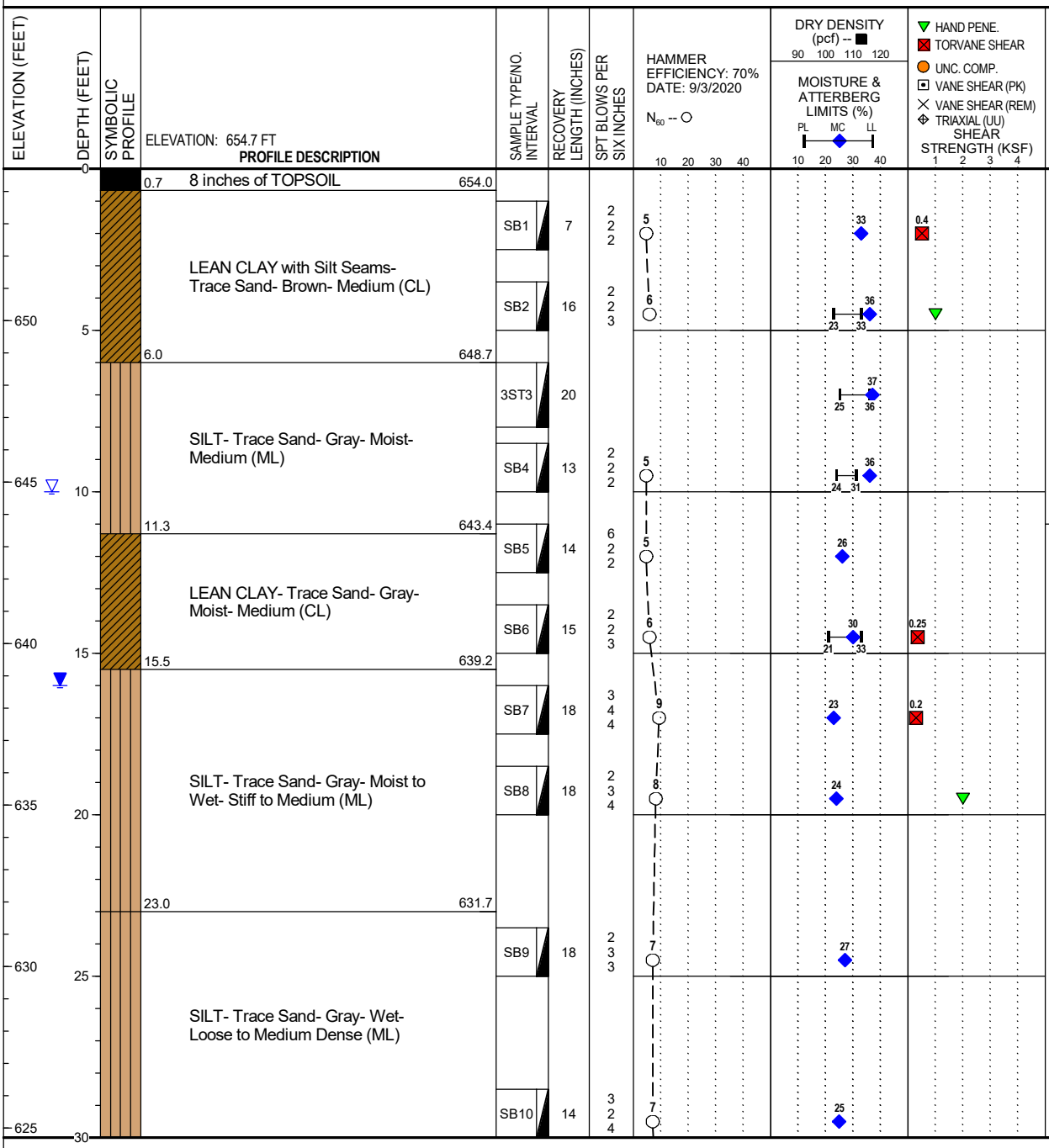
CLIENT: HDR, Inc. **PROJECT LOCATION:** Brecksville, Ohio

DATE STARTED: 3/19/21 **COMPLETED:** 3/19/21 **BORING METHOD:** Hollow-stem Augers, ROD

DRILLER: JH **RIG NO.:** 525 (CME 550RT) **LOGGED BY:** TPO **CHECKED BY:** AKF

ELEVATION: 654.7 FT

PROFILE DESCRIPTION			SAMPLE TYPE/NO. INTERVAL	RECOVERY LENGTH (INCHES)	SPT BLOWS PER SIX INCHES	REMARKS
8 inches of TOPSOIL	0.7	654.0				
LEAN CLAY with Silt Seams- Trace Sand- Brown- Medium (CL)	6.0	648.7	SB1	7	2 2 2	
			SB2	16	2 2 3	
SILT- Trace Sand- Gray- Moist- Medium (ML)	11.3	643.4	3ST3	20		
			SB4	13	2 2 2	
LEAN CLAY- Trace Sand- Gray- Moist- Medium (CL)	15.5	639.2	SB5	14	6 2 2	3" of Poorly Graded Gravel with Sand Seam
			SB6	15	2 2 3	
SILT- Trace Sand- Gray- Moist to Wet- Stiff to Medium (ML)	23.0	631.7	SB7	18	3 4 4	
			SB8	18	2 3 4	
SILT- Trace Sand- Gray- Wet- Loose to Medium Dense (ML)			SB9	18	2 3 3	
			SB10	14	3 2 4	



GROUNDWATER & BACKFILL INFORMATION

	DEPTH (FT)	ELEV (FT)
▽ **DURING BORING:**	10.0	644.7
▼ **AT END OF BORING:**	16.0	638.7
CAVE-IN OF BOREHOLE AT:	28.0	626.7

BACKFILL METHOD: Auger Cuttings & EPCO Hole Plug

NOTES: 1. The indicated stratification lines are approximate. The in-situ transitions between materials may be gradual.
2. The colors depicted on the symbolic profile are solely for visualization purposes and do not necessarily represent the in-situ colors encountered.

(Continued Next Page)

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BORING MMT-1

BORING DEPTH: 45 FEET

PROJECT NAME: NPS Cuyahoga Valley Stream Bank Stabilizations **PROJECT NUMBER:** 086138.00

CLIENT: HDR, Inc. **PROJECT LOCATION:** Brecksville, Ohio

ELEVATION: 654.7 FT

HAMMER EFFICIENCY: 70%
DATE: 9/3/2020

ELEVATION (FEET)	DEPTH (FEET)	PROFILE DESCRIPTION	SAMPLE TYPE/NO. INTERVAL	RECOVERY LENGTH (INCHES)	SPT BLOWS PER SIX INCHES	N_{60} -- ○	DRY DENSITY (pcf) -- ■ / MOISTURE & ATTERBERG LIMITS (PL MC LL)	SHEAR STRENGTH (KSF)	REMARKS
620	35	SILT- Trace Sand- Gray- Wet- Loose to Medium Dense (ML) *(continued)*	SB11	14	3 4 4	9	25		
615	40		SB12	16	4 5 6	13	27		
610	45	45.0 / 609.7	SB13	16	3 5 7	14	31		

END OF BORING AT 45.0 FEET.

605 50
600 55
595 60
590 65
585 70

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BORING MMT-2

BORING DEPTH: 45 FEET

PROJECT NAME: NPS Cuyahoga Valley Stream Bank Stabilizations **PROJECT NUMBER:** 086138.00

CLIENT: HDR, Inc. **PROJECT LOCATION:** Brecksville, Ohio

DATE STARTED: 3/18/21 **COMPLETED:** 3/18/21 **BORING METHOD:** Hollow-stem Augers, ROD

DRILLER: JH **RIG NO.:** 525 (CME 550RT) **LOGGED BY:** TPO **CHECKED BY:** AKF

ELEVATION: 651.2 FT

PROFILE DESCRIPTION	Depth (ft)	Elevation (ft)
12 inches of CRUSHED LIMESTONE	1.0	650.2
SILT- Trace Sand- Brown- Moist- Loose to Medium Dense (ML)	7.0	644.2
LEAN CLAY- Trace Sand- Brown- Moist- Medium (CL)	11.5	639.7
LEAN CLAY with Sand- Trace Roots- Brown & Gray- Wet- Stiff (CL)	13.0	638.2
Silty SAND with Gravel and Cobbles- Trace Clay- Gray- Wet- Medium Dense (SM)	17.0	634.2
SILT- Trace Gravel and Sand- Gray- Wet-Medium to Stiff (ML)		

Sample	Recovery (inches)	SPT blows per six inches	N60	Dry density (pcf)	Moisture	Atterberg PL	Atterberg LL	Hand pene.	Torvane shear	Unc. comp.	Vane shear (PK)	Vane shear (REM)	Triaxial (UU)
SB1	18	4 3 2	6		17								
SB2	6	5 5 5	12		28								
SB3	10	2 2 3	6		28								
SB4	18	2 2 4	7		27								
SB5	18	1 2 6	9		21–31								
SB6	18	9 8 8	19		9								
SB7	9	9 8 3	13		16								
SB8	9	3 3 4	8		26								
3ST9	23				22–26								
SB10	18	3 3 5	9		19–23								

HAMMER EFFICIENCY: 70%
DATE: 9/3/2020

REMARKS: Organic Staining and Odor noted from 3.5 feet to 5 feet.

GROUNDWATER & BACKFILL INFORMATION

	DEPTH (FT)	ELEV (FT)
DURING BORING:	14.0	637.2
AT END OF BORING:	14.0	637.2
CAVE-IN OF BOREHOLE AT:	30.0	621.2

BACKFILL METHOD: Auger Cuttings & EPCO Hole Plug

NOTES: 1. The indicated stratification lines are approximate. The in-situ transitions between materials may be gradual.
2. The colors depicted on the symbolic profile are solely for visualization purposes and do not necessarily represent the in-situ colors encountered.

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BORING MMT-2

BORING DEPTH: 45 FEET

PROJECT NAME: NPS Cuyahoga Valley Stream Bank Stabilizations **PROJECT NUMBER:** 086138.00

CLIENT: HDR, Inc. **PROJECT LOCATION:** Brecksville, Ohio

ELEVATION: 651.2 FT

HAMMER EFFICIENCY: 70%
DATE: 9/3/2020
N_{60} -- ○

DRY DENSITY (pcf) -- ■ (90 100 110 120)
MOISTURE & ATTERBERG LIMITS (%) (PL MC LL) (10 20 30 40)
▼ HAND PENE.
⊠ TORVANE SHEAR
● UNC. COMP.
⊡ VANE SHEAR (PK)
× VANE SHEAR (REM)
⊕ TRIAXIAL (UU)
SHEAR STRENGTH (KSF) (1 2 3 4)

ELEVATION (FEET)	DEPTH (FEET)	PROFILE DESCRIPTION	SAMPLE TYPE/NO. INTERVAL	RECOVERY LENGTH (INCHES)	SPT BLOWS PER SIX INCHES	N_{60}	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS
620	30	SILT- Trace Gravel and Sand- Gray- Wet-Medium to Stiff (ML) *(continued)*							
	33.0 / 618.2								
			SB11	18	3 7 9	19		23	
615	35	SILT- Trace Sand- Gray- Wet- Medium Dense (ML)							
			SB12	18	3 4 5	11		29	
610	40								
			SB13	18	3 5 6	13		27	
	45.0 / 606.2	END OF BORING AT 45.0 FEET.							
605	45								
600	50								
595	55								
590	60								
585	65								
	70								

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BORING MMT-3

BORING DEPTH: 45 FEET

PROJECT NAME: NPS Cuyahoga Valley Stream Bank Stabilizations **PROJECT NUMBER:** 086138.00

CLIENT: HDR, Inc. **PROJECT LOCATION:** Brecksville, Ohio

DATE STARTED: 3/19/21 **COMPLETED:** 3/19/21 **BORING METHOD:** Hollow-stem Augers, ROD

DRILLER: JH **RIG NO.:** 525 (CME 550RT) **LOGGED BY:** TPO **CHECKED BY:** AKF

ELEVATION: 640.5 FT

Depth (ft)	Elev (ft)	Profile Description	Sample Type/No.	Recovery Length (inches)	SPT Blows per Six Inches	N60	Dry Density (pcf)	Moisture (%)	PL	LL	Hand Pene.	Torvane Shear	Remarks
0.8	639.7	10 inches of TOPSOIL											
		Possible FILL- Sandy Silt with Roots & Topsoil- Trace Gravel- Brown & Black- Moist- Meduim to Stiff (ML)	SB1	12	3 3 4	8		32					
			SB2	9	2 3 4	8		33	27	39			
7.0	633.5		SB3	12	2 4 6	12		7					
8.0	632.5	Poorly Graded SAND with Gravel- Moist- Medium Dense (SP)											
		Silty SAND with Gravel- Brown- Moist- Loose (SM)	SB4	8	4 4 3	8		9					
10.5	630.0												
		Silty SAND with Gravel- Trace Cobbles- Gray- Wet- Loose to Medium Dense (SM)	SB5	2	2 3 5	9		13					
			SB6	7	5 7 7	16		10					
16.0	624.5												
		LEAN CLAY- Trace Sand and Gravel- Gray- Moist- Medium to Stiff (CL)	SB7	10	3 3 3	7		29					
			3ST8	24				25	21	29			
			SB9	18	2 3 3	7		26					
27.0	613.5												
		SILT- Gray- Moist to Wet- Loose to Medium Dense (ML)	SB10	18	3 4 4	9		23					

Hammer Efficiency: 70%
Date: 9/3/2020

Dry Density (pcf) -- ■ (90 100 110 120)
Moisture & Atterberg Limits (%) PL MC LL (10 20 30 40)
Shear Strength (KSF) (1 2 3 4)
▼ Hand Pene. ⊠ Torvane Shear ● Unc. Comp. ⊡ Vane Shear (PK) × Vane Shear (Rem) ⊕ Triaxial (UU)

GROUNDWATER & BACKFILL INFORMATION

	Depth (ft)	Elev (ft)
▽ **During Boring:**	10.5	630.0
▼ **At End of Boring:**	10.5	630.0
Cave-in of Borehole At:	40.0	600.5

Backfill Method: Auger Cuttings & EPCO Hole Plug

NOTES: 1. The indicated stratification lines are approximate. The in-situ transitions between materials may be gradual.
2. The colors depicted on the symbolic profile are solely for visualization purposes and do not necessarily represent the in-situ colors encountered.

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BORING MMT-3

BORING DEPTH: 45 FEET

PROJECT NAME: NPS Cuyahoga Valley Stream Bank Stabilizations **PROJECT NUMBER:** 086138.00

CLIENT: HDR, Inc. **PROJECT LOCATION:** Brecksville, Ohio

ELEVATION: 640.5 FT

HAMMER EFFICIENCY: 70%
DATE: 9/3/2020
N_{60} -- ○

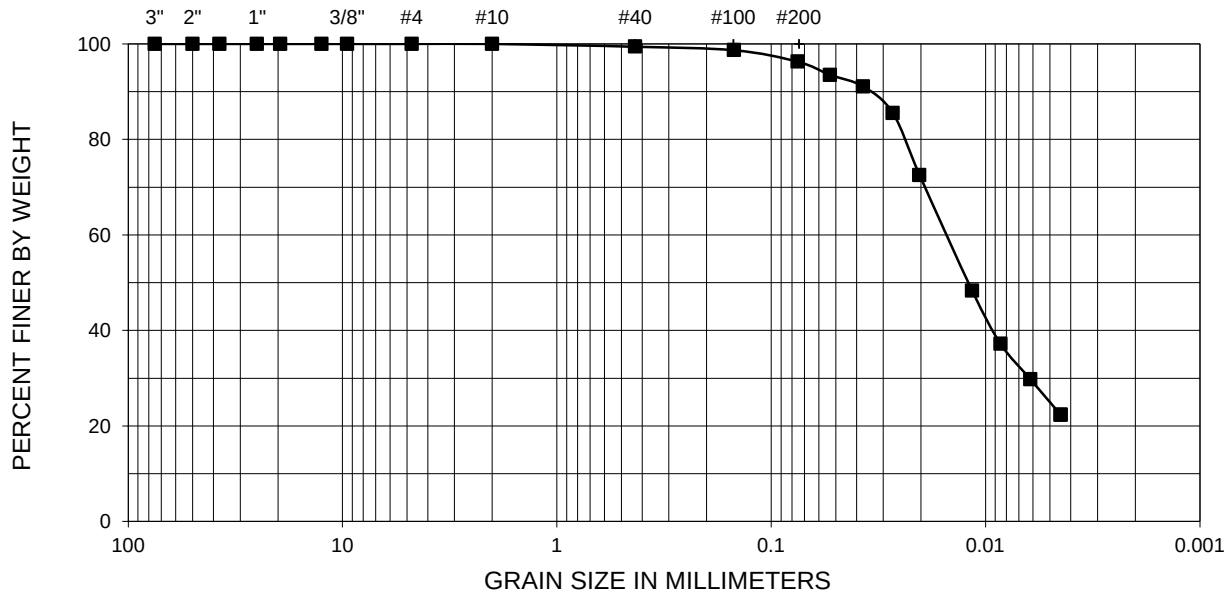
DRY DENSITY (pcf) -- ■ (90 100 110 120)
MOISTURE & ATTERBERG LIMITS (%) (PL MC LL) (10 20 30 40)
SHEAR STRENGTH (KSF) (1 2 3 4)
▼ HAND PENE. ⊠ TORVANE SHEAR ● UNC. COMP. ⊡ VANE SHEAR (PK) × VANE SHEAR (REM) ⊕ TRIAXIAL (UU)

ELEVATION (FEET)	DEPTH (FEET)	PROFILE DESCRIPTION	SAMPLE TYPE/NO. INTERVAL	RECOVERY LENGTH (INCHES)	SPT BLOWS PER SIX INCHES	N60	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS
610	30								
		SILT- Gray- Moist to Wet- Loose to Medium Dense (ML) *(continued)*	SB11	18	3 4 6	12		22	
605	35	36.8 / 603.8							
		Silty CLAY- Trace Sand- Gray- Moist- Medium (CL-ML)	SB12	18	3 3 4	8		27	
600	40	42.0 / 598.5							
		SILT- Trace Sand- Gray- Wet- Very Loose (ML)	SB13	18	0 0 0	0		31	
	45	45.0 / 595.5							
595		END OF BORING AT 45.0 FEET.							
590	50								
585	55								
580	60								
575	65								
	70								

9375 CHILLICOTHE ROAD, KIRTLAND, OH 44094
PHONE: 440-256-6500 FAX: 440-256-6507

PARTICLE SIZE ANALYSIS WITH HYDROMETER ASTM D422

PROJECT INFORMATION		SAMPLE INFORMATION		
Project:	NPS Cuyahoga Valley Stream Bank Stab.	***ASTM Description***	lean clay	CL
Location:	Cuyahoga and Summit County, Ohio			
Project #:	086138.00	***OHIO Modified AASHTO***	Silt	A-4b (8)
Test Date:	March 31, 2021			
Sample #:	SB2	***Sample Location***	MMT-1; 3.5' - 5'	



SIEVE ANALYSIS

Sieve #	Sieve size, mm	Percent Passing
3"	75	100.0
2"	50	100.0
1-1/2"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	100.0
#4	4.75	100.0
#10	2	100.0
#40	0.43	99.4
#100	0.15	98.7
#200	0.074	96.3
#270	0.053	93.5

DISPERSION

Device	ASTM D422, Type A
Agent	Sodium Hexametaphosphate
Time in Agent	16 Hours

HYDROMETER ANALYSIS

Particle Size	Percent Passing
0.074 mm	96.3
0.053 mm	93.5
0.005 mm	25.0
0.0045 mm	22.3

ATTERBERG LIMITS

LIQUID LIMIT	33
PLASTIC LIMIT	23
PLASTICITY INDEX	10

PARTICLE DISTRIBUTION

D_{10}	NA	mm
D_{30}	0.006	mm
D_{50}	0.012	mm
D_{60}	0.015	mm
C_c	NA	
C_u	NA	

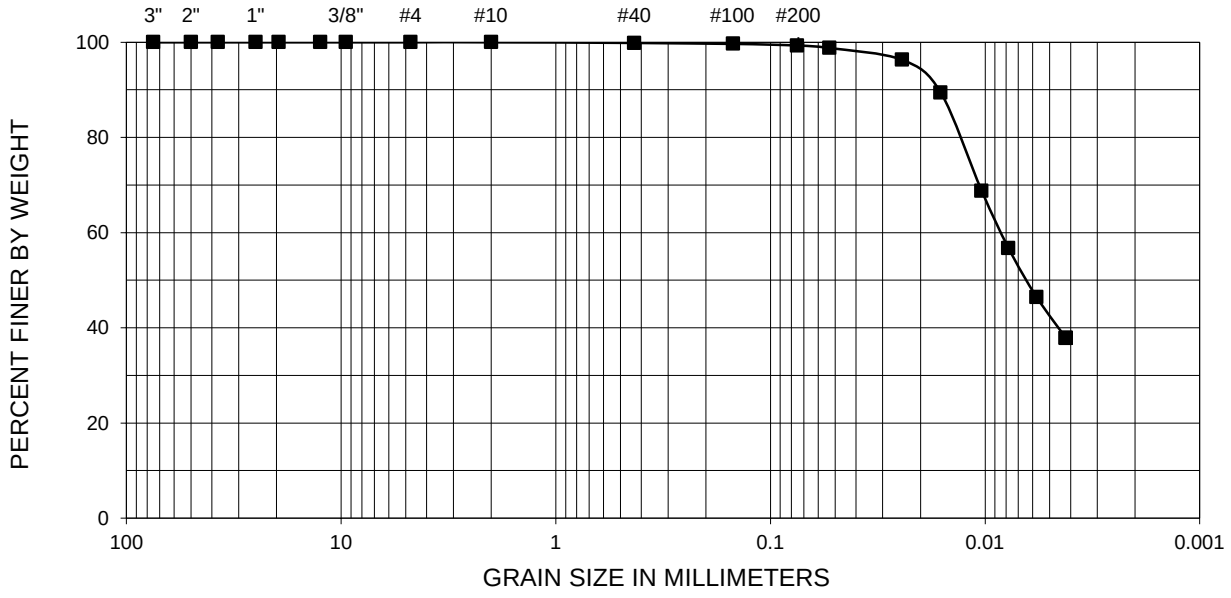
SAND AND GRAVEL DESCRIPTION

SHAPE	Angular
HARDNESS	Hard and durable

9375 CHILLICOTHE ROAD, KIRTLAND, OH 44094
PHONE: 440-256-6500 FAX: 440-256-6507

PARTICLE SIZE ANALYSIS WITH HYDROMETER ASTM D422

PROJECT INFORMATION		SAMPLE INFORMATION		
Project:	NPS Cuyahoga Valley Stream Bank Stab.	***ASTM Description***	silt	ML
Location:	Cuyahoga and Summit County, Ohio			
Project #:	086138.00	***OHIO Modified AASHTO***	Silt and clay	A-6a (8)
Test Date:	March 29, 2021			
Sample #:	3ST3	***Sample Location***	MMT-1; 6' - 8'	



SIEVE ANALYSIS

Sieve #	Sieve size, mm	Percent Passing
3"	75	100.0
2"	50	100.0
1-1/2"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	100.0
#4	4.75	100.0
#10	2	100.0
#40	0.43	99.8
#100	0.15	99.7
#200	0.074	99.3
#270	0.053	98.8

DISPERSION

Device	ASTM D422, Type A
Agent	Sodium Hexametaphosphate
Time in Agent	16 Hours

HYDROMETER ANALYSIS

Particle Size	Percent Passing
0.074 mm	99.3
0.053 mm	98.8
0.005 mm	42.9
0.0042 mm	37.8

ATTERBERG LIMITS

LIQUID LIMIT	36
PLASTIC LIMIT	25
PLASTICITY INDEX	11

PARTICLE DISTRIBUTION

D_{10}	NA	mm
D_{30}	NA	mm
D_{50}	0.006	mm
D_{60}	0.008	mm
C_c	NA	
C_u	NA	

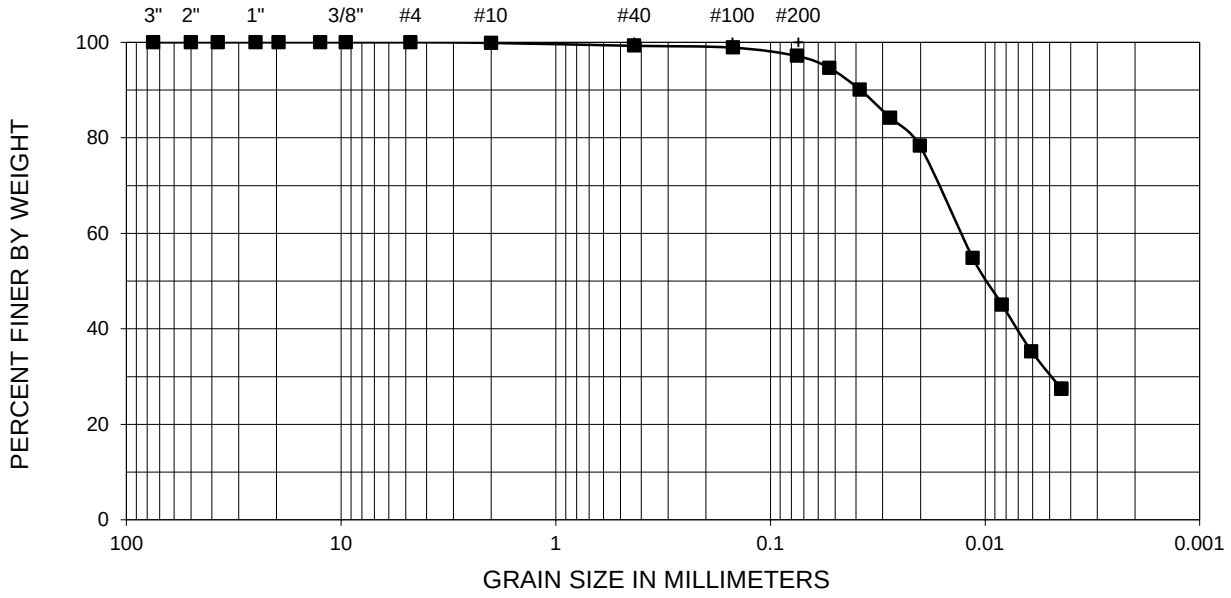
SAND AND GRAVEL DESCRIPTION

SHAPE	Angular
HARDNESS	Hard and durable

9375 CHILLICOTHE ROAD, KIRTLAND, OH 44094
PHONE: 440-256-6500 FAX: 440-256-6507

PARTICLE SIZE ANALYSIS WITH HYDROMETER ASTM D422

PROJECT INFORMATION		SAMPLE INFORMATION		
Project:	NPS Cuyahoga Valley Stream Bank Stab.	***ASTM Description***	silt	ML
Location:	Cuyahoga and Summit County, Ohio			
Project #:	086138.00	***OHIO Modified AASHTO***	Silt	A-4b (8)
Test Date:	March 31, 2021			
Sample #:	SB4-T	***Sample Location***	MMT-1; 8.5' - 10'	



SIEVE ANALYSIS

Sieve #	Sieve size, mm	Percent Passing
3"	75	100.0
2"	50	100.0
1-1/2"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	100.0
#4	4.75	100.0
#10	2	99.9
#40	0.43	99.3
#100	0.15	98.9
#200	0.074	97.1
#270	0.053	94.6

DISPERSION

Device	ASTM D422, Type A
Agent	Sodium Hexametaphosphate
Time in Agent	16 Hours

HYDROMETER ANALYSIS

Particle Size	Percent Passing
0.074 mm	97.1
0.053 mm	94.6
0.005 mm	30.7
0.0044 mm	27.4

ATTERBERG LIMITS

LIQUID LIMIT	31
PLASTIC LIMIT	24
PLASTICITY INDEX	7

PARTICLE DISTRIBUTION

D_{10}	NA	mm
D_{30}	0.005	mm
D_{50}	0.010	mm
D_{60}	0.013	mm
C_c	NA	
C_u	NA	

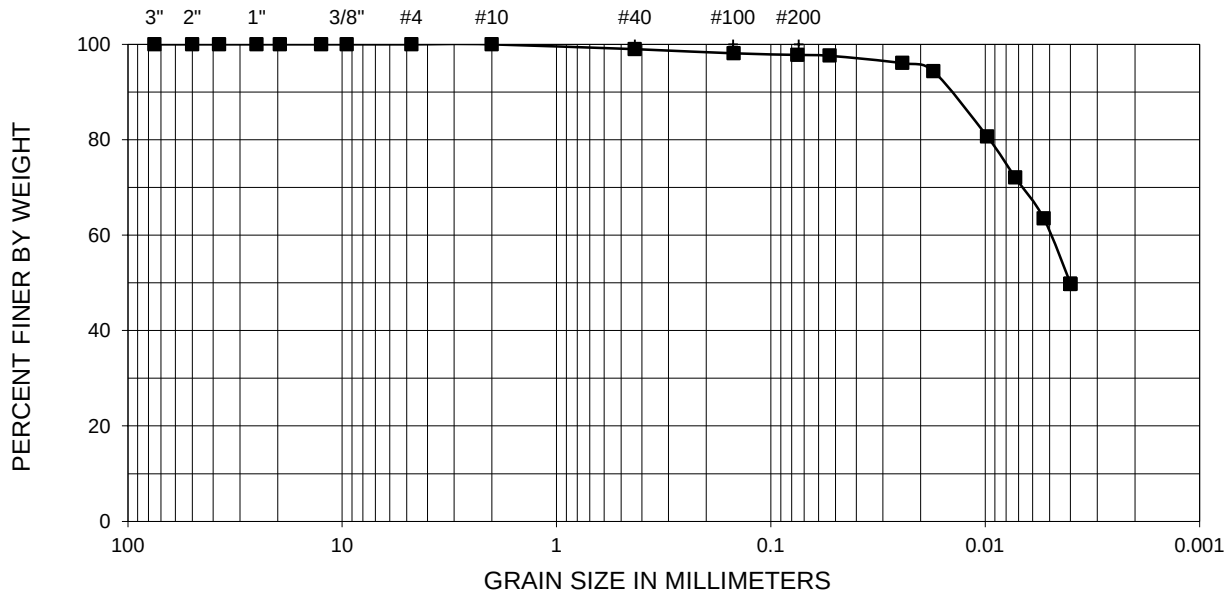
SAND AND GRAVEL DESCRIPTION

SHAPE	Angular
HARDNESS	Hard and durable

9375 CHILLICOTHE ROAD, KIRTLAND, OH 44094
PHONE: 440-256-6500 FAX: 440-256-6507

PARTICLE SIZE ANALYSIS WITH HYDROMETER ASTM D422

PROJECT INFORMATION		SAMPLE INFORMATION		
Project:	NPS Cuyahoga Valley Stream Bank Stab.	***ASTM Description***	lean clay	CL
Location:	Cuyahoga and Summit County, Ohio			
Project #:	086138.00	***OHIO Modified AASHTO***	Silt and clay	A-6a (9)
Test Date:	March 31, 2021			
Sample #:	SB6	***Sample Location***	MMT-1; 13.5' - 15'	



SIEVE ANALYSIS

Sieve #	Sieve size, mm	Percent Passing
3"	75	100.0
2"	50	100.0
1-1/2"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	100.0
#4	4.75	100.0
#10	2	100.0
#40	0.43	99.0
#100	0.15	98.1
#200	0.074	97.8
#270	0.053	97.6

DISPERSION

Device	ASTM D422, Type A
Agent	Sodium Hexametaphosphate
Time in Agent	16 Hours

HYDROMETER ANALYSIS

Particle Size	Percent Passing
0.074 mm	97.8
0.053 mm	97.6
0.005 mm	60.5
0.0040 mm	49.7

ATTERBERG LIMITS

LIQUID LIMIT	33
PLASTIC LIMIT	21
PLASTICITY INDEX	12

PARTICLE DISTRIBUTION

D_{10}	NA	mm
D_{30}	NA	mm
D_{50}	0.004	mm
D_{60}	0.005	mm
C_c	NA	
C_u	NA	

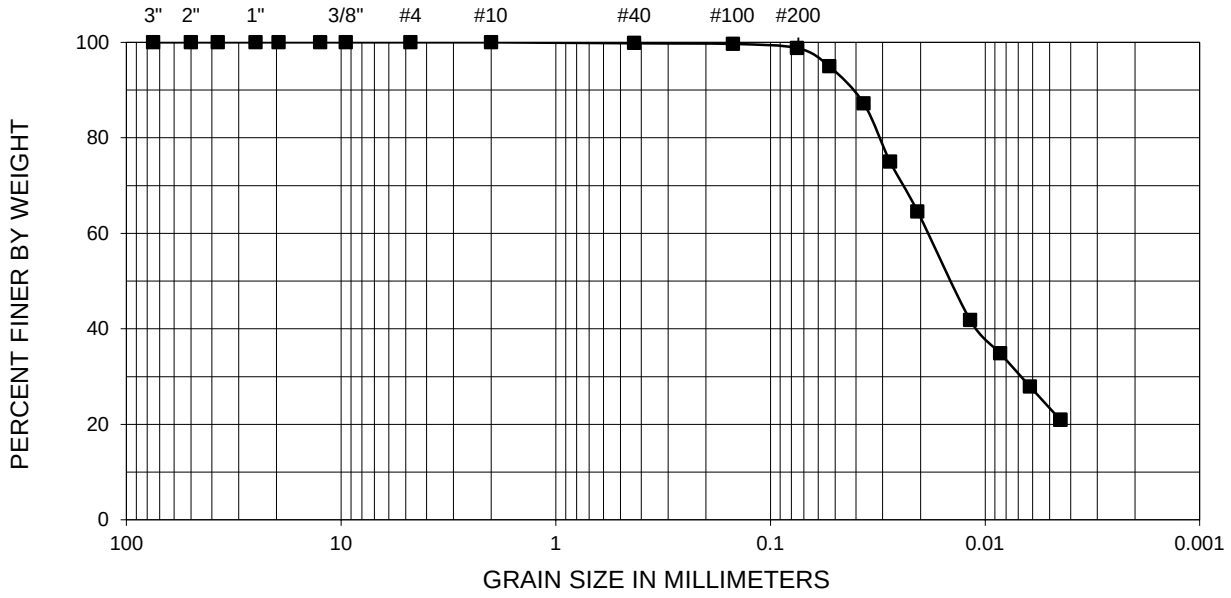
SAND AND GRAVEL DESCRIPTION

SHAPE	Angular
HARDNESS	Hard and durable

9375 CHILLICOTHE ROAD, KIRTLAND, OH 44094
PHONE: 440-256-6500 FAX: 440-256-6507

PARTICLE SIZE ANALYSIS WITH HYDROMETER ASTM D422

PROJECT INFORMATION		SAMPLE INFORMATION		
Project:	NPS Cuyahoga Valley Stream Bank Stab.	***ASTM Description***	silt	ML
Location:	Cuyahoga and Summit County, Ohio			
Project #:	086138.00	***OHIO Modified AASHTO***	Silt	A-4b (8)
Test Date:	March 31, 2021			
Sample #:	SB9	***Sample Location***	MMT-1; 23.5' - 25'	



SIEVE ANALYSIS

Sieve #	Sieve size, mm	Percent Passing
3"	75	100.0
2"	50	100.0
1-1/2"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	100.0
#4	4.75	100.0
#10	2	100.0
#40	0.43	99.8
#100	0.15	99.7
#200	0.074	98.8
#270	0.053	94.9

DISPERSION

Device	ASTM D422, Type A
Agent	Sodium Hexametaphosphate
Time in Agent	16 Hours

HYDROMETER ANALYSIS

Particle Size	Percent Passing
0.074 mm	98.8
0.053 mm	94.9
0.005 mm	23.5
0.0045 mm	20.9

ATTERBERG LIMITS

LIQUID LIMIT	NP
PLASTIC LIMIT	NP
PLASTICITY INDEX	NP

PARTICLE DISTRIBUTION

D_{10}	NA	mm
D_{30}	0.007	mm
D_{50}	0.016	mm
D_{60}	0.018	mm
C_c	NA	
C_u	NA	

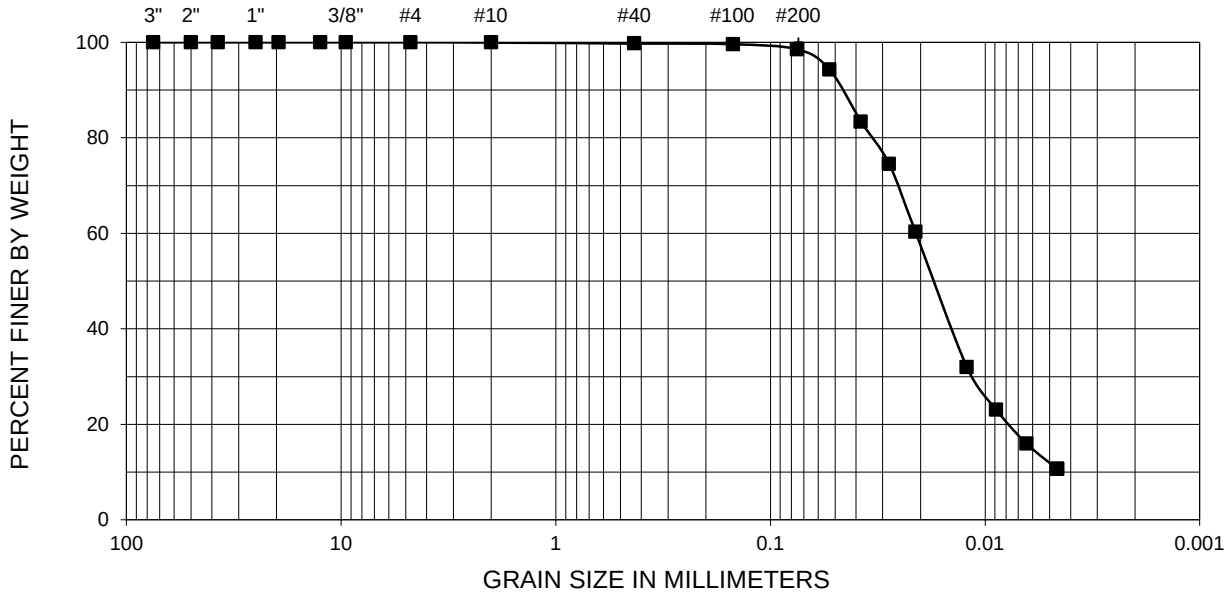
SAND AND GRAVEL DESCRIPTION

SHAPE	Angular
HARDNESS	Hard and durable

9375 CHILLICOTHE ROAD, KIRTLAND, OH 44094
PHONE: 440-256-6500 FAX: 440-256-6507

PARTICLE SIZE ANALYSIS WITH HYDROMETER ASTM D422

PROJECT INFORMATION		SAMPLE INFORMATION		
Project:	NPS Cuyahoga Valley Stream Bank Stab.	***ASTM Description***	silt	ML
Location:	Cuyahoga and Summit County, Ohio			
Project #:	086138.00	***OHIO Modified AASHTO***	Silt	A-4b (8)
Test Date:	March 31, 2021			
Sample #:	SB11	***Sample Location***	MMT-1; 33.5' - 35'	



SIEVE ANALYSIS

Sieve #	Sieve size, mm	Percent Passing
3"	75	100.0
2"	50	100.0
1-1/2"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	100.0
#4	4.75	100.0
#10	2	100.0
#40	0.43	99.8
#100	0.15	99.6
#200	0.074	98.5
#270	0.053	94.3

DISPERSION

Device	ASTM D422, Type A
Agent	Sodium Hexametaphosphate
Time in Agent	16 Hours

HYDROMETER ANALYSIS

Particle Size	Percent Passing
0.074 mm	98.5
0.053 mm	94.3
0.005 mm	12.0
0.0046 mm	10.6

ATTERBERG LIMITS

LIQUID LIMIT	NP
PLASTIC LIMIT	NP
PLASTICITY INDEX	NP

PARTICLE DISTRIBUTION

D_{10}	NA	mm
D_{30}	0.011	mm
D_{50}	0.018	mm
D_{60}	0.021	mm
C_c	NA	
C_u	NA	

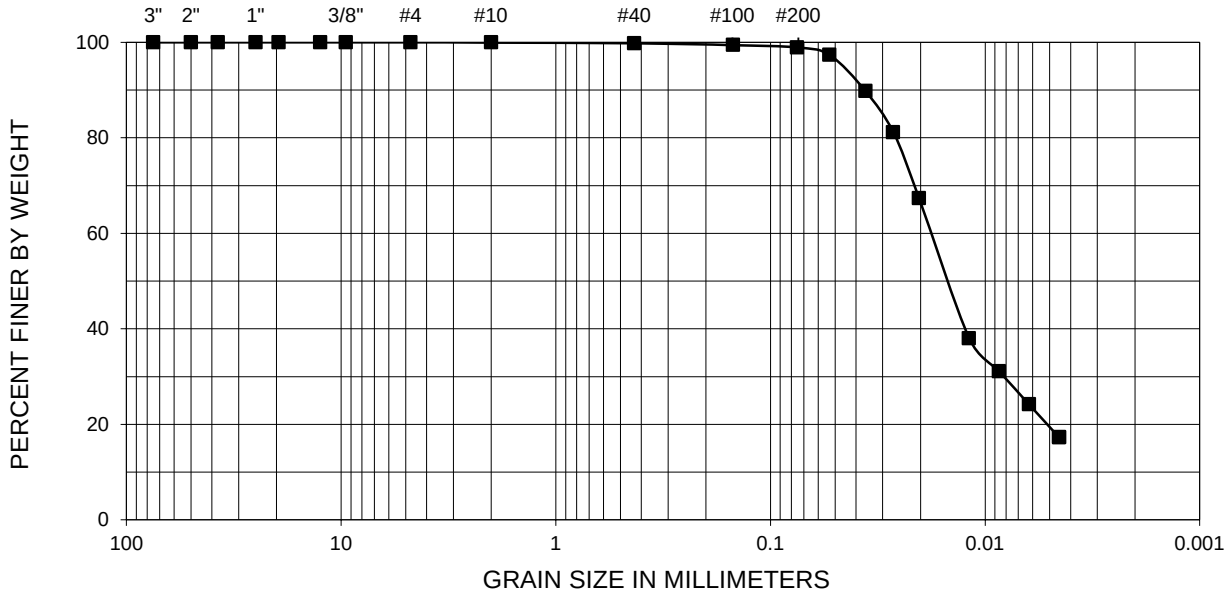
SAND AND GRAVEL DESCRIPTION

SHAPE	Angular
HARDNESS	Hard and durable

9375 CHILLICOTHE ROAD, KIRTLAND, OH 44094
PHONE: 440-256-6500 FAX: 440-256-6507

PARTICLE SIZE ANALYSIS WITH HYDROMETER ASTM D422

PROJECT INFORMATION		SAMPLE INFORMATION		
Project:	NPS Cuyahoga Valley Stream Bank Stab.	***ASTM Description***	silt	ML
Location:	Cuyahoga and Summit County, Ohio			
Project #:	086138.00	***OHIO Modified AASHTO***	Silt	A-4b (8)
Test Date:	March 31, 2021			
Sample #:	SB12	***Sample Location***	MMT-1; 38.5' - 40'	



SIEVE ANALYSIS

Sieve #	Sieve size, mm	Percent Passing
3"	75	100.0
2"	50	100.0
1-1/2"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	100.0
#4	4.75	100.0
#10	2	100.0
#40	0.43	99.8
#100	0.15	99.4
#200	0.074	98.9
#270	0.053	97.4

DISPERSION

Device	ASTM D422, Type A
Agent	Sodium Hexametaphosphate
Time in Agent	16 Hours

HYDROMETER ANALYSIS

Particle Size	Percent Passing
0.074 mm	98.9
0.053 mm	97.4
0.005 mm	19.8
0.0045 mm	17.3

ATTERBERG LIMITS

LIQUID LIMIT	NP
PLASTIC LIMIT	NP
PLASTICITY INDEX	NP

PARTICLE DISTRIBUTION

D_{10}	NA	mm
D_{30}	0.008	mm
D_{50}	0.015	mm
D_{60}	0.018	mm
C_c	NA	
C_u	NA	

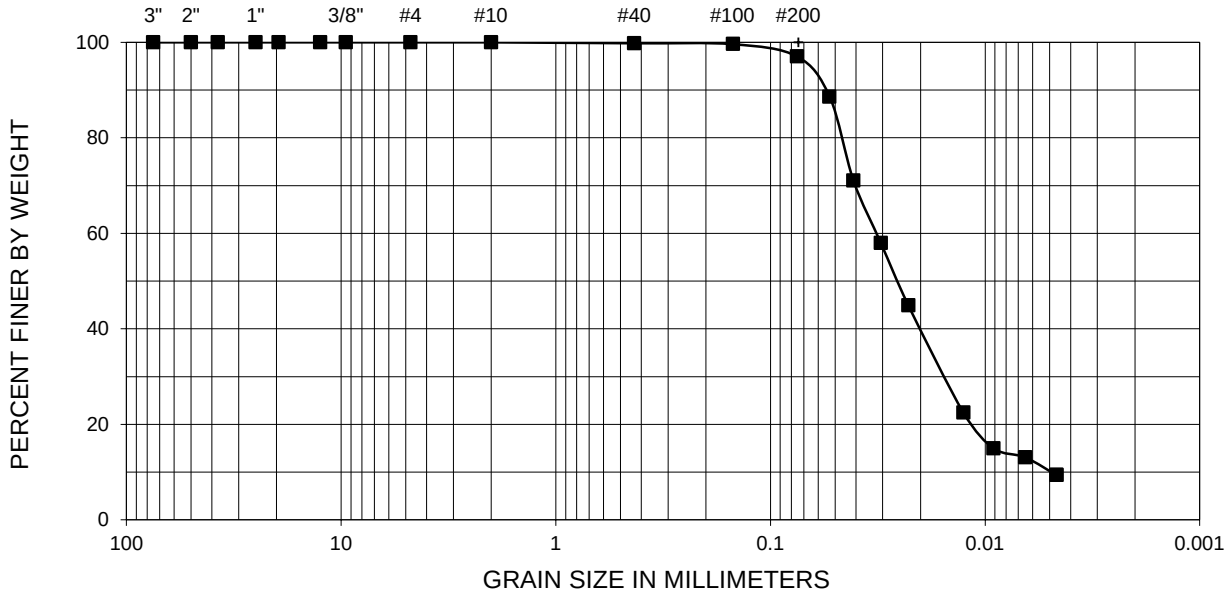
SAND AND GRAVEL DESCRIPTION

SHAPE	Angular
HARDNESS	Hard and durable

9375 CHILLICOTHE ROAD, KIRTLAND, OH 44094
PHONE: 440-256-6500 FAX: 440-256-6507

PARTICLE SIZE ANALYSIS WITH HYDROMETER ASTM D422

PROJECT INFORMATION		SAMPLE INFORMATION		
Project:	NPS Cuyahoga Valley Stream Bank Stab.	***ASTM Description***	silt	ML
Location:	Cuyahoga and Summit County, Ohio			
Project #:	086138.00	***OHIO Modified AASHTO***	Silt	A-4b (8)
Test Date:	April 1, 2021			
Sample #:	SB13	***Sample Location***	MMT-1; 43.5' - 45'	



SIEVE ANALYSIS

Sieve #	Sieve size, mm	Percent Passing
3"	75	100.0
2"	50	100.0
1-1/2"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	100.0
#4	4.75	100.0
#10	2	100.0
#40	0.43	99.8
#100	0.15	99.6
#200	0.074	97.0
#270	0.053	88.6

DISPERSION

Device	ASTM D422, Type A
Agent	Sodium Hexametaphosphate
Time in Agent	16 Hours

HYDROMETER ANALYSIS

Particle Size	Percent Passing
0.074 mm	97.0
0.053 mm	88.6
0.005 mm	10.3
0.0045 mm	9.3

ATTERBERG LIMITS

LIQUID LIMIT	NP
PLASTIC LIMIT	NP
PLASTICITY INDEX	NP

PARTICLE DISTRIBUTION

D_{10}	0.005	mm
D_{30}	0.015	mm
D_{50}	0.025	mm
D_{60}	0.032	mm
C_c	1.50	
C_u	6.50	

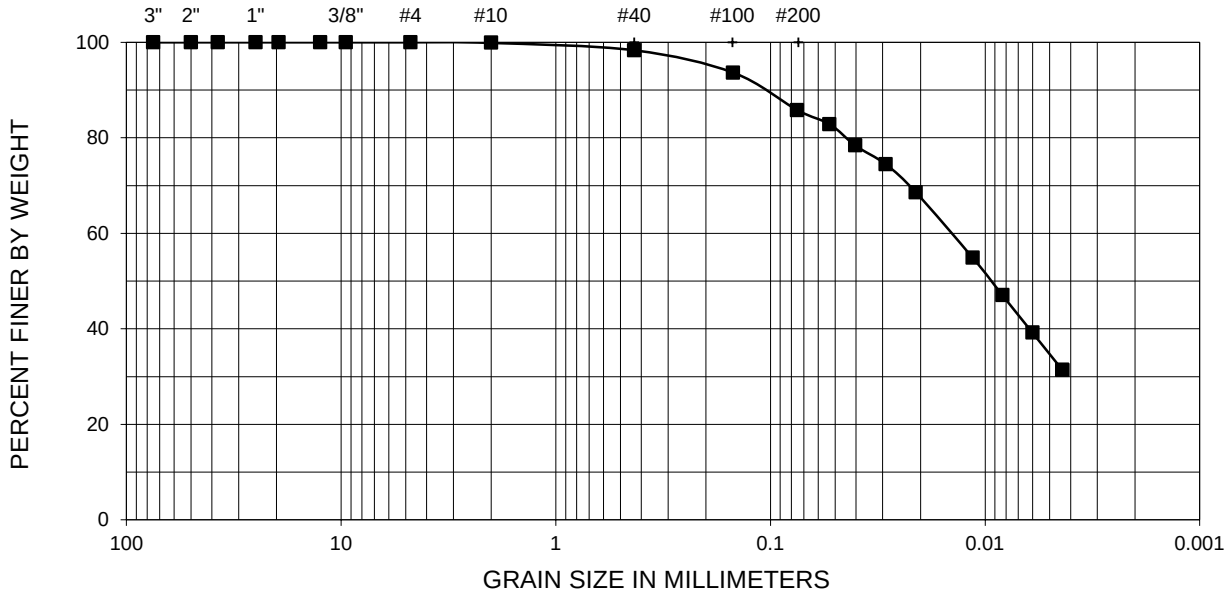
SAND AND GRAVEL DESCRIPTION

SHAPE	Angular
HARDNESS	Hard and durable

9375 CHILLICOTHE ROAD, KIRTLAND, OH 44094
PHONE: 440-256-6500 FAX: 440-256-6507

PARTICLE SIZE ANALYSIS WITH HYDROMETER ASTM D422

PROJECT INFORMATION		SAMPLE INFORMATION		
Project:	NPS Cuyahoga Valley Stream Bank Stab.	***ASTM Description***	silt	ML
Location:	Cuyahoga and Summit County, Ohio			
Project #:	086138.00	***OHIO Modified AASHTO***	Silt	A-4b (8)
Test Date:	April 1, 2021			
Sample #:	SB2	***Sample Location***	MMT-2; 3.5' - 5'	



SIEVE ANALYSIS

Sieve #	Sieve size, mm	Percent Passing
3"	75	100.0
2"	50	100.0
1-1/2"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	100.0
#4	4.75	100.0
#10	2	99.9
#40	0.43	98.3
#100	0.15	93.6
#200	0.074	85.8
#270	0.053	82.9

DISPERSION

Device	ASTM D422, Type A
Agent	Sodium Hexametaphosphate
Time in Agent	16 Hours

HYDROMETER ANALYSIS

Particle Size	Percent Passing
0.074 mm	85.8
0.053 mm	82.9
0.005 mm	34.8
0.0044 mm	31.4

ATTERBERG LIMITS

LIQUID LIMIT	NP
PLASTIC LIMIT	NP
PLASTICITY INDEX	NP

PARTICLE DISTRIBUTION

D_{10}	NA	mm
D_{30}	NA	mm
D_{50}	0.009	mm
D_{60}	0.014	mm
C_c	NA	
C_u	NA	

SAND AND GRAVEL DESCRIPTION

SHAPE	Angular
HARDNESS	Hard and durable

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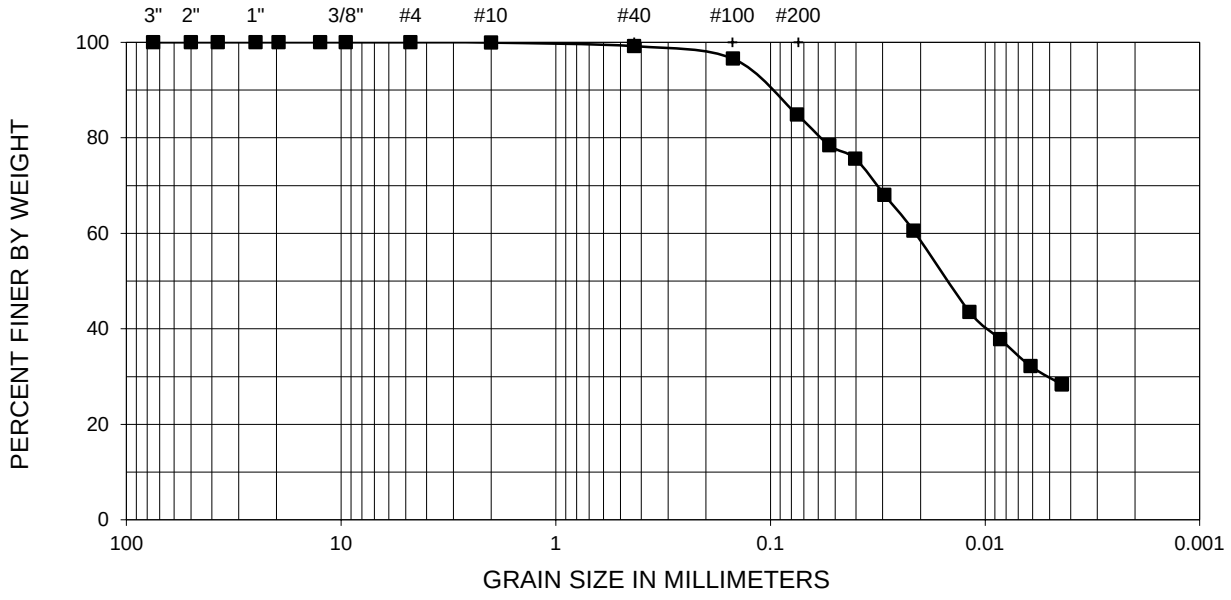
PHONE: 440-256-6500 FAX: 440-256-6507

PARTICLE SIZE ANALYSIS WITH HYDROMETER ASTM D422

PROJECT INFORMATION		SAMPLE INFORMATION		
Project:	NPS Cuyahoga Valley Stream Bank Stab.	***ASTM Description***	lean clay with sand	CL
Location:	Cuyahoga and Summit County, Ohio			
Project #:	086138.00	***OHIO Modified AASHTO***	Silt	A-4b (8)
Test Date:	April 1, 2021			
Sample #:	SB5	***Sample Location***	MMT-2; 11' - 12.5'	



SIEVE ANALYSIS

Sieve #	Sieve size, mm	Percent Passing
3"	75	100.0
2"	50	100.0
1-1/2"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	100.0
#4	4.75	100.0
#10	2	99.9
#40	0.43	99.2
#100	0.15	96.5
#200	0.074	84.8
#270	0.053	78.4

DISPERSION

Device	ASTM D422, Type A
Agent	Sodium Hexametaphosphate
Time in Agent	16 Hours

HYDROMETER ANALYSIS

Particle Size	Percent Passing
0.074 mm	84.8
0.053 mm	78.4
0.005 mm	29.9
0.0044 mm	28.4

ATTERBERG LIMITS

LIQUID LIMIT	31
PLASTIC LIMIT	21
PLASTICITY INDEX	10

PARTICLE DISTRIBUTION

D_{10}	NA	mm
D_{30}	0.005	mm
D_{50}	0.015	mm
D_{60}	0.021	mm
C_c	NA	
C_u	NA	

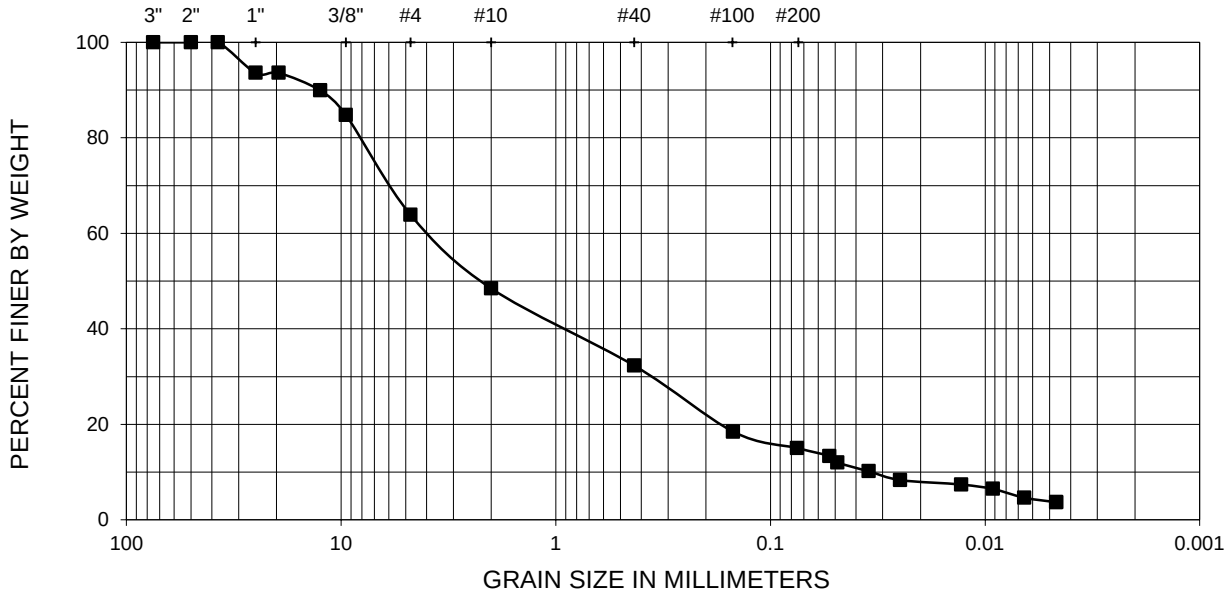
SAND AND GRAVEL DESCRIPTION

SHAPE	Angular
HARDNESS	Hard and durable

9375 CHILLICOTHE ROAD, KIRTLAND, OH 44094
PHONE: 440-256-6500 FAX: 440-256-6507

PARTICLE SIZE ANALYSIS WITH HYDROMETER ASTM D422

PROJECT INFORMATION		SAMPLE INFORMATION		
Project:	NPS Cuyahoga Valley Stream Bank Stab.	***ASTM Description***	Silty sand	SM
Location:	Cuyahoga and Summit County, Ohio			
Project #:	086138.00	***OHIO Modified AASHTO***	Gravel and/or stone fragments with sand	A-1-b (0)
Test Date:	March 31, 2021			
Sample #:	SB6	***Sample Location***	MMT-2; 13.5' - 15'	



SIEVE ANALYSIS

Sieve #	Sieve size, mm	Percent Passing
3"	75	100.0
2"	50	100.0
1-1/2"	37.5	100.0
1"	25	93.6
3/4"	19	93.6
3/8"	9.5	84.8
#4	4.75	63.9
#10	2	48.4
#40	0.43	32.3
#100	0.15	18.4
#200	0.074	15.0
#270	0.053	13.3

DISPERSION

Device	ASTM D422, Type A
Agent	Sodium Hexametaphosphate
Time in Agent	16 Hours

HYDROMETER ANALYSIS

Particle Size	Percent Passing
0.074 mm	15.0
0.053 mm	13.3
0.005 mm	4.0
0.0047 mm	3.7

ATTERBERG LIMITS

LIQUID LIMIT	NP
PLASTIC LIMIT	NP
PLASTICITY INDEX	NP

PARTICLE DISTRIBUTION

D_{10}	0.034	mm
D_{30}	0.361	mm
D_{50}	2.219	mm
D_{60}	3.823	mm
C_c	1.01	
C_u	113.27	

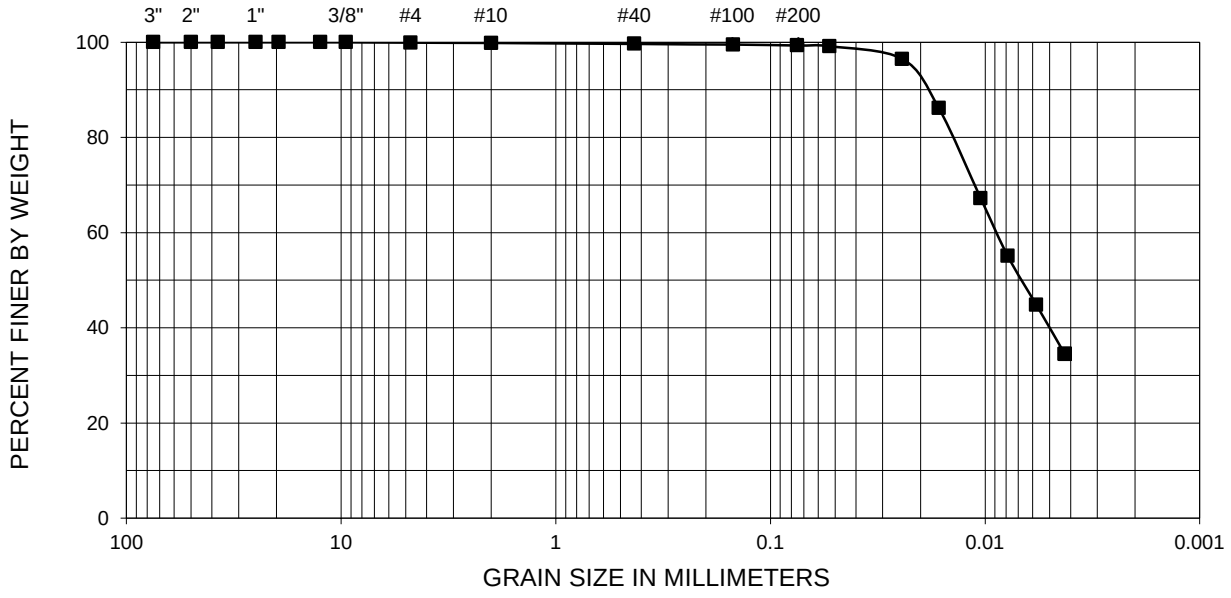
SAND AND GRAVEL DESCRIPTION

SHAPE	Angular
HARDNESS	Hard and durable

9375 CHILLICOTHE ROAD, KIRTLAND, OH 44094
PHONE: 440-256-6500 FAX: 440-256-6507

PARTICLE SIZE ANALYSIS WITH HYDROMETER ASTM D422

PROJECT INFORMATION		SAMPLE INFORMATION		
Project:	NPS Cuyahoga Valley Stream Bank Stab.	***ASTM Description***	silt	ML
Location:	Cuyahoga and Summit County, Ohio			
Project #:	086138.00	***OHIO Modified AASHTO***	Silt	A-4b (8)
Test Date:	March 29, 2021			
Sample #:	3ST9	***Sample Location***	MMT-2; 23.5' - 25.5'	



SIEVE ANALYSIS

Sieve #	Sieve size, mm	Percent Passing
3"	75	100.0
2"	50	100.0
1-1/2"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	100.0
#4	4.75	99.9
#10	2	99.8
#40	0.43	99.7
#100	0.15	99.5
#200	0.074	99.3
#270	0.053	99.1

DISPERSION

Device	ASTM D422, Type A
Agent	Sodium Hexametaphosphate
Time in Agent	16 Hours

HYDROMETER ANALYSIS

Particle Size	Percent Passing
0.074 mm	99.3
0.053 mm	99.1
0.005 mm	40.5
0.0042 mm	34.5

ATTERBERG LIMITS

LIQUID LIMIT	26
PLASTIC LIMIT	22
PLASTICITY INDEX	4

PARTICLE DISTRIBUTION

D_{10}	NA	mm
D_{30}	NA	mm
D_{50}	0.007	mm
D_{60}	0.009	mm
C_c	NA	
C_u	NA	

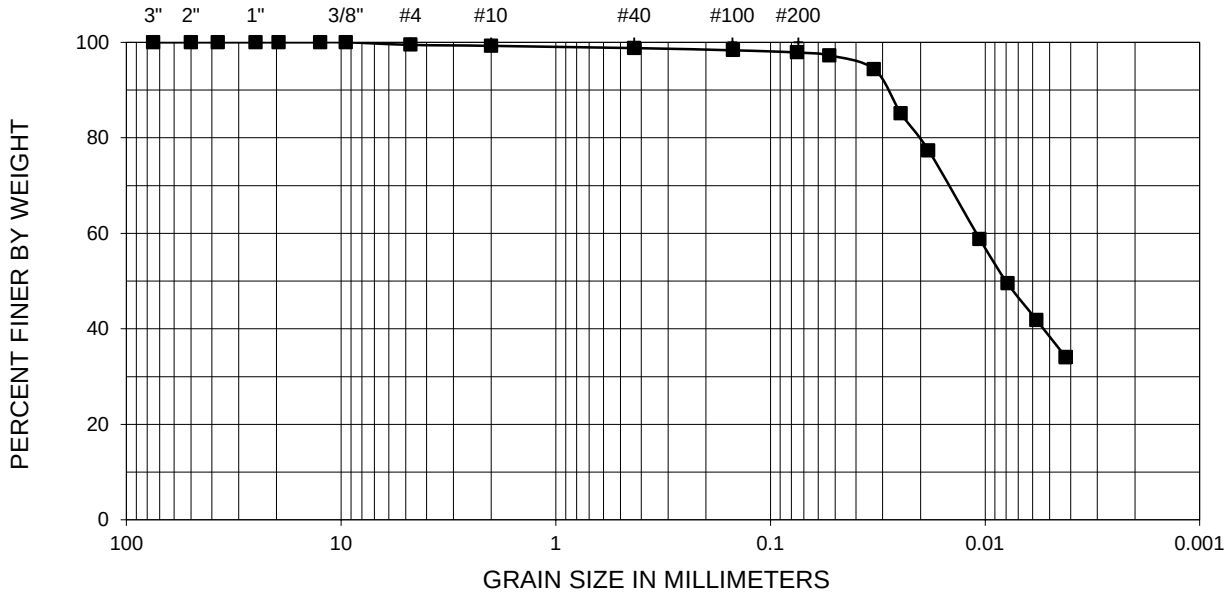
SAND AND GRAVEL DESCRIPTION

SHAPE	Angular
HARDNESS	Hard and durable

9375 CHILLICOTHE ROAD, KIRTLAND, OH 44094
PHONE: 440-256-6500 FAX: 440-256-6507

PARTICLE SIZE ANALYSIS WITH HYDROMETER ASTM D422

PROJECT INFORMATION		SAMPLE INFORMATION		
Project:	NPS Cuyahoga Valley Stream Bank Stab.	***ASTM Description***	silt	ML
Location:	Cuyahoga and Summit County, Ohio			
Project #:	086138.00	***OHIO Modified AASHTO***	Silt	A-4b (8)
Test Date:	March 31, 2021			
Sample #:	SB10	***Sample Location***	MMT-2; 28.5' - 30'	



SIEVE ANALYSIS

Sieve #	Sieve size, mm	Percent Passing
3"	75	100.0
2"	50	100.0
1-1/2"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	100.0
#4	4.75	99.5
#10	2	99.3
#40	0.43	98.8
#100	0.15	98.3
#200	0.074	97.9
#270	0.053	97.3

DISPERSION

Device	ASTM D422, Type A
Agent	Sodium Hexametaphosphate
Time in Agent	16 Hours

HYDROMETER ANALYSIS

Particle Size	Percent Passing
0.074 mm	97.9
0.053 mm	97.3
0.005 mm	39.2
0.0042 mm	34.0

ATTERBERG LIMITS

LIQUID LIMIT	22
PLASTIC LIMIT	19
PLASTICITY INDEX	3

PARTICLE DISTRIBUTION

D_{10}	NA	mm
D_{30}	NA	mm
D_{50}	0.008	mm
D_{60}	0.011	mm
C_c	NA	
C_u	NA	

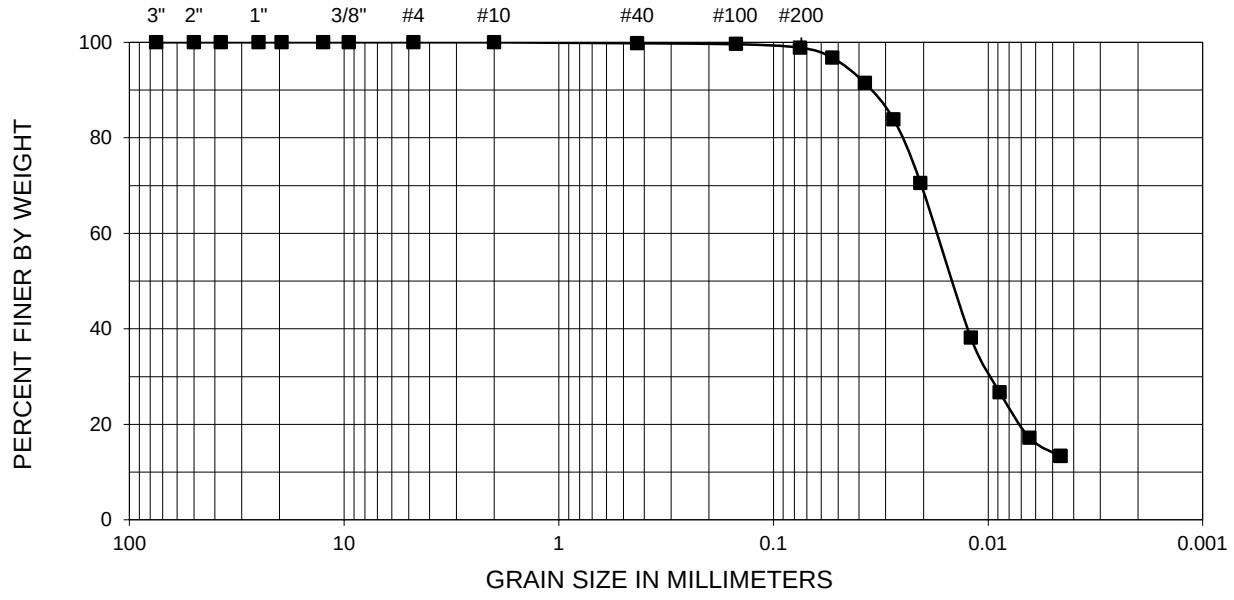
SAND AND GRAVEL DESCRIPTION

SHAPE	Angular
HARDNESS	Hard and durable

9375 CHILLICOTHE ROAD, KIRTLAND, OH 44094
PHONE: 440-256-6500 FAX: 440-256-6507

PARTICLE SIZE ANALYSIS WITH HYDROMETER ASTM D422

PROJECT INFORMATION		SAMPLE INFORMATION		
Project:	NPS Cuyahoga Valley Stream Bank Stab.	***ASTM Description***	silt	ML
Location:	Cuyahoga and Summit County, Ohio			
Project #:	086138.00	***OHIO Modified AASHTO***	Silt	A-4b (8)
Test Date:	April 1, 2021			
Sample #:	SB12	***Sample Location***	MMT-2; 38.5' - 40'	



SIEVE ANALYSIS

Sieve #	Sieve size, mm	Percent Passing
3"	75	100.0
2"	50	100.0
1-1/2"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	100.0
#4	4.75	100.0
#10	2	100.0
#40	0.43	99.8
#100	0.15	99.6
#200	0.074	98.9
#270	0.053	96.8

DISPERSION

Device	ASTM D422, Type A
Agent	Sodium Hexametaphosphate
Time in Agent	16 Hours

HYDROMETER ANALYSIS

Particle Size	Percent Passing
0.074 mm	98.9
0.053 mm	96.8
0.005 mm	14.3
0.0046 mm	13.3

ATTERBERG LIMITS

LIQUID LIMIT	NP
PLASTIC LIMIT	NP
PLASTICITY INDEX	NP

PARTICLE DISTRIBUTION

D_{10}	NA	mm
D_{30}	0.010	mm
D_{50}	0.016	mm
D_{60}	0.017	mm
C_c	NA	
C_u	NA	

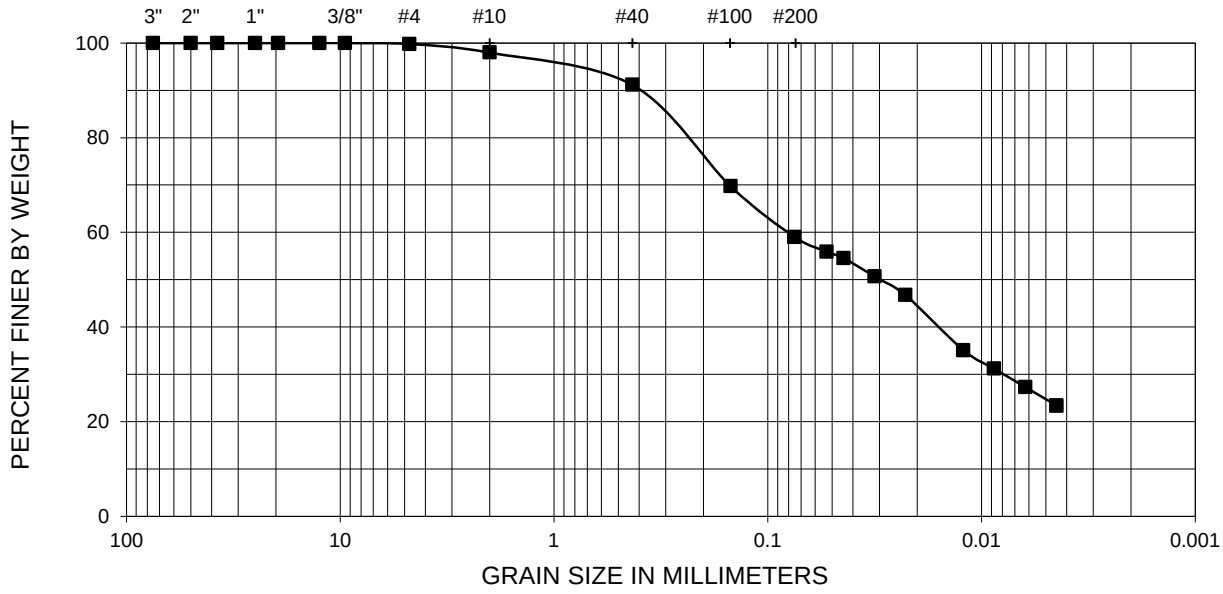
SAND AND GRAVEL DESCRIPTION

SHAPE	Angular
HARDNESS	Hard and durable

9375 CHILLICOTHE ROAD, KIRTLAND, OH 44094
PHONE: 440-256-6500 FAX: 440-256-6507

PARTICLE SIZE ANALYSIS WITH HYDROMETER ASTM D422

PROJECT INFORMATION		SAMPLE INFORMATION		
Project:	NPS Cuyahoga Valley Stream Bank Stab.	***ASTM Description***	Sandy silt	ML
Location:	Cuyahoga and Summit County, Ohio			
Project #:	086138.00	***OHIO Modified AASHTO***	Silt and clay	A-6a (6)
Test Date:	April 1, 2021			
Sample #:	SB2	***Sample Location***	MMT-3; 3.5' - 5'	



SIEVE ANALYSIS

Sieve #	Sieve size, mm	Percent Passing
3"	75	100.0
2"	50	100.0
1-1/2"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	100.0
#4	4.75	99.8
#10	2	98.0
#40	0.43	91.2
#100	0.15	69.7
#200	0.074	59.0
#270	0.053	55.9

DISPERSION

Device	ASTM D422, Type A
Agent	Sodium Hexametaphosphate
Time in Agent	16 Hours

HYDROMETER ANALYSIS

Particle Size	Percent Passing
0.074 mm	59.0
0.053 mm	55.9
0.005 mm	24.8
0.0045 mm	23.4

ATTERBERG LIMITS

LIQUID LIMIT	39
PLASTIC LIMIT	27
PLASTICITY INDEX	12

PARTICLE DISTRIBUTION

D_{10}	NA	mm
D_{30}	0.008	mm
D_{50}	0.031	mm
D_{60}	0.080	mm
C_c	NA	
C_u	NA	

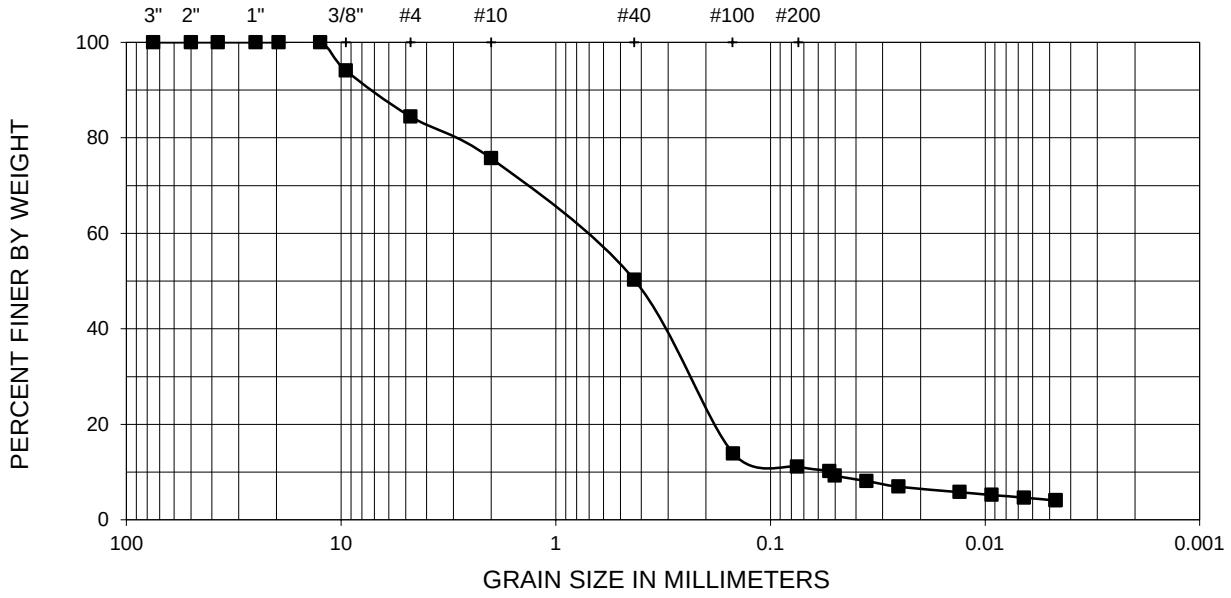
SAND AND GRAVEL DESCRIPTION

SHAPE	Angular
HARDNESS	Hard and durable

9375 CHILLICOTHE ROAD, KIRTLAND, OH 44094
PHONE: 440-256-6500 FAX: 440-256-6507

PARTICLE SIZE ANALYSIS WITH HYDROMETER ASTM D422

PROJECT INFORMATION		SAMPLE INFORMATION		
Project:	NPS Cuyahoga Valley Stream Bank Stab.	***ASTM Description***	Poorly graded sand with silt and gravel	SP-SM
Location:	Cuyahoga and Summit County, Ohio			
Project #:	086138.00	***OHIO Modified AASHTO***	Coarse and fine sand	A-3a (0)
Test Date:	March 30, 2021			
Sample #:	SB3-B	***Sample Location***	MMT-3; 7' - 7.5'	



SIEVE ANALYSIS

Sieve #	Sieve size, mm	Percent Passing
3"	75	100.0
2"	50	100.0
1-1/2"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	94.1
#4	4.75	84.4
#10	2	75.7
#40	0.43	50.2
#100	0.15	13.9
#200	0.074	11.1
#270	0.053	10.2

DISPERSION

Device	ASTM D422, Type A
Agent	Sodium Hexametaphosphate
Time in Agent	16 Hours

HYDROMETER ANALYSIS

Particle Size	Percent Passing
0.074 mm	11.1
0.053 mm	10.2
0.005 mm	4.3
0.0047 mm	4.1

ATTERBERG LIMITS

LIQUID LIMIT	NP
PLASTIC LIMIT	NP
PLASTICITY INDEX	NP

PARTICLE DISTRIBUTION

D_{10}	0.052	mm
D_{30}	0.238	mm
D_{50}	0.423	mm
D_{60}	0.775	mm
C_c	1.40	
C_u	14.79	

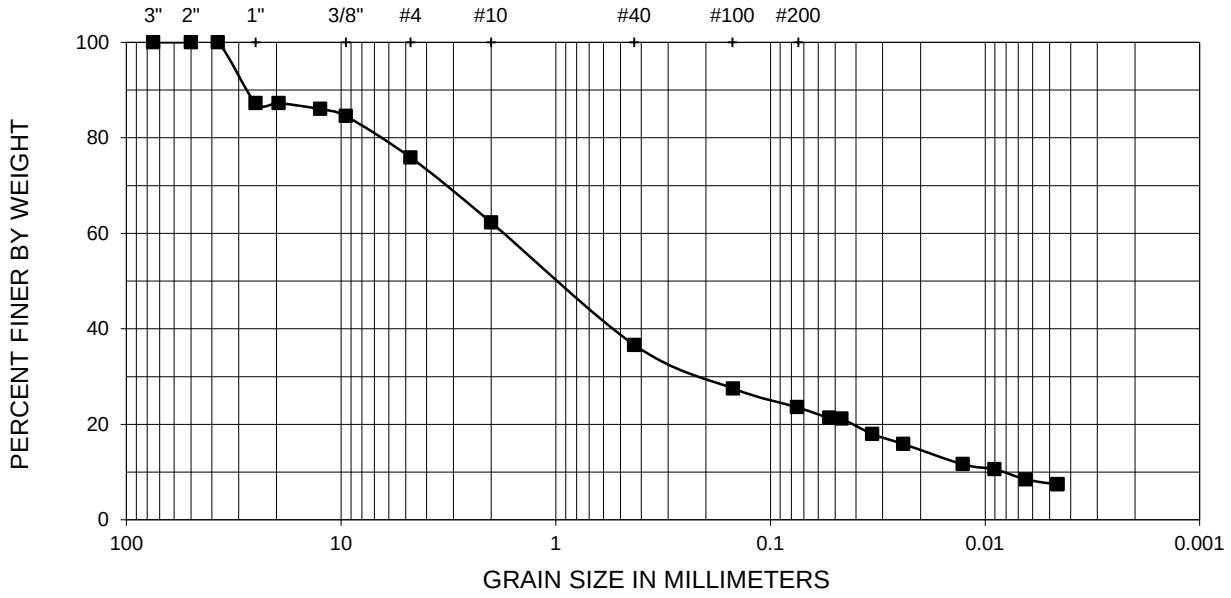
SAND AND GRAVEL DESCRIPTION

SHAPE	Angular
HARDNESS	Hard and durable

9375 CHILLICOTHE ROAD, KIRTLAND, OH 44094
PHONE: 440-256-6500 FAX: 440-256-6507

PARTICLE SIZE ANALYSIS WITH HYDROMETER ASTM D422

PROJECT INFORMATION		SAMPLE INFORMATION		
Project:	NPS Cuyahoga Valley Stream Bank Stab.	***ASTM Description***	Silty sand	SM
Location:	Cuyahoga and Summit County, Ohio			
Project #:	086138.00	***OHIO Modified AASHTO***	Gravel and/or stone fragments with sand	A-1-b (0)
Test Date:	April 1, 2021			
Sample #:	SB4	***Sample Location***	MMT-3; 8.5' - 10'	



SIEVE ANALYSIS

Sieve #	Sieve size, mm	Percent Passing
3"	75	100.0
2"	50	100.0
1-1/2"	37.5	100.0
1"	25	87.3
3/4"	19	87.3
3/8"	9.5	84.6
#4	4.75	75.9
#10	2	62.3
#40	0.43	36.6
#100	0.15	27.5
#200	0.074	23.6
#270	0.053	21.3

DISPERSION

Device	ASTM D422, Type A
Agent	Sodium Hexametaphosphate
Time in Agent	16 Hours

HYDROMETER ANALYSIS

Particle Size	Percent Passing
0.074 mm	23.6
0.053 mm	21.3
0.005 mm	7.7
0.0046 mm	7.4

ATTERBERG LIMITS

LIQUID LIMIT	NP
PLASTIC LIMIT	NP
PLASTICITY INDEX	NP

PARTICLE DISTRIBUTION

D_{10}	0.008	mm
D_{30}	0.200	mm
D_{50}	1.108	mm
D_{60}	1.745	mm
C_c	2.78	
C_u	211.81	

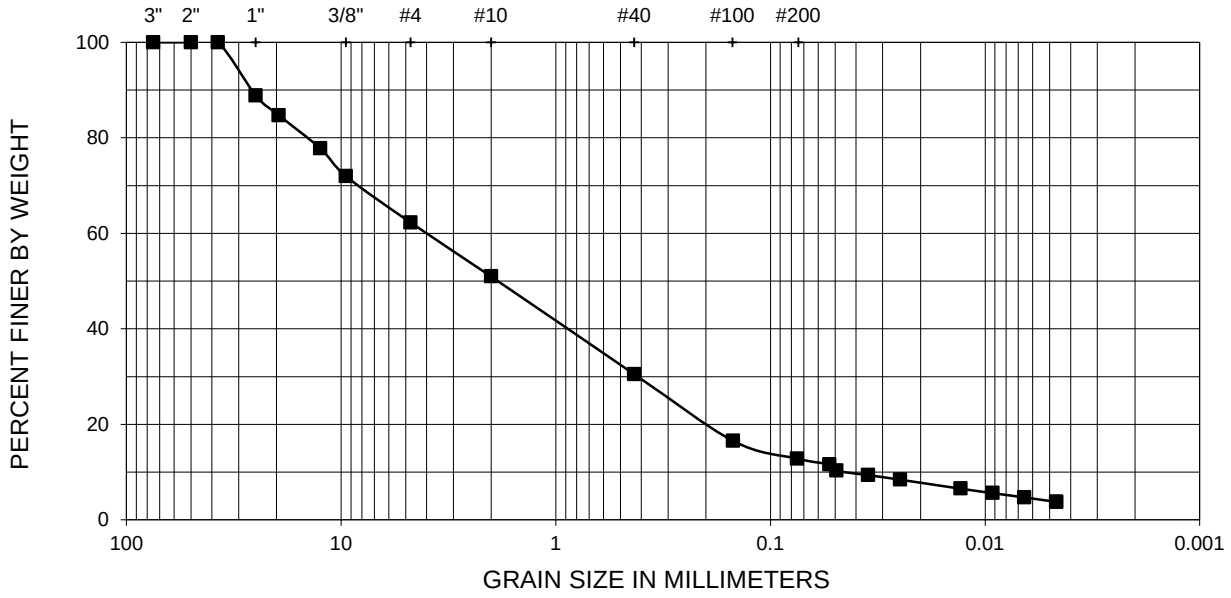
SAND AND GRAVEL DESCRIPTION

SHAPE	Angular
HARDNESS	Hard and durable

9375 CHILLICOTHE ROAD, KIRTLAND, OH 44094
PHONE: 440-256-6500 FAX: 440-256-6507

PARTICLE SIZE ANALYSIS WITH HYDROMETER ASTM D422

PROJECT INFORMATION		SAMPLE INFORMATION		
Project:	NPS Cuyahoga Valley Stream Bank Stab.	***ASTM Description***	Silty sand	SM
Location:	Cuyahoga and Summit County, Ohio			
Project #:	086138.00	***OHIO Modified AASHTO***	Gravel and/or stone fragments with sand	A-1-b (0)
Test Date:	April 1, 2021			
Sample #:	SB6	***Sample Location***	MMT-3; 13.5' - 15'	



SIEVE ANALYSIS

Sieve #	Sieve size, mm	Percent Passing
3"	75	100.0
2"	50	100.0
1-1/2"	37.5	100.0
1"	25	88.9
3/4"	19	84.7
3/8"	9.5	72.0
#4	4.75	62.3
#10	2	51.0
#40	0.43	30.5
#100	0.15	16.5
#200	0.074	12.8
#270	0.053	11.6

DISPERSION

Device	ASTM D422, Type A
Agent	Sodium Hexametaphosphate
Time in Agent	16 Hours

HYDROMETER ANALYSIS

Particle Size	Percent Passing
0.074 mm	12.8
0.053 mm	11.6
0.005 mm	4.0
0.0045 mm	3.7

ATTERBERG LIMITS

LIQUID LIMIT	NP
PLASTIC LIMIT	NP
PLASTICITY INDEX	NP

PARTICLE DISTRIBUTION

D_{10}	NA	mm
D_{30}	0.415	mm
D_{50}	1.878	mm
D_{60}	3.991	mm
C_c	NA	
C_u	NA	

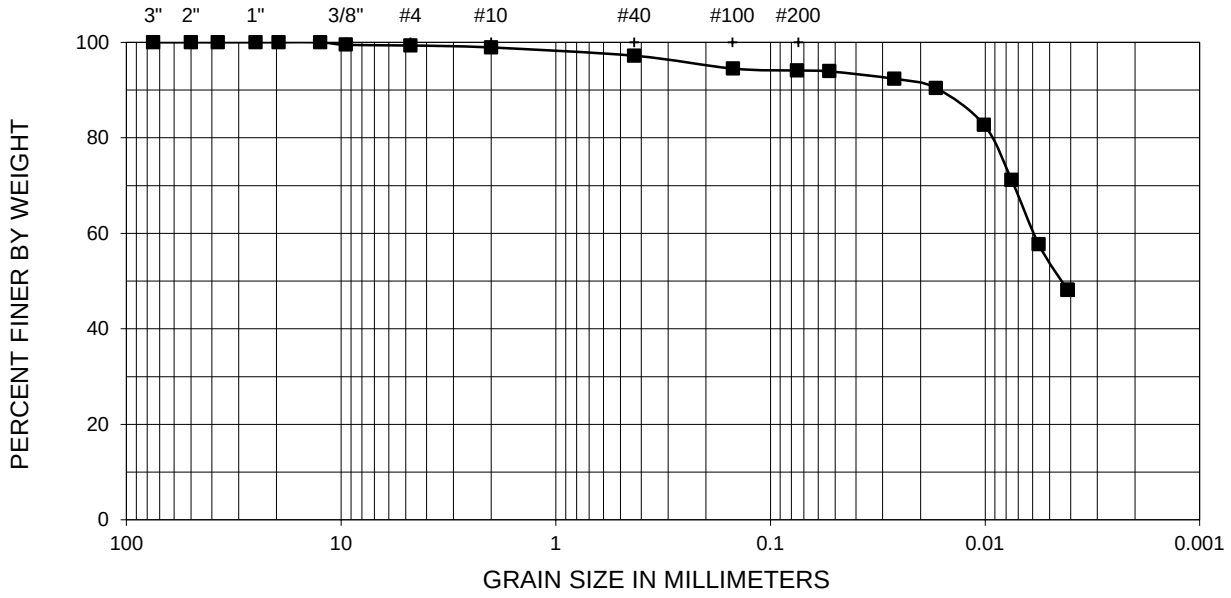
SAND AND GRAVEL DESCRIPTION

SHAPE	Angular
HARDNESS	Hard and durable

9375 CHILLICOTHE ROAD, KIRTLAND, OH 44094
PHONE: 440-256-6500 FAX: 440-256-6507

PARTICLE SIZE ANALYSIS WITH HYDROMETER ASTM D422

PROJECT INFORMATION		SAMPLE INFORMATION		
Project:	NPS Cuyahoga Valley Stream Bank Stab.	***ASTM Description***	lean clay	CL
Location:	Cuyahoga and Summit County, Ohio			
Project #:	086138.00	***OHIO Modified AASHTO***	Sandy silt	A-4a (8)
Test Date:	March 30, 2021			
Sample #:	3ST8	***Sample Location***	MMT-3; 18.5' - 20.5'	



SIEVE ANALYSIS

Sieve #	Sieve size, mm	Percent Passing
3"	75	100.0
2"	50	100.0
1-1/2"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	99.5
#4	4.75	99.3
#10	2	98.9
#40	0.43	97.2
#100	0.15	94.5
#200	0.074	94.1
#270	0.053	93.9

DISPERSION

Device	ASTM D422, Type A
Agent	Sodium Hexametaphosphate
Time in Agent	16 Hours

HYDROMETER ANALYSIS

Particle Size	Percent Passing
0.074 mm	94.1
0.053 mm	93.9
0.005 mm	54.3
0.0041 mm	48.1

ATTERBERG LIMITS

LIQUID LIMIT	29
PLASTIC LIMIT	21
PLASTICITY INDEX	8

PARTICLE DISTRIBUTION

D_{10}	NA	mm
D_{30}	NA	mm
D_{50}	0.004	mm
D_{60}	0.006	mm
C_c	NA	
C_u	NA	

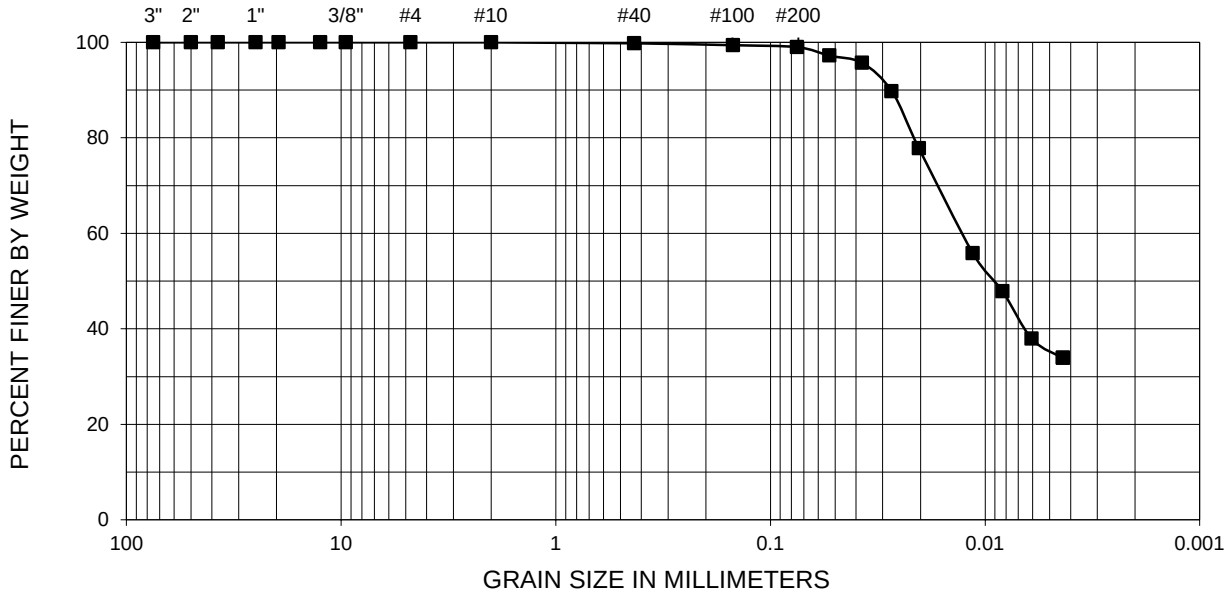
SAND AND GRAVEL DESCRIPTION

SHAPE	Angular
HARDNESS	Hard and durable

9375 CHILLICOTHE ROAD, KIRTLAND, OH 44094
PHONE: 440-256-6500 FAX: 440-256-6507

PARTICLE SIZE ANALYSIS WITH HYDROMETER ASTM D422

PROJECT INFORMATION		SAMPLE INFORMATION		
Project:	NPS Cuyahoga Valley Stream Bank Stab.	***ASTM Description***	silt	ML
Location:	Cuyahoga and Summit County, Ohio			
Project #:	086138.00	***OHIO Modified AASHTO***	Silt	A-4b (8)
Test Date:	April 1, 2021			
Sample #:	SB10	***Sample Location***	MMT-3; 28.5' - 30'	



SIEVE ANALYSIS

Sieve #	Sieve size, mm	Percent Passing
3"	75	100.0
2"	50	100.0
1-1/2"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	100.0
#4	4.75	100.0
#10	2	100.0
#40	0.43	99.8
#100	0.15	99.4
#200	0.074	99.0
#270	0.053	97.2

DISPERSION

Device	ASTM D422, Type A
Agent	Sodium Hexametaphosphate
Time in Agent	16 Hours

HYDROMETER ANALYSIS

Particle Size	Percent Passing
0.074 mm	99.0
0.053 mm	97.2
0.005 mm	35.5
0.0043 mm	33.9

ATTERBERG LIMITS

LIQUID LIMIT	NP
PLASTIC LIMIT	NP
PLASTICITY INDEX	NP

PARTICLE DISTRIBUTION

D_{10}	NA	mm
D_{30}	NA	mm
D_{50}	0.009	mm
D_{60}	0.013	mm
C_c	NA	
C_u	NA	

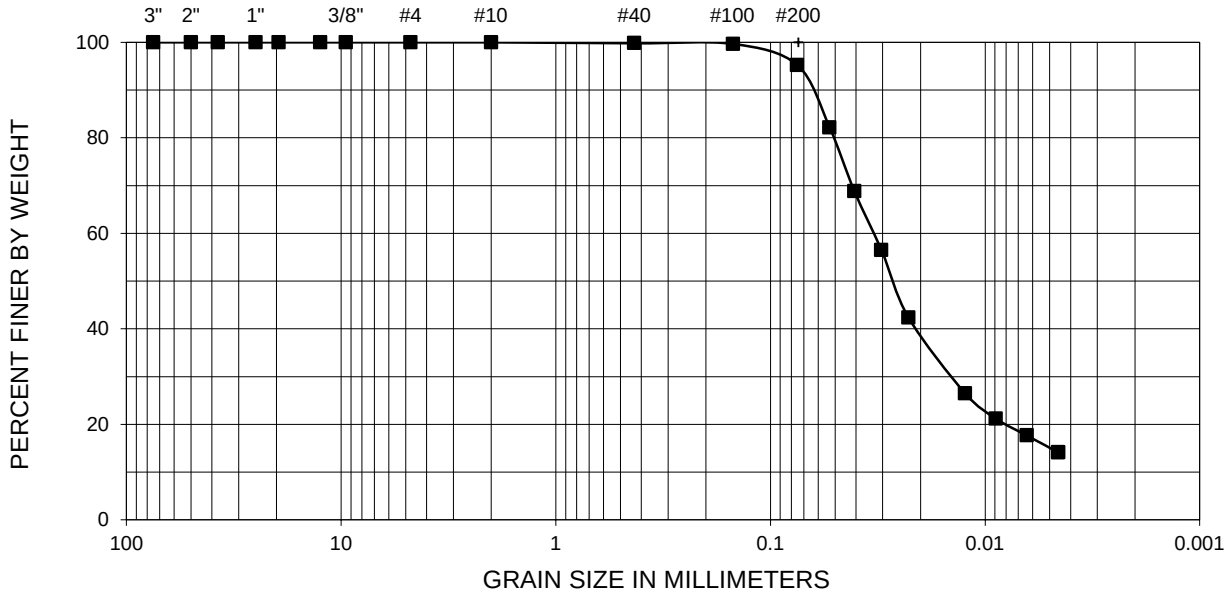
SAND AND GRAVEL DESCRIPTION

SHAPE	Angular
HARDNESS	Hard and durable

9375 CHILLICOTHE ROAD, KIRTLAND, OH 44094
PHONE: 440-256-6500 FAX: 440-256-6507

PARTICLE SIZE ANALYSIS WITH HYDROMETER ASTM D422

PROJECT INFORMATION		SAMPLE INFORMATION		
Project:	NPS Cuyahoga Valley Stream Bank Stab.	***ASTM Description***	silt	ML
Location:	Cuyahoga and Summit County, Ohio			
Project #:	086138.00	***OHIO Modified AASHTO***	Silt	A-4b (8)
Test Date:	April 1, 2021			
Sample #:	SB11	***Sample Location***	MMT-3; 33.5' - 35'	



SIEVE ANALYSIS

Sieve #	Sieve size, mm	Percent Passing
3"	75	100.0
2"	50	100.0
1-1/2"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	100.0
#4	4.75	100.0
#10	2	100.0
#40	0.43	99.8
#100	0.15	99.6
#200	0.074	95.2
#270	0.053	82.2

DISPERSION

Device	ASTM D422, Type A
Agent	Sodium Hexametaphosphate
Time in Agent	16 Hours

HYDROMETER ANALYSIS

Particle Size	Percent Passing
0.074 mm	95.2
0.053 mm	82.2
0.005 mm	15.2
0.0046 mm	14.1

ATTERBERG LIMITS

LIQUID LIMIT	NP
PLASTIC LIMIT	NP
PLASTICITY INDEX	NP

PARTICLE DISTRIBUTION

D_{10}	NA	mm
D_{30}	0.014	mm
D_{50}	0.027	mm
D_{60}	0.033	mm
C_c	NA	
C_u	NA	

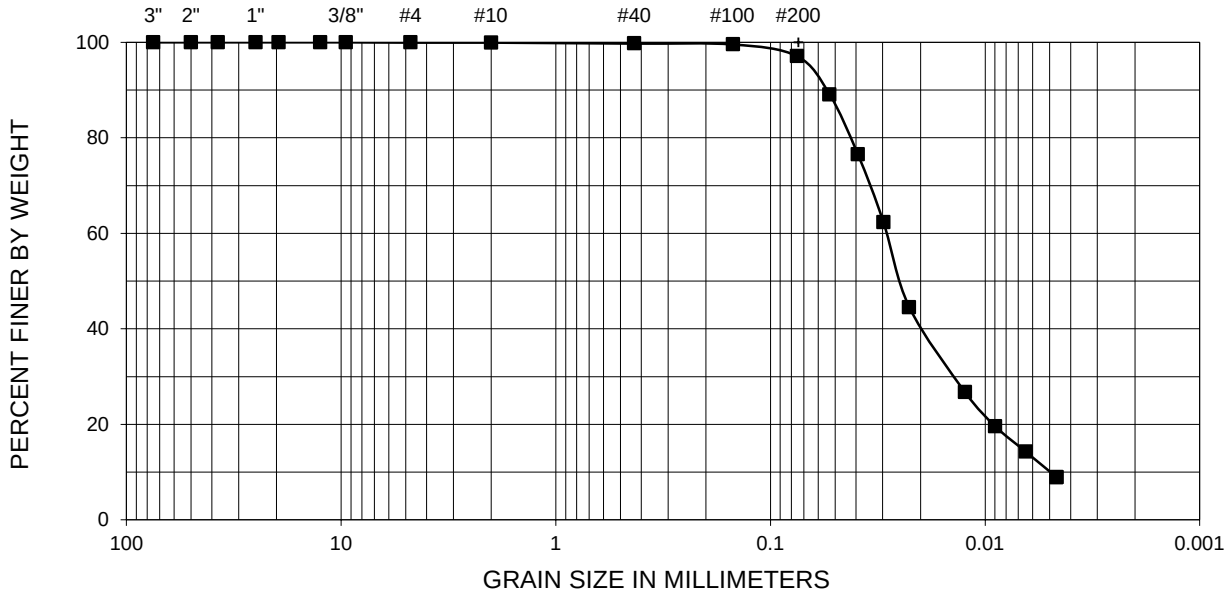
SAND AND GRAVEL DESCRIPTION

SHAPE	Angular
HARDNESS	Hard and durable

9375 CHILLICOTHE ROAD, KIRTLAND, OH 44094
PHONE: 440-256-6500 FAX: 440-256-6507

PARTICLE SIZE ANALYSIS WITH HYDROMETER ASTM D422

PROJECT INFORMATION		SAMPLE INFORMATION		
Project:	NPS Cuyahoga Valley Stream Bank Stab.	***ASTM Description***	silt	ML
Location:	Cuyahoga and Summit County, Ohio			
Project #:	086138.00	***OHIO Modified AASHTO***	Silt	A-4b (8)
Test Date:	March 30, 2021			
Sample #:	SB13	***Sample Location***	MMT-3; 43.5' - 45'	



SIEVE ANALYSIS

Sieve #	Sieve size, mm	Percent Passing
3"	75	100.0
2"	50	100.0
1-1/2"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	100.0
#4	4.75	100.0
#10	2	99.9
#40	0.43	99.8
#100	0.15	99.6
#200	0.074	97.1
#270	0.053	89.1

DISPERSION

Device	ASTM D422, Type A
Agent	Sodium Hexametaphosphate
Time in Agent	16 Hours

HYDROMETER ANALYSIS

Particle Size	Percent Passing
0.074 mm	97.1
0.053 mm	89.1
0.005 mm	10.3
0.0046 mm	8.9

ATTERBERG LIMITS

LIQUID LIMIT	NP
PLASTIC LIMIT	NP
PLASTICITY INDEX	NP

PARTICLE DISTRIBUTION

D_{10}	0.005	mm
D_{30}	0.014	mm
D_{50}	0.025	mm
D_{60}	0.029	mm
C_c	1.34	
C_u	5.77	

SAND AND GRAVEL DESCRIPTION

SHAPE	Angular
HARDNESS	Hard and durable

This report was generated by LimitState:GEO3.6.1.26217 - limitstate.com

About this Report

This report has been generated using LimitState:GEO, a software application capable of directly identifying the critical collapse mechanism for a wide variety of geotechnical stability problems, including those involving slopes, retaining walls, footings etc.

The software utilizes the Discontinuity Layout Optimization (DLO) procedure to obtain a solution (Smith and Gilbert 2007). The main steps involved are: (i) distribution of nodes across the problem domain; (ii) connection of every node to every other node with potential discontinuities (e.g. slip-lines); (iii) application of rigorous optimization techniques to identify the critical subset of potential discontinuities, and hence also the critical failure mechanism and margin of safety.

The accuracy of the DLO solution is controlled by the specified nodal density. Within the set of all possible discontinuities linking pairs of nodes, all potential translational failure mechanisms are considered, whether anticipated or not by the engineer. Failure mechanisms involving rotations along the edges of solid bodies in the problem can also be identified. Thus in this case the solution identified by the DLO procedure is guaranteed to be the most critical solution for the problem posed. This means that there is no need to prescribe any aspect of the collapse mechanism prior to an analysis, or to separately consider different failure modes. The critical mechanism and collapse load factor are determined according to the well established upper bound theorem of plasticity.

LimitState:GEO reports the solution to a problem both visually as a collapse mechanism and numerically in terms of an Adequacy Factor, which is defined as the factor by which specified loads must be increased, or material strengths decreased, in order for the system under consideration to reach a collapse state.

REFERENCE

Smith, C.C. and Gilbert, M. (2007) Application of discontinuity layout optimization to plane plasticity problems, Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences, Vol. 463, 2086, pp 2461-2484.

Summary

Name	Date of Analysis	Name of Engineer	Organization
CUVA Bank Stabilization	Tue Aug 8 2023	GPD User	GPD Group

Reference #	Location	Map Reference	Tags
2022281.00	Tow Path Trail Mile Marker 20, Sagamore Hills Township, Summit County, Ohio		

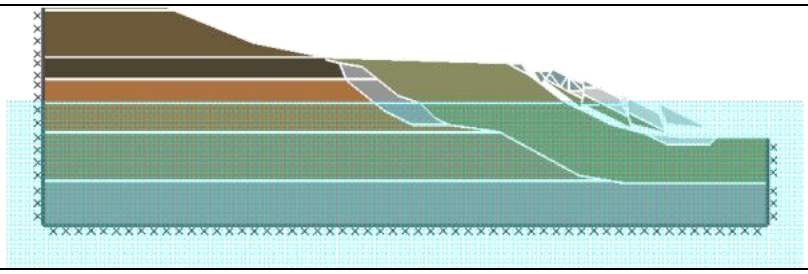
Comments
STA 640+50 LT

Target Nodal Density	Nodal Spacing Scale Factor	Water	Model Translational Failures?	Model Rotational Failures?	Seismic Accelerations: Horiz. / Vert. (g)
Fine (1000 nodes)	1.44124	Enabled	True	Along edges	None

Scenario	Partial Factor Set	Short / Long Term?**	Analysis Type	Adequacy Factor
1*	**Unity**	**Long Term**	**Factor Strength(s)**	**1.548**

**This report provides details of this scenario, which has been identified as the most critical.*

***For Mohr Coulomb materials with Drainage Behaviour specified as 'drained/undrained', undrained properties are used in a short term analysis, and drained properties are used in a long term analysis.*

Failure Mechanism (Scenario 1)


Analysis Options

Factor Strength(s)

Solution Tolerance (%)	Automatic Adequacy on Load(s)	Factor on Load(s)	Artificial Cohesion (kN/m² (kPa))
1	True	1	0.1

Geometry

(all distances in ft)

All Geometrical Objects

No. of Vertices (V)	No. of Boundaries (B)	No. of Solids (S)
45	59	11

Boundary Objects

ID	Start Vertex ID (x, y)	End Vertex ID (x, y)	Baseline Nodal Spacing	Support Type	Material(s)
B1	V1 (-121.391, 623.36)	V110 (-20.0131, 623.36)	1.64042	Fixed	-
B7	V5 (-101.706, 656.168)	V7 (-121.391, 656.168)	1.64042	Free	-
B8	V1 (-121.391, 623.36)	V28 (-121.391, 623.36)	1.64042	Fixed	-
B14	V9 (-68.8976, 623.36)	V122 (-72.1785, 623.36)	1.64042	Free	-
B15	V14 (-121.391, 656.168)	V15 (-101.706, 656.168)	1.64042	Free	-
B16	V14 (-121.391, 656.168)	V7 (-121.391, 656.168)	1.64042	Fixed	-
B17	V15 (-101.706, 656.168)	V5 (-101.706, 656.168)	1.64042	Free	-
B18	V16 (-121.391, 656.168)	V17 (-82.021, 656.168)	1.64042	Free	-
B19	V16 (-121.391, 656.168)	V14 (-121.391, 656.168)	1.64042	Fixed	-

B20	V17 (-82.021, 656.168)	V120 (-91.8635, 656.168)	1.64042	Free	-
B21	V18 (-121.391, 656.168)	V135 (-78.7402, 656.168)	1.64042	Free	-
B22	V18 (-121.391, 656.168)	V16 (-121.391, 656.168)	1.64042	Fixed	-
B23	V19 (-72.1785, 656.168)	V121 (-75.4593, 656.168)	1.64042	Free	-
B30	V28 (-121.391, 623.36)	V109 (-39.3701, 623.36)	1.64042	Free	-
B31	V28 (-121.391, 623.36)	V70 (-121.391, 623.36)	1.64042	Fixed	-
B66	V70 (-121.391, 623.36)	V71 (-55.7743, 623.36)	1.64042	Free	-
B67	V70 (-121.391, 623.36)	V202 (-121.391, 623.36)	1.64042	Fixed	-
B68	V71 (-55.7743, 623.36)	V124 (-65.6168, 623.36)	1.64042	Free	-
B82	V84 (-45.9318, 623.36)	V71 (-55.7743, 623.36)	1.64042	Free	-
B99	V101 (-65.6168, 623.36)	V9 (-68.8976, 623.36)	1.64042	Free	-
B106	V84 (-45.9318, 623.36)	V109 (-39.3701, 623.36)	1.64042	Free	-
B109	V109 (-39.3701, 623.36)	V126 (-20.0131, 623.36)	1.64042	Free	-
B116	V120 (-91.8635, 656.168)	V15 (-101.706, 656.168)	1.64042	Free	-
B117	V121 (-75.4593, 656.168)	V137 (-78.7402, 656.168)	1.64042	Free	-
B118	V122 (-72.1785, 623.36)	V19 (-72.1785, 656.168)	1.64042	Free	-
B120	V124 (-65.6168, 623.36)	V101 (-65.6168, 623.36)	1.64042	Free	-
B122	V126 (-20.0131, 623.36)	V110 (-20.0131, 623.36)	1.64042	Fixed	-
B131	V124 (-65.6168, 623.36)	V136 (-68.8976, 623.36)	1.64042	Free	-
B132	V135 (-78.7402, 656.168)	V19 (-72.1785, 656.168)	1.64042	Free	-
B133	V136 (-68.8976, 623.36)	V138 (-72.1785, 623.36)	1.64042	Free	-
B134	V135 (-78.7402, 656.168)	V137 (-78.7402, 656.168)	1.64042	Free	-
B135	V137 (-78.7402, 656.168)	V17 (-82.021, 656.168)	1.64042	Free	-
B136	V138 (-72.1785, 623.36)	V204 (-75.4593, 623.36)	1.64042	Free	-
B149	V17 (-82.021, 656.168)	V174 (-55.7743, 656.168)	1.64042	Free	-
B151	V151 (-20.0131, 623.36)	V176 (-26.9029, 623.36)	1.64042	Free	-
B152	V152 (-32.1522, 623.36)	V211 (-42.6509, 623.36)	1.64042	Free	-
B178	V126 (-20.0131, 623.36)	V151 (-20.0131, 623.36)	1.64042	Fixed	-
B179	V174 (-55.7743, 656.168)	V150 (-52.4934, 656.168)	1.64042	Free	-
B180	V175 (-32.8084, 623.36)	V212 (-45.9318, 623.36)	1.64042	Free	-
B181	V176 (-26.9029, 623.36)	V177 (-27.8871, 623.36)	1.64042	Free	-
B182	V176 (-26.9029, 623.36)	V152 (-32.1522, 623.36)	1.64042	Free	-
B183	V177 (-27.8871, 623.36)	V175 (-32.8084, 623.36)	1.64042	Free	-

B184	V178 (-45.9318, 623.36)	V179 (-49.2126, 623.36)	1.64042	Free	-
B185	V178 (-45.9318, 623.36)	V150 (-52.4934, 656.168)	1.64042	Free	-
B186	V179 (-49.2126, 623.36)	V174 (-55.7743, 656.168)	1.64042	Free	-
B215	V202 (-121.391, 623.36)	V18 (-121.391, 656.168)	1.64042	Fixed	-
B216	V204 (-75.4593, 623.36)	V135 (-78.7402, 656.168)	1.64042	Free	-
B217	V205 (-88.5827, 623.36)	V204 (-75.4593, 623.36)	0.82021	Free	-
B218	V206 (-91.8635, 623.36)	V205 (-88.5827, 623.36)	0.82021	Free	-
B219	V207 (-98.4252, 623.36)	V206 (-91.8635, 623.36)	0.82021	Free	-
B220	V208 (-98.4252, 623.36)	V207 (-98.4252, 623.36)	0.82021	Free	-
B221	V209 (-111.549, 623.36)	V208 (-98.4252, 623.36)	0.82021	Free	-
B222	V202 (-121.391, 623.36)	V209 (-111.549, 623.36)	0.82021	Free	-
B223	V210 (-68.8976, 623.36)	V9 (-68.8976, 623.36)	0.82021	Free	-
B224	V204 (-75.4593, 623.36)	V210 (-68.8976, 623.36)	0.82021	Free	-
B225	V211 (-42.6509, 623.36)	V178 (-45.9318, 623.36)	1.64042	Free	-
B226	V212 (-45.9318, 623.36)	V179 (-49.2126, 623.36)	1.64042	Free	-
B227	V212 (-45.9318, 623.36)	V211 (-42.6509, 623.36)	0.82021	Free	-
B228	V9 (-68.8976, 623.36)	V212 (-45.9318, 623.36)	0.82021	Free	-

** Loaded boundary.*

Solid Objects

ID	Vertex IDs (x, y)	Boundary IDs	Baseline Nodal Spacing (x / y)	Material(s)/Water Regime(s)
S12*	V15 (-101.706,656.168) V5 (-101.706,656.168) V7 (-121.391,656.168) V14 (-121.391,656.168)	B17 B7 B16 B15	3.28084 / 3.28084	Topsoil
S15*	V17 (-82.021,656.168) V120 (-91.8635,656.168) V15 (-101.706,656.168) V14 (-121.391,656.168) V16 (-121.391,656.168)	B20 B116 B15 B19 B18	3.28084 / 3.28084	S MC
S48*	V84 (-45.9318,623.36) V71 (-55.7743,623.36) V70 (-121.391,623.36) V28 (-121.391,623.36) V109 (-39.3701,623.36)	B82 B66 B31 B30 B106	3.28084 / 3.28084	VL-L M-C S-G
S50*	V109 (-39.3701,623.36) V28 (-121.391,623.36) V1 (-121.391,623.36) V110 (-20.0131,623.36) V126 (-20.0131,623.36)	B30 B8 B1 B122 B109	3.28084 / 3.28084	L F-C S-G
S57*	V137 (-78.7402,656.168) V17 (-82.021,656.168) V16 (-121.391,656.168) V18 (-121.391,656.168)	B135 B18 B22 B21	3.28084 / 3.28084	MST MC

	V135 (-78.7402,656.168)	B134		
S58*	V135 (-78.7402,656.168) V19 (-72.1785,656.168) V121 (-75.4593,656.168) V137 (-78.7402,656.168)	B132 B23 B117 B134	3.28084 / 3.28084	ODOT Type B LS
S80*	V179 (-49.2126,623.36) V174 (-55.7743,656.168) V150 (-52.4934,656.168) V178 (-45.9318,623.36)	B186 B179 B185 B184	3.28084 / 3.28084	Slope Protection
S55	V135 (-78.7402,656.168) V18 (-121.391,656.168) V202 (-121.391,623.36) V70 (-121.391,623.36) V71 (-55.7743,623.36) V124 (-65.6168,623.36) V136 (-68.8976,623.36) V138 (-72.1785,623.36) V204 (-75.4593,623.36)	B21 B215 B67 B66 B68 B131 B133 B136 B216	3.28084 / 3.28084	MD M-C S-G
S56	V124 (-65.6168,623.36) V101 (-65.6168,623.36) V9 (-68.8976,623.36) V122 (-72.1785,623.36) V19 (-72.1785,656.168) V135 (-78.7402,656.168) V204 (-75.4593,623.36) V138 (-72.1785,623.36) V136 (-68.8976,623.36)	B120 B99 B14 B118 B132 B216 B136 B133 B131	3.28084 / 3.28084	ODOT Type B LS
S81	V178 (-45.9318,623.36) V211 (-42.6509,623.36) V152 (-32.1522,623.36) V176 (-26.9029,623.36) V177 (-27.8871,623.36) V175 (-32.8084,623.36) V212 (-45.9318,623.36) V179 (-49.2126,623.36)	B225 B152 B182 B181 B183 B180 B226 B184	3.28084 / 3.28084	Toe Protection
S82	V126 (-20.0131,623.36) V109 (-39.3701,623.36) V84 (-45.9318,623.36) V71 (-55.7743,623.36) V124 (-65.6168,623.36) V101 (-65.6168,623.36) V9 (-68.8976,623.36) V122 (-72.1785,623.36) V19 (-72.1785,656.168) V121 (-75.4593,656.168) V137 (-78.7402,656.168) V17 (-82.021,656.168) V174 (-55.7743,656.168) V179 (-49.2126,623.36) V212 (-45.9318,623.36) V175 (-32.8084,623.36) V177 (-27.8871,623.36) V176 (-26.9029,623.36) V151 (-20.0131,623.36)	B109 B106 B82 B68 B120 B99 B14 B118 B23 B117 B135 B149 B186 B226 B180 B183 B181 B151 B178	3.28084 / 3.28084	Bankrun

** Loaded solid (self weight).*

Water Table

(all distances in ft)

Water Table Status	Vertices (x, y)
Enabled	(-120, 637) (-110, 637) (-100, 637) (-97, 637) (-93, 637) (-90, 637) (-70, 637)

Water Regimes

(potentials in ft, pressures in psf (lb/ft²))

(No water regime defined)

Materials

(unit weights (weight densities) in pcf (lb/ft³), strengths in psf (lb/ft²), angles in degrees, datum level in ft, undrained strength gradient in psf (lb/ft²)/ft)

Mohr-Coulomb Material(s)

Key	Name	Unit Weight (Saturated Unit Weight)	Drainage Behaviour	c' (ϕ')	c_u (datum) (gradient) (grid)
	Topsoil	95 (110)	Drained/undrained	200* (20*)	2000 (0) (0) (-)
	S MC	120 (135)	Drained/undrained	100* (24*)	1000 (0) (0) (-)
	VL-L M-C S-G	120 (135)	Always drained	115* (24*)	1150 (0) (0) (-)
	L F-C S-G	125 (150)	Always drained	10* (30*)	100 (0) (0) (-)
	MST MC	120 (135)	Drained/undrained	120* (26*)	1200 (0) (0) (-)
	ODOT Type B LS	135 (150)	Always drained	10* (40*)	0 (0) (0) (-)
	Slope Protection	130 (150)	Always drained	10* (40*)	0 (0) (0) (-)
	MD M-C S-G	120 (145)	Always drained	10* (30*)	100 (0) (0) (-)
	Toe Protection	130 (140)	Always drained	10* (45*)	0 (0) (0) (-)
	Bankrun	120 (135)	Always drained	10* (32*)	0 (0) (0) (-)

**Property used in Scenario 1 (described in this report).*

Partial Factors

Factor	Unity*			
Unfavourable: permanent	1			
Unfavourable: variable	1			
Unfavourable: accidental	1			
Favourable: permanent	1			
Favourable: variable	1			

Favourable: accidental	1			
c'	1			
tanϕ'	1			
c_u	1			

**These partial factors were used in Scenario 1 (described in this report).*

Loads

(normal and shear loads in psf (lb/ft²))

Solid Objects

Loaded Object	Type	Loading Type	Adequacy?
S12	Permanent (unfactored self weight: 95 pcf (lb/ft³))	neutral	true
S15	Permanent (unfactored self weight: 120 pcf (lb/ft³))	neutral	true
S48	Permanent (unfactored self weight: 135 pcf (lb/ft³))	neutral	true
S50	Permanent (unfactored self weight: 150 pcf (lb/ft³))	neutral	true
S57	Permanent (unfactored self weight: 120 pcf (lb/ft³))	neutral	true
S58	Permanent (unfactored self weight: 135 pcf (lb/ft³))	neutral	true
S80	Permanent (unfactored self weight: 130 pcf (lb/ft³))	neutral	true
S99	Permanent (unfactored self weight: 145 pcf (lb/ft³))	neutral	true
S100	Permanent (unfactored self weight: 120 pcf (lb/ft³))	neutral	true
S101	Permanent (unfactored self weight: 150 pcf (lb/ft³))	neutral	true
S102	Permanent (unfactored self weight: 135 pcf (lb/ft³))	neutral	true
S103	Permanent (unfactored self weight: 140 pcf (lb/ft³))	neutral	true
S104	Permanent (unfactored self weight: 130 pcf (lb/ft³))	neutral	true
S105	Permanent (unfactored self weight: 135 pcf (lb/ft³))	neutral	true
S106	Permanent (unfactored self weight: 120 pcf (lb/ft³))	neutral	true

This report was generated by LimitState:GEO3.6.1.26217 - limitstate.com

About this Report

This report has been generated using LimitState:GEO, a software application capable of directly identifying the critical collapse mechanism for a wide variety of geotechnical stability problems, including those involving slopes, retaining walls, footings etc.

The software utilizes the Discontinuity Layout Optimization (DLO) procedure to obtain a solution (Smith and Gilbert 2007). The main steps involved are: (i) distribution of nodes across the problem domain; (ii) connection of every node to every other node with potential discontinuities (e.g. slip-lines); (iii) application of rigorous optimization techniques to identify the critical subset of potential discontinuities, and hence also the critical failure mechanism and margin of safety.

The accuracy of the DLO solution is controlled by the specified nodal density. Within the set of all possible discontinuities linking pairs of nodes, all potential translational failure mechanisms are considered, whether anticipated or not by the engineer. Failure mechanisms involving rotations along the edges of solid bodies in the problem can also be identified. Thus in this case the solution identified by the DLO procedure is guaranteed to be the most critical solution for the problem posed. This means that there is no need to prescribe any aspect of the collapse mechanism prior to an analysis, or to separately consider different failure modes. The critical mechanism and collapse load factor are determined according to the well established upper bound theorem of plasticity.

LimitState:GEO reports the solution to a problem both visually as a collapse mechanism and numerically in terms of an Adequacy Factor, which is defined as the factor by which specified loads must be increased, or material strengths decreased, in order for the system under consideration to reach a collapse state.

REFERENCE

Smith, C.C. and Gilbert, M. (2007) Application of discontinuity layout optimization to plane plasticity problems, Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences, Vol. 463, 2086, pp 2461-2484.

Summary

Name	Date of Analysis	Name of Engineer	Organization
CUVA Bank Stabilization	Tue Aug 8 2023	GPD User	GPD Group

Reference #	Location	Map Reference	Tags
2022281.00	Tow Path Trail Mile Marker 20, Sagamore Hills Township, Summit County, Ohio		

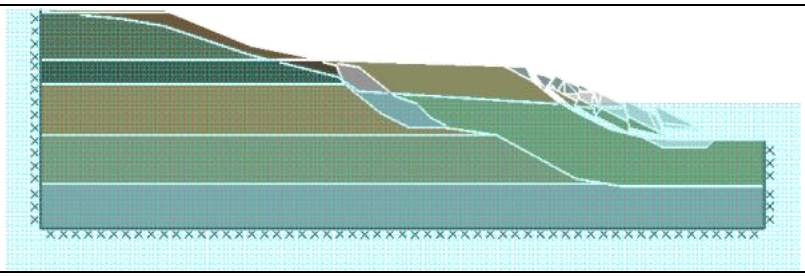
Comments
STA 640+50 ST Rapid Drawdown

Target Nodal Density	Nodal Spacing Scale Factor	Water	Model Translational Failures?	Model Rotational Failures?	Seismic Accelerations: Horiz. / Vert. (g)
Fine (1000 nodes)	1.44635	Enabled	True	Along edges	None

Scenario	Partial Factor Set	Short / Long Term?**	Analysis Type	Adequacy Factor
1*	**Unity**	**Short Term**	**Factor Strength(s)**	**1.535**

**This report provides details of this scenario, which has been identified as the most critical.*

***For Mohr Coulomb materials with Drainage Behaviour specified as 'drained/undrained', undrained properties are used in a short term analysis, and drained properties are used in a long term analysis.*

Failure Mechanism (Scenario 1)


Analysis Options

Factor Strength(s)

Solution Tolerance (%)	Automatic Adequacy on Load(s)	Factor on Load(s)	Artificial Cohesion (kN/m² (kPa))
1	True	1	0.1

Geometry

(all distances in ft)

All Geometrical Objects

No. of Vertices (V)	No. of Boundaries (B)	No. of Solids (S)
46	61	10

Boundary Objects

ID	Start Vertex ID (x, y)	End Vertex ID (x, y)	Baseline Nodal Spacing	Support Type	Material(s)
B1	V1 (-121.391, 623.36)	V110 (-20.0131, 623.36)	1.64042	Fixed	-
B7	V5 (-101.706, 656.168)	V7 (-121.391, 656.168)	1.64042	Free	-
B8	V1 (-121.391, 623.36)	V28 (-121.391, 623.36)	1.64042	Fixed	-
B14	V9 (-68.8976, 623.36)	V122 (-72.1785, 623.36)	1.64042	Free	-
B15	V14 (-121.391, 656.168)	V225 (-114.829, 656.168)	1.64042	Free	-
B16	V14 (-121.391, 656.168)	V7 (-121.391, 656.168)	1.64042	Fixed	-
B17	V15 (-101.706, 656.168)	V5 (-101.706, 656.168)	1.64042	Free	-
B18	V16 (-121.391, 656.168)	V226 (-88.5827, 656.168)	1.64042	Free	-
B19	V16 (-121.391, 656.168)	V14 (-121.391, 656.168)	1.64042	Fixed	-

B20	V17 (-82.021, 656.168)	V120 (-91.8635, 656.168)	1.64042	Free	-
B21	V18 (-121.391, 656.168)	V135 (-78.7402, 656.168)	1.64042	Free	-
B22	V18 (-121.391, 656.168)	V16 (-121.391, 656.168)	1.64042	Fixed	-
B30	V28 (-121.391, 623.36)	V109 (-39.3701, 623.36)	1.64042	Free	-
B31	V28 (-121.391, 623.36)	V70 (-121.391, 623.36)	1.64042	Fixed	-
B66	V70 (-121.391, 623.36)	V71 (-55.7743, 623.36)	1.64042	Free	-
B67	V70 (-121.391, 623.36)	V18 (-121.391, 656.168)	1.64042	Fixed	-
B68	V71 (-55.7743, 623.36)	V124 (-65.6168, 623.36)	1.64042	Free	-
B82	V84 (-45.9318, 623.36)	V71 (-55.7743, 623.36)	1.64042	Free	-
B99	V101 (-65.6168, 623.36)	V9 (-68.8976, 623.36)	1.64042	Free	-
B106	V84 (-45.9318, 623.36)	V109 (-39.3701, 623.36)	1.64042	Free	-
B109	V109 (-39.3701, 623.36)	V126 (-20.0131, 623.36)	1.64042	Free	-
B116	V120 (-91.8635, 656.168)	V15 (-101.706, 656.168)	1.64042	Free	-
B117	V121 (-75.4593, 656.168)	V137 (-78.7402, 656.168)	1.64042	Free	-
B118	V122 (-72.1785, 623.36)	V235 (-72.1785, 623.36)	1.64042	Free	-
B120	V124 (-65.6168, 623.36)	V101 (-65.6168, 623.36)	1.64042	Free	-
B122	V126 (-20.0131, 623.36)	V110 (-20.0131, 623.36)	1.64042	Fixed	-
B131	V124 (-65.6168, 623.36)	V136 (-68.8976, 623.36)	1.64042	Free	-
B133	V136 (-68.8976, 623.36)	V138 (-72.1785, 623.36)	1.64042	Free	-
B134	V135 (-78.7402, 656.168)	V230 (-78.7402, 656.168)	1.64042	Free	-
B135	V137 (-78.7402, 656.168)	V17 (-82.021, 656.168)	1.64042	Free	-
B136	V138 (-72.1785, 623.36)	V135 (-78.7402, 656.168)	1.64042	Free	-
B149	V17 (-82.021, 656.168)	V174 (-55.7743, 656.168)	1.64042	Free	-
B151	V151 (-20.0131, 623.36)	V176 (-26.9029, 623.36)	1.64042	Free	-
B152	V152 (-32.1522, 623.36)	V233 (-42.6509, 623.36)	1.64042	Free	-
B178	V126 (-20.0131, 623.36)	V151 (-20.0131, 623.36)	1.64042	Fixed	-
B179	V174 (-55.7743, 656.168)	V150 (-52.4934, 656.168)	1.64042	Free	-
B180	V175 (-32.8084, 623.36)	V232 (-45.9318, 623.36)	1.64042	Free	-
B181	V176 (-26.9029, 623.36)	V177 (-27.8871, 623.36)	1.64042	Free	-
B182	V176 (-26.9029, 623.36)	V152 (-32.1522, 623.36)	1.64042	Free	-
B183	V177 (-27.8871, 623.36)	V175 (-32.8084, 623.36)	1.64042	Free	-
B184	V178 (-45.9318, 623.36)	V179 (-49.2126, 623.36)	1.64042	Free	-
B185	V178 (-45.9318, 623.36)	V150 (-52.4934, 656.168)	1.64042	Free	-

B186	V179 (-49.2126, 623.36)	V174 (-55.7743, 656.168)	1.64042	Free	-
B247	V225 (-114.829, 656.168)	V15 (-101.706, 656.168)	1.64042	Free	-
B248	V7 (-121.391, 656.168)	V225 (-114.829, 656.168)	0.82021	Free	-
B249	V226 (-88.5827, 656.168)	V17 (-82.021, 656.168)	1.64042	Free	-
B250	V227 (-91.8635, 656.168)	V226 (-88.5827, 656.168)	0.82021	Free	-
B251	V228 (-101.706, 656.168)	V227 (-91.8635, 656.168)	0.82021	Free	-
B252	V229 (-108.268, 656.168)	V228 (-101.706, 656.168)	0.82021	Free	-
B253	V225 (-114.829, 656.168)	V229 (-108.268, 656.168)	0.82021	Free	-
B254	V230 (-78.7402, 656.168)	V137 (-78.7402, 656.168)	1.64042	Free	-
B255	V231 (-78.7402, 656.168)	V230 (-78.7402, 656.168)	0.82021	Free	-
B256	V226 (-88.5827, 656.168)	V231 (-78.7402, 656.168)	0.82021	Free	-
B257	V232 (-45.9318, 623.36)	V179 (-49.2126, 623.36)	1.64042	Free	-
B258	V233 (-42.6509, 623.36)	V178 (-45.9318, 623.36)	1.64042	Free	-
B259	V232 (-45.9318, 623.36)	V234 (-42.6509, 623.36)	0.82021	Free	-
B260	V234 (-42.6509, 623.36)	V233 (-42.6509, 623.36)	0.82021	Free	-
B261	V235 (-72.1785, 623.36)	V121 (-75.4593, 656.168)	1.64042	Free	-
B262	V235 (-72.1785, 623.36)	V232 (-45.9318, 623.36)	0.82021	Free	-
B263	V236 (-75.4593, 623.36)	V235 (-72.1785, 623.36)	0.82021	Free	-
B264	V230 (-78.7402, 656.168)	V236 (-75.4593, 623.36)	0.82021	Free	-

** Loaded boundary.*

Solid Objects

ID	Vertex IDs (x, y)	Boundary IDs	Baseline Nodal Spacing (x / y)	Material(s)/Water Regime(s)
S48*	V84 (-45.9318,623.36) V71 (-55.7743,623.36) V70 (-121.391,623.36) V28 (-121.391,623.36) V109 (-39.3701,623.36)	B82 B66 B31 B30 B106	3.28084 / 3.28084	VL-L M-C S-G
S50*	V109 (-39.3701,623.36) V28 (-121.391,623.36) V1 (-121.391,623.36) V110 (-20.0131,623.36) V126 (-20.0131,623.36)	B30 B8 B1 B122 B109	3.28084 / 3.28084	L F-C S-G
S80*	V179 (-49.2126,623.36) V174 (-55.7743,656.168) V150 (-52.4934,656.168) V178 (-45.9318,623.36)	B186 B179 B185 B184	3.28084 / 3.28084	Slope Protection
S55*	V135 (-78.7402,656.168) V18 (-121.391,656.168) V70 (-121.391,623.36) V71 (-55.7743,623.36) V124 (-65.6168,623.36)	B21 B67 B66 B68 B131	3.28084 / 3.28084	MD M-C S-G

	V136 (-68.8976,623.36) V138 (-72.1785,623.36)	B133 B136		
S12	V15 (-101.706,656.168) V5 (-101.706,656.168) V7 (-121.391,656.168) V14 (-121.391,656.168) V225 (-114.829,656.168)	B17 B7 B16 B15 B247	3.28084 / 3.28084	Topsoil
S15	V17 (-82.021,656.168) V120 (-91.8635,656.168) V15 (-101.706,656.168) V225 (-114.829,656.168) V14 (-121.391,656.168) V16 (-121.391,656.168) V226 (-88.5827,656.168)	B20 B116 B247 B15 B19 B18 B249	3.28084 / 3.28084	S MC
S57	V137 (-78.7402,656.168) V17 (-82.021,656.168) V226 (-88.5827,656.168) V16 (-121.391,656.168) V18 (-121.391,656.168) V135 (-78.7402,656.168) V230 (-78.7402,656.168)	B135 B249 B18 B22 B21 B134 B254	3.28084 / 3.28084	MST MC
S81	V178 (-45.9318,623.36) V233 (-42.6509,623.36) V152 (-32.1522,623.36) V176 (-26.9029,623.36) V177 (-27.8871,623.36) V175 (-32.8084,623.36) V232 (-45.9318,623.36) V179 (-49.2126,623.36)	B258 B152 B182 B181 B183 B180 B257 B184	3.28084 / 3.28084	Toe Protection
S82	V126 (-20.0131,623.36) V109 (-39.3701,623.36) V84 (-45.9318,623.36) V71 (-55.7743,623.36) V124 (-65.6168,623.36) V101 (-65.6168,623.36) V9 (-68.8976,623.36) V122 (-72.1785,623.36) V235 (-72.1785,623.36) V121 (-75.4593,656.168) V137 (-78.7402,656.168) V17 (-82.021,656.168) V174 (-55.7743,656.168) V179 (-49.2126,623.36) V232 (-45.9318,623.36) V175 (-32.8084,623.36) V177 (-27.8871,623.36) V176 (-26.9029,623.36) V151 (-20.0131,623.36)	B109 B106 B82 B68 B120 B99 B14 B118 B261 B117 B135 B149 B186 B257 B180 B183 B181 B151 B178	3.28084 / 3.28084	Bankrun
S107	V121 (-75.4593,656.168) V137 (-78.7402,656.168) V230 (-78.7402,656.168) V135 (-78.7402,656.168) V138 (-72.1785,623.36) V136 (-68.8976,623.36) V124 (-65.6168,623.36) V101 (-65.6168,623.36) V9 (-68.8976,623.36) V122 (-72.1785,623.36) V235 (-72.1785,623.36)	B117 B254 B134 B136 B133 B131 B120 B99 B14 B118 B261	3.28084 / 3.28084	ODOT Type B LS

** Loaded solid (self weight).*

Water Table

(all distances in ft)

Water Table Status	Vertices (x, y)
Enabled	(-120, 650) (-109, 649) (-103, 648) (-91, 644) (-79, 641) (-76, 639) (-44, 637)

Water Regimes

(potentials in ft, pressures in psf (lb/ft²))

(No water regime defined)

Materials

(unit weights (weight densities) in pcf (lb/ft³), strengths in psf (lb/ft²), angles in degrees, datum level in ft, undrained strength gradient in psf (lb/ft²)/ft)

Mohr-Coulomb Material(s)

Key	Name	Unit Weight (Saturated Unit Weight)	Drainage Behaviour	c' (ϕ')	c_u (datum) (gradient) (grid)
	VL-L M-C S-G	120 (135)	Always drained	115* (24*)	1150 (0) (0) (-)
	L F-C S-G	125 (150)	Always drained	10* (30*)	100 (0) (0) (-)
	Slope Protection	130 (150)	Always drained	10* (40*)	0 (0) (0) (-)
	MD M-C S-G	120 (145)	Always drained	10* (30*)	100 (0) (0) (-)
	Topsoil	95 (110)	Drained/undrained	200 (20)	2000* (0*) (0*) (-)
	S MC	120 (135)	Drained/undrained	100 (24)	1000* (0*) (0*) (-)
	MST MC	120 (135)	Drained/undrained	120 (26)	1200* (0*) (0*) (-)
	Toe Protection	130 (140)	Always drained	10* (45*)	0 (0) (0) (-)
	Bankrun	120 (135)	Always drained	10* (32*)	0 (0) (0) (-)
	ODOT Type B LS	135 (150)	Always drained	10* (40*)	0 (0) (0) (-)

**Property used in Scenario 1 (described in this report).*

Partial Factors

Factor	Unity*			
Unfavourable: permanent	1			
Unfavourable: variable	1			
Unfavourable: accidental	1			
Favourable: permanent	1			

Favourable: variable	1			
Favourable: accidental	1			
c'	1			
tanϕ'	1			
c_u	1			

**These partial factors were used in Scenario 1 (described in this report).*

Loads

(normal and shear loads in psf (lb/ft²))

Solid Objects

Loaded Object	Type	Loading Type	Adequacy?
S48	Permanent (unfactored self weight: 135 pcf (lb/ft³))	neutral	true
S50	Permanent (unfactored self weight: 150 pcf (lb/ft³))	neutral	true
S80	Permanent (unfactored self weight: 130 pcf (lb/ft³))	neutral	true
S55	Permanent (unfactored self weight: 145 pcf (lb/ft³))	neutral	true
S120	Permanent (unfactored self weight: 110 pcf (lb/ft³))	neutral	true
S121	Permanent (unfactored self weight: 95 pcf (lb/ft³))	neutral	true
S122	Permanent (unfactored self weight: 135 pcf (lb/ft³))	neutral	true
S123	Permanent (unfactored self weight: 120 pcf (lb/ft³))	neutral	true
S124	Permanent (unfactored self weight: 135 pcf (lb/ft³))	neutral	true
S125	Permanent (unfactored self weight: 120 pcf (lb/ft³))	neutral	true
S126	Permanent (unfactored self weight: 140 pcf (lb/ft³))	neutral	true
S127	Permanent (unfactored self weight: 130 pcf (lb/ft³))	neutral	true
S128	Permanent (unfactored self weight: 135 pcf (lb/ft³))	neutral	true
S129	Permanent (unfactored self weight: 120 pcf (lb/ft³))	neutral	true
S130	Permanent (unfactored self weight: 150 pcf (lb/ft³))	neutral	true
S131	Permanent (unfactored self weight: 135 pcf (lb/ft³))	neutral	true

This report was generated by LimitState:GEO3.6.1.26217 - limitstate.com

About this Report

This report has been generated using LimitState:GEO, a software application capable of directly identifying the critical collapse mechanism for a wide variety of geotechnical stability problems, including those involving slopes, retaining walls, footings etc.

The software utilizes the Discontinuity Layout Optimization (DLO) procedure to obtain a solution (Smith and Gilbert 2007). The main steps involved are: (i) distribution of nodes across the problem domain; (ii) connection of every node to every other node with potential discontinuities (e.g. slip-lines); (iii) application of rigorous optimization techniques to identify the critical subset of potential discontinuities, and hence also the critical failure mechanism and margin of safety.

The accuracy of the DLO solution is controlled by the specified nodal density. Within the set of all possible discontinuities linking pairs of nodes, all potential translational failure mechanisms are considered, whether anticipated or not by the engineer. Failure mechanisms involving rotations along the edges of solid bodies in the problem can also be identified. Thus in this case the solution identified by the DLO procedure is guaranteed to be the most critical solution for the problem posed. This means that there is no need to prescribe any aspect of the collapse mechanism prior to an analysis, or to separately consider different failure modes. The critical mechanism and collapse load factor are determined according to the well established upper bound theorem of plasticity.

LimitState:GEO reports the solution to a problem both visually as a collapse mechanism and numerically in terms of an Adequacy Factor, which is defined as the factor by which specified loads must be increased, or material strengths decreased, in order for the system under consideration to reach a collapse state.

REFERENCE

Smith, C.C. and Gilbert, M. (2007) Application of discontinuity layout optimization to plane plasticity problems, Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences, Vol. 463, 2086, pp 2461-2484.

Summary

Name	Date of Analysis	Name of Engineer	Organization
CUVA Bank Stabilization	Tue Aug 8 2023	GPD User	GPD Group

Reference #	Location	Map Reference	Tags
2022281.00	Tow Path Trail Mile Marker 20, Sagamore Hills Township, Summit County, Ohio		

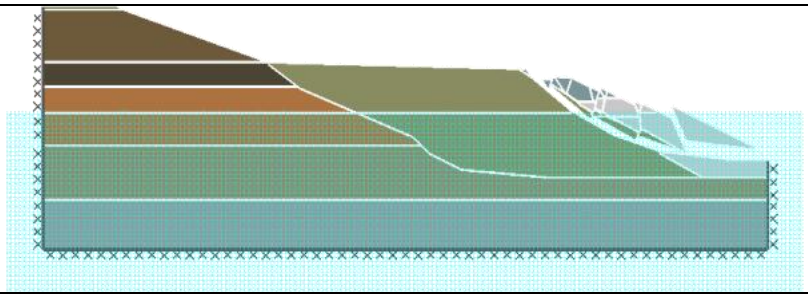
Comments
STA 641+05 LT

Target Nodal Density	Nodal Spacing Scale Factor	Water	Model Translational Failures?	Model Rotational Failures?	Seismic Accelerations: Horiz. / Vert. (g)
Fine (1000 nodes)	1.58665	Enabled	True	Along edges	None

Scenario	Partial Factor Set	Short / Long Term?**	Analysis Type	Adequacy Factor
1*	**Unity**	**Long Term**	**Factor Strength(s)**	**1.652**

**This report provides details of this scenario, which has been identified as the most critical.*

***For Mohr Coulomb materials with Drainage Behaviour specified as 'drained/undrained', undrained properties are used in a short term analysis, and drained properties are used in a long term analysis.*

Failure Mechanism (Scenario 1)


Analysis Options

Factor Strength(s)

Solution Tolerance (%)	Automatic Adequacy on Load(s)	Factor on Load(s)	Artificial Cohesion (kN/m² (kPa))
1	True	1	0.1

Geometry

(all distances in ft)

All Geometrical Objects

No. of Vertices (V)	No. of Boundaries (B)	No. of Solids (S)
36	47	9

Boundary Objects

ID	Start Vertex ID (x, y)	End Vertex ID (x, y)	Baseline Nodal Spacing	Support Type	Material(s)
B1	V1 (-121.391, 623.36)	V110 (-29.8556, 623.36)	1.64042	Fixed	-
B7	V5 (-111.549, 656.168)	V7 (-121.391, 656.168)	1.64042	Free	-
B8	V1 (-121.391, 623.36)	V28 (-121.391, 623.36)	1.64042	Fixed	-
B15	V14 (-121.391, 656.168)	V15 (-111.549, 656.168)	1.64042	Free	-
B16	V14 (-121.391, 656.168)	V7 (-121.391, 656.168)	1.64042	Fixed	-
B17	V15 (-111.549, 656.168)	V5 (-111.549, 656.168)	1.64042	Free	-
B18	V16 (-121.391, 656.168)	V17 (-91.8635, 656.168)	1.64042	Free	-
B19	V16 (-121.391, 656.168)	V14 (-121.391, 656.168)	1.64042	Fixed	-

B20	V17 (-91.8635, 656.168)	V15 (-111.549, 656.168)	1.64042	Free	-
B21	V18 (-121.391, 656.168)	V19 (-88.5827, 656.168)	1.64042	Free	-
B22	V18 (-121.391, 656.168)	V16 (-121.391, 656.168)	1.64042	Fixed	-
B23	V19 (-88.5827, 656.168)	V17 (-91.8635, 656.168)	1.64042	Free	-
B29	V27 (-68.8976, 623.36)	V102 (-72.1785, 623.36)	1.64042	Free	-
B30	V28 (-121.391, 623.36)	V109 (-29.8556, 623.36)	1.64042	Free	-
B31	V28 (-121.391, 623.36)	V70 (-121.391, 623.36)	1.64042	Fixed	-
B66	V70 (-121.391, 623.36)	V71 (-72.1785, 623.36)	1.64042	Free	-
B67	V70 (-121.391, 623.36)	V134 (-121.391, 623.36)	1.64042	Fixed	-
B68	V71 (-72.1785, 623.36)	V101 (-75.4593, 623.36)	1.64042	Free	-
B82	V84 (-55.7743, 623.36)	V27 (-68.8976, 623.36)	1.64042	Free	-
B99	V101 (-75.4593, 623.36)	V135 (-82.021, 623.36)	1.64042	Free	-
B100	V102 (-72.1785, 623.36)	V71 (-72.1785, 623.36)	1.64042	Free	-
B106	V84 (-55.7743, 623.36)	V130 (-39.3701, 623.36)	1.64042	Free	-
B109	V109 (-29.8556, 623.36)	V110 (-29.8556, 623.36)	1.64042	Fixed	-
B110	V113 (-29.8556, 623.36)	V109 (-29.8556, 623.36)	1.64042	Fixed	-
B124	V17 (-91.8635, 656.168)	V131 (-62.336, 656.168)	1.64042	Free	-
B125	V127 (-55.7743, 656.168)	V133 (-52.4934, 623.36)	1.64042	Free	-
B126	V128 (-36.0892, 623.36)	V129 (-29.8556, 623.36)	1.64042	Free	-
B127	V113 (-29.8556, 623.36)	V129 (-29.8556, 623.36)	1.64042	Fixed	-
B128	V130 (-39.3701, 623.36)	V141 (-52.4934, 623.36)	1.64042	Free	-
B129	V130 (-39.3701, 623.36)	V113 (-29.8556, 623.36)	1.64042	Free	-
B130	V131 (-62.336, 656.168)	V127 (-55.7743, 656.168)	1.64042	Free	-
B131	V132 (-55.7743, 623.36)	V133 (-52.4934, 623.36)	1.64042	Free	-
B132	V132 (-55.7743, 623.36)	V131 (-62.336, 656.168)	1.64042	Free	-
B133	V133 (-52.4934, 623.36)	V143 (-45.9318, 623.36)	1.64042	Free	-
B134	V134 (-121.391, 623.36)	V18 (-121.391, 656.168)	1.64042	Fixed	-
B135	V135 (-82.021, 623.36)	V19 (-88.5827, 656.168)	1.64042	Free	-
B136	V136 (-88.5827, 623.36)	V135 (-82.021, 623.36)	0.82021	Free	-
B137	V137 (-91.8635, 623.36)	V136 (-88.5827, 623.36)	0.82021	Free	-
B138	V138 (-98.4252, 623.36)	V137 (-91.8635, 623.36)	0.82021	Free	-
B139	V139 (-98.4252, 623.36)	V138 (-98.4252, 623.36)	0.82021	Free	-
B140	V140 (-111.549, 623.36)	V139 (-98.4252, 623.36)	0.82021	Free	-

B141	V134 (-121.391, 623.36)	V140 (-111.549, 623.36)	0.82021	Free	-
B142	V141 (-52.4934, 623.36)	V132 (-55.7743, 623.36)	1.64042	Free	-
B143	V135 (-82.021, 623.36)	V142 (-68.8976, 623.36)	0.82021	Free	-
B144	V142 (-68.8976, 623.36)	V141 (-52.4934, 623.36)	0.82021	Free	-
B145	V143 (-45.9318, 623.36)	V128 (-36.0892, 623.36)	1.64042	Free	-
B146	V141 (-52.4934, 623.36)	V143 (-45.9318, 623.36)	0.82021	Free	-

** Loaded boundary.*

Solid Objects

ID	Vertex IDs (x, y)	Boundary IDs	Baseline Nodal Spacing (x / y)	Material(s)/Water Regime(s)
S12*	V15 (-111.549,656.168) V5 (-111.549,656.168) V7 (-121.391,656.168) V14 (-121.391,656.168)	B17 B7 B16 B15	3.28084 / 3.28084	Topsoil
S15*	V17 (-91.8635,656.168) V15 (-111.549,656.168) V14 (-121.391,656.168) V16 (-121.391,656.168)	B20 B15 B19 B18	3.28084 / 3.28084	S MC
S17*	V19 (-88.5827,656.168) V17 (-91.8635,656.168) V16 (-121.391,656.168) V18 (-121.391,656.168)	B23 B18 B22 B21	3.28084 / 3.28084	MST MC
S48*	V84 (-55.7743,623.36) V27 (-68.8976,623.36) V102 (-72.1785,623.36) V71 (-72.1785,623.36) V70 (-121.391,623.36) V28 (-121.391,623.36) V109 (-29.8556,623.36) V113 (-29.8556,623.36) V130 (-39.3701,623.36)	B82 B29 B100 B66 B31 B30 B110 B129 B106	3.28084 / 3.28084	VL-L M-C S-G
S50*	V109 (-29.8556,623.36) V28 (-121.391,623.36) V1 (-121.391,623.36) V110 (-29.8556,623.36)	B30 B8 B1 B109	3.28084 / 3.28084	L F-C S-G
S59*	V132 (-55.7743,623.36) V131 (-62.336,656.168) V127 (-55.7743,656.168) V133 (-52.4934,623.36)	B132 B130 B125 B131	3.28084 / 3.28084	Slope Protection
S52	V19 (-88.5827,656.168) V18 (-121.391,656.168) V134 (-121.391,623.36) V70 (-121.391,623.36) V71 (-72.1785,623.36) V101 (-75.4593,623.36) V135 (-82.021,623.36)	B21 B134 B67 B66 B68 B99 B135	3.28084 / 3.28084	MD M-C S-G
S56	V130 (-39.3701,623.36) V84 (-55.7743,623.36) V27 (-68.8976,623.36) V102 (-72.1785,623.36) V71 (-72.1785,623.36) V101 (-75.4593,623.36) V135 (-82.021,623.36) V19 (-88.5827,656.168) V17 (-91.8635,656.168) V131 (-62.336,656.168)	B106 B82 B29 B100 B68 B99 B135 B23 B124 B132	3.28084 / 3.28084	Bankrun

	V132 (-55.7743,623.36) V141 (-52.4934,623.36)	B142 B128		
S58	V133 (-52.4934,623.36) V143 (-45.9318,623.36) V128 (-36.0892,623.36) V129 (-29.8556,623.36) V113 (-29.8556,623.36) V130 (-39.3701,623.36) V141 (-52.4934,623.36) V132 (-55.7743,623.36)	B133 B145 B126 B127 B129 B128 B142 B131	3.28084 / 3.28084	Toe Protection

** Loaded solid (self weight).*

Water Table

(all distances in ft)

Water Table Status	Vertices (x, y)
Enabled	(-120, 637) (-110, 637) (-100, 637) (-97, 637) (-93, 637) (-90, 637) (-70, 637)

Water Regimes

(potentials in ft, pressures in psf (lb/ft²))

(No water regime defined)

Materials

(unit weights (weight densities) in pcf (lb/ft³), strengths in psf (lb/ft²), angles in degrees, datum level in ft, undrained strength gradient in psf (lb/ft²)/ft)

Mohr-Coulomb Material(s)

Key	Name	Unit Weight (Saturated Unit Weight)	Drainage Behaviour	c' (ϕ')	c_u (datum) (gradient) (grid)
	Topsoil	95 (110)	Drained/undrained	200* (20*)	2000 (0) (0) (-)
	S MC	120 (135)	Drained/undrained	100* (24*)	1000 (0) (0) (-)
	MST MC	120 (135)	Drained/undrained	120* (26*)	1200 (0) (0) (-)
	VL-L M-C S-G	120 (135)	Always drained	115* (24*)	1150 (0) (0) (-)
	L F-C S-G	125 (150)	Always drained	10* (30*)	100 (0) (0) (-)
	Slope Protection	130 (150)	Always drained	10* (40*)	0 (0) (0) (-)
	MD M-C S-G	120 (145)	Always drained	10* (30*)	100 (0) (0) (-)
	Bankrun	120 (135)	Always drained	10* (32*)	0 (0) (0) (-)
	Toe Protection	130 (140)	Always drained	10* (45*)	0 (0) (0) (-)

**Property used in Scenario 1 (described in this report).*

Partial Factors

Factor	Unity*			
Unfavourable: permanent	1			
Unfavourable: variable	1			
Unfavourable: accidental	1			
Favourable: permanent	1			
Favourable: variable	1			
Favourable: accidental	1			
c'	1			
tanϕ'	1			
c_u	1			

**These partial factors were used in Scenario 1 (described in this report).*

Loads

(normal and shear loads in psf (lb/ft²))

Solid Objects

Loaded Object	Type	Loading Type	Adequacy?
S12	Permanent (unfactored self weight: 95 pcf (lb/ft³))	neutral	true
S15	Permanent (unfactored self weight: 120 pcf (lb/ft³))	neutral	true
S17	Permanent (unfactored self weight: 120 pcf (lb/ft³))	neutral	true
S48	Permanent (unfactored self weight: 135 pcf (lb/ft³))	neutral	true
S50	Permanent (unfactored self weight: 150 pcf (lb/ft³))	neutral	true
S59	Permanent (unfactored self weight: 130 pcf (lb/ft³))	neutral	true
S60	Permanent (unfactored self weight: 145 pcf (lb/ft³))	neutral	true
S61	Permanent (unfactored self weight: 120 pcf (lb/ft³))	neutral	true
S62	Permanent (unfactored self weight: 135 pcf (lb/ft³))	neutral	true
S63	Permanent (unfactored self weight: 120 pcf (lb/ft³))	neutral	true
S64	Permanent (unfactored self weight: 140 pcf (lb/ft³))	neutral	true
S65	Permanent (unfactored self weight: 130 pcf (lb/ft³))	neutral	true

This report was generated by LimitState:GEO3.6.1.26217 - limitstate.com

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The software utilizes the Discontinuity Layout Optimization (DLO) procedure to obtain a solution (Smith and Gilbert 2007). The main steps involved are: (i) distribution of nodes across the problem domain; (ii) connection of every node to every other node with potential discontinuities (e.g. slip-lines); (iii) application of rigorous optimization techniques to identify the critical subset of potential discontinuities, and hence also the critical failure mechanism and margin of safety.

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LimitState:GEO reports the solution to a problem both visually as a collapse mechanism and numerically in terms of an Adequacy Factor, which is defined as the factor by which specified loads must be increased, or material strengths decreased, in order for the system under consideration to reach a collapse state.

REFERENCE

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Summary

Name	Date of Analysis	Name of Engineer	Organization
CUVA Bank Stabilization	Tue Aug 8 2023	GPD User	GPD Group

Reference #	Location	Map Reference	Tags
2022281.00	Tow Path Trail Mile Marker 20, Sagamore Hills Township, Summit County, Ohio		

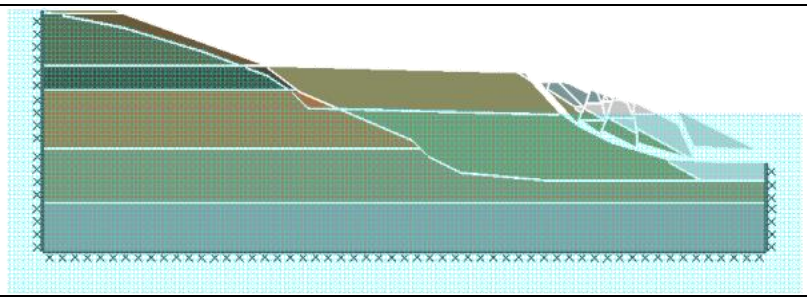
Comments
STA641+05 ST Rapid Drawdown

Target Nodal Density	Nodal Spacing Scale Factor	Water	Model Translational Failures?	Model Rotational Failures?	Seismic Accelerations: Horiz. / Vert. (g)
Fine (1000 nodes)	1.58665	Enabled	True	Along edges	None

Scenario	Partial Factor Set	Short / Long Term?**	Analysis Type	Adequacy Factor
1*	**Unity**	**Short Term**	**Factor Strength(s)**	**1.639**

**This report provides details of this scenario, which has been identified as the most critical.*

***For Mohr Coulomb materials with Drainage Behaviour specified as 'drained/undrained', undrained properties are used in a short term analysis, and drained properties are used in a long term analysis.*

Failure Mechanism (Scenario 1)


Analysis Options

Factor Strength(s)

Solution Tolerance (%)	Automatic Adequacy on Load(s)	Factor on Load(s)	Artificial Cohesion (kN/m² (kPa))
1	True	1	0.1

Geometry

(all distances in ft)

All Geometrical Objects

No. of Vertices (V)	No. of Boundaries (B)	No. of Solids (S)
37	51	9

Boundary Objects

ID	Start Vertex ID (x, y)	End Vertex ID (x, y)	Baseline Nodal Spacing	Support Type	Material(s)
B1	V1 (-121.391, 623.36)	V110 (-29.8556, 623.36)	1.64042	Fixed	-
B7	V5 (-111.549, 656.168)	V7 (-121.391, 656.168)	1.64042	Free	-
B8	V1 (-121.391, 623.36)	V28 (-121.391, 623.36)	1.64042	Fixed	-
B15	V14 (-121.391, 656.168)	V145 (-118.11, 656.168)	1.64042	Free	-
B16	V14 (-121.391, 656.168)	V7 (-121.391, 656.168)	1.64042	Fixed	-
B17	V15 (-111.549, 656.168)	V5 (-111.549, 656.168)	1.64042	Free	-
B18	V16 (-121.391, 656.168)	V146 (-95.1444, 656.168)	1.64042	Free	-
B19	V16 (-121.391, 656.168)	V14 (-121.391, 656.168)	1.64042	Fixed	-

B20	V17 (-91.8635, 656.168)	V15 (-111.549, 656.168)	1.64042	Free	-
B21	V18 (-121.391, 656.168)	V144 (-88.5827, 656.168)	1.64042	Free	-
B22	V18 (-121.391, 656.168)	V16 (-121.391, 656.168)	1.64042	Fixed	-
B23	V19 (-88.5827, 656.168)	V17 (-91.8635, 656.168)	1.64042	Free	-
B29	V27 (-68.8976, 623.36)	V102 (-72.1785, 623.36)	1.64042	Free	-
B30	V28 (-121.391, 623.36)	V109 (-29.8556, 623.36)	1.64042	Free	-
B31	V28 (-121.391, 623.36)	V70 (-121.391, 623.36)	1.64042	Fixed	-
B66	V70 (-121.391, 623.36)	V71 (-72.1785, 623.36)	1.64042	Free	-
B67	V70 (-121.391, 623.36)	V18 (-121.391, 656.168)	1.64042	Fixed	-
B68	V71 (-72.1785, 623.36)	V101 (-75.4593, 623.36)	1.64042	Free	-
B82	V84 (-55.7743, 623.36)	V27 (-68.8976, 623.36)	1.64042	Free	-
B99	V101 (-75.4593, 623.36)	V150 (-82.021, 623.36)	1.64042	Free	-
B100	V102 (-72.1785, 623.36)	V71 (-72.1785, 623.36)	1.64042	Free	-
B106	V84 (-55.7743, 623.36)	V130 (-39.3701, 623.36)	1.64042	Free	-
B109	V109 (-29.8556, 623.36)	V110 (-29.8556, 623.36)	1.64042	Fixed	-
B110	V113 (-29.8556, 623.36)	V109 (-29.8556, 623.36)	1.64042	Fixed	-
B124	V17 (-91.8635, 656.168)	V131 (-62.336, 656.168)	1.64042	Free	-
B125	V127 (-55.7743, 656.168)	V133 (-52.4934, 623.36)	1.64042	Free	-
B126	V128 (-36.0892, 623.36)	V129 (-29.8556, 623.36)	1.64042	Free	-
B127	V113 (-29.8556, 623.36)	V129 (-29.8556, 623.36)	1.64042	Fixed	-
B128	V130 (-39.3701, 623.36)	V152 (-52.4934, 623.36)	1.64042	Free	-
B129	V130 (-39.3701, 623.36)	V113 (-29.8556, 623.36)	1.64042	Free	-
B130	V131 (-62.336, 656.168)	V127 (-55.7743, 656.168)	1.64042	Free	-
B131	V132 (-55.7743, 623.36)	V133 (-52.4934, 623.36)	1.64042	Free	-
B132	V132 (-55.7743, 623.36)	V131 (-62.336, 656.168)	1.64042	Free	-
B133	V133 (-52.4934, 623.36)	V153 (-45.9318, 623.36)	1.64042	Free	-
B147	V144 (-88.5827, 656.168)	V19 (-88.5827, 656.168)	1.64042	Free	-
B148	V145 (-118.11, 656.168)	V15 (-111.549, 656.168)	1.64042	Free	-
B149	V7 (-121.391, 656.168)	V145 (-118.11, 656.168)	0.82021	Free	-
B150	V146 (-95.1444, 656.168)	V17 (-91.8635, 656.168)	1.64042	Free	-
B151	V147 (-98.4252, 656.168)	V146 (-95.1444, 656.168)	0.82021	Free	-
B152	V148 (-111.549, 656.168)	V147 (-98.4252, 656.168)	0.82021	Free	-
B153	V145 (-118.11, 656.168)	V148 (-111.549, 656.168)	0.82021	Free	-

B154	V149 (-91.8635, 656.168)	V144 (-88.5827, 656.168)	0.82021	Free	-
B155	V146 (-95.1444, 656.168)	V149 (-91.8635, 656.168)	0.82021	Free	-
B156	V150 (-82.021, 623.36)	V19 (-88.5827, 656.168)	1.64042	Free	-
B157	V151 (-88.5827, 623.36)	V150 (-82.021, 623.36)	0.82021	Free	-
B158	V144 (-88.5827, 656.168)	V151 (-88.5827, 623.36)	0.82021	Free	-
B159	V152 (-52.4934, 623.36)	V132 (-55.7743, 623.36)	1.64042	Free	-
B160	V150 (-82.021, 623.36)	V152 (-52.4934, 623.36)	0.82021	Free	-
B161	V153 (-45.9318, 623.36)	V128 (-36.0892, 623.36)	1.64042	Free	-
B162	V152 (-52.4934, 623.36)	V154 (-49.2126, 623.36)	0.82021	Free	-
B163	V154 (-49.2126, 623.36)	V153 (-45.9318, 623.36)	0.82021	Free	-

** Loaded boundary.*

Solid Objects

ID	Vertex IDs (x, y)	Boundary IDs	Baseline Nodal Spacing (x / y)	Material(s)/Water Regime(s)
S48*	V84 (-55.7743,623.36) V27 (-68.8976,623.36) V102 (-72.1785,623.36) V71 (-72.1785,623.36) V70 (-121.391,623.36) V28 (-121.391,623.36) V109 (-29.8556,623.36) V113 (-29.8556,623.36) V130 (-39.3701,623.36)	B82 B29 B100 B66 B31 B30 B110 B129 B106	3.28084 / 3.28084	VL-L M-C S-G
S50*	V109 (-29.8556,623.36) V28 (-121.391,623.36) V1 (-121.391,623.36) V110 (-29.8556,623.36)	B30 B8 B1 B109	3.28084 / 3.28084	L F-C S-G
S59*	V132 (-55.7743,623.36) V131 (-62.336,656.168) V127 (-55.7743,656.168) V133 (-52.4934,623.36)	B132 B130 B125 B131	3.28084 / 3.28084	Slope Protection
S12*	V15 (-111.549,656.168) V5 (-111.549,656.168) V7 (-121.391,656.168) V14 (-121.391,656.168) V145 (-118.11,656.168)	B17 B7 B16 B15 B148	3.28084 / 3.28084	Topsoil
S15*	V17 (-91.8635,656.168) V15 (-111.549,656.168) V145 (-118.11,656.168) V14 (-121.391,656.168) V16 (-121.391,656.168) V146 (-95.1444,656.168)	B20 B148 B15 B19 B18 B150	3.28084 / 3.28084	S MC
S17*	V19 (-88.5827,656.168) V17 (-91.8635,656.168) V146 (-95.1444,656.168) V16 (-121.391,656.168) V18 (-121.391,656.168) V144 (-88.5827,656.168)	B23 B150 B18 B22 B21 B147	3.28084 / 3.28084	MST MC
S52	V19 (-88.5827,656.168) V144 (-88.5827,656.168) V18 (-121.391,656.168)	B147 B21 B67	3.28084 / 3.28084	MD M-C S-G

	V70 (-121.391,623.36) V71 (-72.1785,623.36) V101 (-75.4593,623.36) V150 (-82.021,623.36)	B66 B68 B99 B156		
S56	V130 (-39.3701,623.36) V84 (-55.7743,623.36) V27 (-68.8976,623.36) V102 (-72.1785,623.36) V71 (-72.1785,623.36) V101 (-75.4593,623.36) V150 (-82.021,623.36) V19 (-88.5827,656.168) V17 (-91.8635,656.168) V131 (-62.336,656.168) V132 (-55.7743,623.36) V152 (-52.4934,623.36)	B106 B82 B29 B100 B68 B99 B156 B23 B124 B132 B159 B128	3.28084 / 3.28084	Bankrun
S58	V133 (-52.4934,623.36) V153 (-45.9318,623.36) V128 (-36.0892,623.36) V129 (-29.8556,623.36) V113 (-29.8556,623.36) V130 (-39.3701,623.36) V152 (-52.4934,623.36) V132 (-55.7743,623.36)	B133 B161 B126 B127 B129 B128 B159 B131	3.28084 / 3.28084	Toe Protection

** Loaded solid (self weight).*

Water Table

(all distances in ft)

Water Table Status	Vertices (x, y)
Enabled	(-120, 650) (-110, 648) (-100, 645) (-92, 642) (-89, 640) (-87, 638) (-48, 637)

Water Regimes

(potentials in ft, pressures in psf (lb/ft²))

(No water regime defined)

Materials

(unit weights (weight densities) in pcf (lb/ft³), strengths in psf (lb/ft²), angles in degrees, datum level in ft, undrained strength gradient in psf (lb/ft²)/ft)

Mohr-Coulomb Material(s)

Key	Name	Unit Weight (Saturated Unit Weight)	Drainage Behaviour	c' (ϕ')	c_u (datum) (gradient) (grid)
	VL-L M-C S-G	120 (135)	Always drained	115* (24*)	1150 (0) (0) (-)
	L F-C S-G	125 (150)	Always drained	10* (30*)	100 (0) (0) (-)
	Slope Protection	130 (150)	Always drained	10* (40*)	0 (0) (0) (-)
	Topsoil	95 (110)	Drained/undrained	200 (20)	2000* (0*) (0*) (-)
	S MC	120 (135)	Drained/undrained	100 (24)	1000* (0*) (0*) (-)
	MST MC	120 (135)	Drained/undrained	120 (26)	1200* (0*) (0*) (-)
	MD M-C S-G	120 (145)	Always drained	10* (30*)	100 (0) (0) (-)
	Bankrun	120 (135)	Always drained	10* (32*)	0 (0) (0) (-)
	Toe Protection	130 (140)	Always drained	10* (45*)	0 (0) (0) (-)

**Property used in Scenario 1 (described in this report).*

Partial Factors

Factor	Unity*			
Unfavourable: permanent	1			
Unfavourable: variable	1			
Unfavourable: accidental	1			
Favourable: permanent	1			
Favourable: variable	1			
Favourable: accidental	1			
c'	1			
tanϕ'	1			
c_u	1			

**These partial factors were used in Scenario 1 (described in this report).*

Loads

(normal and shear loads in psf (lb/ft²))

Solid Objects

Loaded Object	Type	Loading Type	Adequacy?
S48	Permanent (unfactored self weight: 135 pcf (lb/ft³))	neutral	true
S50	Permanent (unfactored self weight: 150 pcf (lb/ft³))	neutral	true
S59	Permanent (unfactored self weight: 130 pcf (lb/ft³))	neutral	true
S66	Permanent (unfactored self weight: 110 pcf (lb/ft³))	neutral	true
S67	Permanent (unfactored self weight: 95 pcf (lb/ft³))	neutral	true

S68	Permanent (unfactored self weight: 135 pcf (lb/ft³))	neutral	true
S69	Permanent (unfactored self weight: 120 pcf (lb/ft³))	neutral	true
S70	Permanent (unfactored self weight: 135 pcf (lb/ft³))	neutral	true
S71	Permanent (unfactored self weight: 120 pcf (lb/ft³))	neutral	true
S72	Permanent (unfactored self weight: 145 pcf (lb/ft³))	neutral	true
S73	Permanent (unfactored self weight: 120 pcf (lb/ft³))	neutral	true
S74	Permanent (unfactored self weight: 135 pcf (lb/ft³))	neutral	true
S75	Permanent (unfactored self weight: 120 pcf (lb/ft³))	neutral	true
S76	Permanent (unfactored self weight: 140 pcf (lb/ft³))	neutral	true
S77	Permanent (unfactored self weight: 130 pcf (lb/ft³))	neutral	true

This report was generated by LimitState:GEO3.6.1.26217 - limitstate.com

About this Report

This report has been generated using LimitState:GEO, a software application capable of directly identifying the critical collapse mechanism for a wide variety of geotechnical stability problems, including those involving slopes, retaining walls, footings etc.

The software utilizes the Discontinuity Layout Optimization (DLO) procedure to obtain a solution (Smith and Gilbert 2007). The main steps involved are: (i) distribution of nodes across the problem domain; (ii) connection of every node to every other node with potential discontinuities (e.g. slip-lines); (iii) application of rigorous optimization techniques to identify the critical subset of potential discontinuities, and hence also the critical failure mechanism and margin of safety.

The accuracy of the DLO solution is controlled by the specified nodal density. Within the set of all possible discontinuities linking pairs of nodes, all potential translational failure mechanisms are considered, whether anticipated or not by the engineer. Failure mechanisms involving rotations along the edges of solid bodies in the problem can also be identified. Thus in this case the solution identified by the DLO procedure is guaranteed to be the most critical solution for the problem posed. This means that there is no need to prescribe any aspect of the collapse mechanism prior to an analysis, or to separately consider different failure modes. The critical mechanism and collapse load factor are determined according to the well established upper bound theorem of plasticity.

LimitState:GEO reports the solution to a problem both visually as a collapse mechanism and numerically in terms of an Adequacy Factor, which is defined as the factor by which specified loads must be increased, or material strengths decreased, in order for the system under consideration to reach a collapse state.

REFERENCE

Smith, C.C. and Gilbert, M. (2007) Application of discontinuity layout optimization to plane plasticity problems, Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences, Vol. 463, 2086, pp 2461-2484.

Summary

Name	Date of Analysis	Name of Engineer	Organization
CUVA Bank Stabilization	Tue Aug 8 2023	GPD User	GPD Group

Reference #	Location	Map Reference	Tags
2022281.00	Tow Path Trail Mile Marker 20, Sagamore Hills Township, Summit County, Ohio		

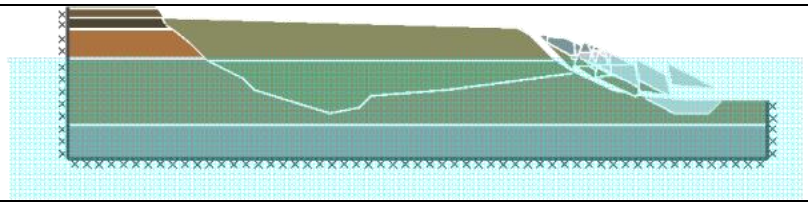
Comments
STA 642+57 LT

Target Nodal Density	Nodal Spacing Scale Factor	Water	Model Translational Failures?	Model Rotational Failures?	Seismic Accelerations: Horiz. / Vert. (g)
Fine (1000 nodes)	1.4083	Enabled	True	Along edges	None

Scenario	Partial Factor Set	Short / Long Term?**	Analysis Type	Adequacy Factor
1*	**Unity**	**Long Term**	**Factor Strength(s)**	**1.752**

**This report provides details of this scenario, which has been identified as the most critical.*

***For Mohr Coulomb materials with Drainage Behaviour specified as 'drained/undrained', undrained properties are used in a short term analysis, and drained properties are used in a long term analysis.*

Failure Mechanism (Scenario 1)


Analysis Options

Factor Strength(s)

Solution Tolerance (%)	Automatic Adequacy on Load(s)	Factor on Load(s)	Artificial Cohesion (kN/m² (kPa))
1	True	1	0.1

Geometry

(all distances in ft)

All Geometrical Objects

No. of Vertices (V)	No. of Boundaries (B)	No. of Solids (S)
39	49	9

Boundary Objects

ID	Start Vertex ID (x, y)	End Vertex ID (x, y)	Baseline Nodal Spacing	Support Type	Material(s)
B1	V1 (-111.549, 623.36)	V3 (9.84252, 623.36)	1.64042	Fixed	-
B2	V3 (9.84252, 623.36)	V29 (9.84252, 623.36)	1.64042	Fixed	-
B3	V2 (9.84252, 623.36)	V73 (2.00131, 623.36)	1.64042	Free	-
B6	V6 (-65.6168, 623.36)	V11 (-78.7402, 623.36)	1.64042	Free	-
B7	V5 (-95.1444, 656.168)	V7 (-111.549, 656.168)	1.64042	Free	-
B8	V1 (-111.549, 623.36)	V28 (-111.549, 623.36)	1.64042	Fixed	-
B10	V8 (-91.8635, 656.168)	V17 (-91.8635, 656.168)	1.64042	Free	-
B11	V9 (-85.3018, 623.36)	V12 (-88.5827, 656.168)	1.64042	Free	-
B12	V10 (-78.7402, 623.36)	V9 (-85.3018, 623.36)	1.64042	Free	-
B14	V12 (-88.5827, 656.168)	V19 (-91.8635, 656.168)	1.64042	Free	-
B15	V14 (-111.549, 656.168)	V15 (-95.1444, 656.168)	1.64042	Free	-

B16	V14 (-111.549, 656.168)	V7 (-111.549, 656.168)	1.64042	Fixed	-
B17	V15 (-95.1444, 656.168)	V5 (-95.1444, 656.168)	1.64042	Free	-
B18	V16 (-111.549, 656.168)	V17 (-91.8635, 656.168)	1.64042	Free	-
B19	V16 (-111.549, 656.168)	V14 (-111.549, 656.168)	1.64042	Fixed	-
B20	V17 (-91.8635, 656.168)	V15 (-95.1444, 656.168)	1.64042	Free	-
B21	V18 (-111.549, 656.168)	V19 (-91.8635, 656.168)	1.64042	Free	-
B22	V18 (-111.549, 656.168)	V16 (-111.549, 656.168)	1.64042	Fixed	-
B23	V19 (-91.8635, 656.168)	V8 (-91.8635, 656.168)	1.64042	Free	-
B29	V11 (-78.7402, 623.36)	V10 (-78.7402, 623.36)	1.64042	Free	-
B30	V28 (-111.549, 623.36)	V29 (9.84252, 623.36)	1.64042	Free	-
B31	V28 (-111.549, 623.36)	V30 (-111.549, 623.36)	1.64042	Fixed	-
B32	V29 (9.84252, 623.36)	V2 (9.84252, 623.36)	1.64042	Fixed	-
B33	V9 (-85.3018, 623.36)	V83 (-88.5827, 623.36)	1.64042	Free	-
B34	V30 (-111.549, 623.36)	V18 (-111.549, 656.168)	1.64042	Fixed	-
B64	V68 (-59.0551, 623.36)	V6 (-65.6168, 623.36)	1.64042	Free	-
B65	V69 (-59.0551, 623.36)	V68 (-59.0551, 623.36)	1.64042	Free	-
B66	V70 (-45.9318, 623.36)	V69 (-59.0551, 623.36)	1.64042	Free	-
B67	V71 (-5.90551, 623.36)	V72 (-20.0131, 623.36)	1.64042	Free	-
B68	V72 (-20.0131, 623.36)	V70 (-45.9318, 623.36)	1.64042	Free	-
B69	V73 (2.00131, 623.36)	V74 (0, 623.36)	1.64042	Free	-
B70	V74 (0, 623.36)	V71 (-5.90551, 623.36)	1.64042	Free	-
B71	V17 (-91.8635, 656.168)	V77 (-32.8084, 656.168)	1.64042	Free	-
B72	V75 (-27.8871, 656.168)	V79 (-21.6535, 623.36)	1.64042	Free	-
B73	V76 (-3.93701, 623.36)	V73 (2.00131, 623.36)	1.64042	Free	-
B74	V72 (-20.0131, 623.36)	V85 (-23.294, 623.36)	1.64042	Free	-
B75	V77 (-32.8084, 656.168)	V75 (-27.8871, 656.168)	1.64042	Free	-
B76	V78 (-26.9029, 623.36)	V79 (-21.6535, 623.36)	1.64042	Free	-
B77	V78 (-26.9029, 623.36)	V77 (-32.8084, 656.168)	1.64042	Free	-
B78	V79 (-21.6535, 623.36)	V87 (-17.7165, 623.36)	1.64042	Free	-
B79	V80 (-98.4252, 623.36)	V30 (-111.549, 623.36)	1.64042	Free	-
B80	V81 (-98.4252, 623.36)	V80 (-98.4252, 623.36)	1.64042	Free	-
B81	V82 (-91.8635, 623.36)	V81 (-98.4252, 623.36)	1.64042	Free	-
B82	V83 (-88.5827, 623.36)	V82 (-91.8635, 623.36)	1.64042	Free	-
B83	V85 (-23.294, 623.36)	V78 (-26.9029, 623.36)	1.64042	Free	-
B84	V9 (-85.3018, 623.36)	V86 (-68.8976, 623.36)	0.82021	Free	-
B85	V86 (-68.8976, 623.36)	V85 (-23.294, 623.36)	0.82021	Free	-

B86	V87 (-17.7165, 623.36)	V76 (-3.93701, 623.36)	1.64042	Free	-
B87	V85 (-23.294, 623.36)	V87 (-17.7165, 623.36)	0.82021	Free	-

** Loaded boundary.*

Solid Objects

ID	Vertex IDs (x, y)	Boundary IDs	Baseline Nodal Spacing (x / y)	Material(s)/Water Regime(s)
S12*	V15 (-95.1444,656.168) V5 (-95.1444,656.168) V7 (-111.549,656.168) V14 (-111.549,656.168)	B17 B7 B16 B15	3.28084 / 3.28084	Topsoil
S15*	V17 (-91.8635,656.168) V15 (-95.1444,656.168) V14 (-111.549,656.168) V16 (-111.549,656.168)	B20 B15 B19 B18	3.28084 / 3.28084	S MC
S17*	V19 (-91.8635,656.168) V8 (-91.8635,656.168) V17 (-91.8635,656.168) V16 (-111.549,656.168) V18 (-111.549,656.168)	B23 B10 B18 B22 B21	3.28084 / 3.28084	MST MC
S23*	V28 (-111.549,623.36) V1 (-111.549,623.36) V3 (9.84252,623.36) V29 (9.84252,623.36)	B8 B1 B2 B30	3.28084 / 3.28084	L F-C S-G
S25*	V9 (-85.3018,623.36) V12 (-88.5827,656.168) V19 (-91.8635,656.168) V18 (-111.549,656.168) V30 (-111.549,623.36) V80 (-98.4252,623.36) V81 (-98.4252,623.36) V82 (-91.8635,623.36) V83 (-88.5827,623.36)	B11 B14 B21 B34 B79 B80 B81 B82 B33	3.28084 / 3.28084	MD M-C S-G
S40*	V78 (-26.9029,623.36) V77 (-32.8084,656.168) V75 (-27.8871,656.168) V79 (-21.6535,623.36)	B77 B75 B72 B76	3.28084 / 3.28084	Slope Protection
S35	V30 (-111.549,623.36) V28 (-111.549,623.36) V29 (9.84252,623.36) V2 (9.84252,623.36) V73 (2.00131,623.36) V74 (0,623.36) V71 (-5.90551,623.36) V72 (-20.0131,623.36) V70 (-45.9318,623.36) V69 (-59.0551,623.36) V68 (-59.0551,623.36) V6 (-65.6168,623.36) V11 (-78.7402,623.36) V10 (-78.7402,623.36) V9 (-85.3018,623.36) V83 (-88.5827,623.36) V82 (-91.8635,623.36) V81 (-98.4252,623.36) V80 (-98.4252,623.36)	B31 B30 B32 B3 B69 B70 B67 B68 B66 B65 B64 B6 B29 B12 B33 B82 B81 B80 B79	3.28084 / 3.28084	VL-L M-C S-G
S38	V72 (-20.0131,623.36) V70 (-45.9318,623.36) V69 (-59.0551,623.36) V68 (-59.0551,623.36) V6 (-65.6168,623.36) V11 (-78.7402,623.36)	B68 B66 B65 B64 B6 B29	3.28084 / 3.28084	Bankrun

	V10 (-78.7402,623.36) V9 (-85.3018,623.36) V12 (-88.5827,656.168) V19 (-91.8635,656.168) V8 (-91.8635,656.168) V17 (-91.8635,656.168) V77 (-32.8084,656.168) V78 (-26.9029,623.36) V85 (-23.294,623.36)	B12 B11 B14 B23 B10 B71 B77 B83 B74		
S39	V79 (-21.6535,623.36) V87 (-17.7165,623.36) V76 (-3.93701,623.36) V73 (2.00131,623.36) V74 (0,623.36) V71 (-5.90551,623.36) V72 (-20.0131,623.36) V85 (-23.294,623.36) V78 (-26.9029,623.36)	B78 B86 B73 B69 B70 B67 B74 B83 B76	3.28084 / 3.28084	Toe Protection

** Loaded solid (self weight).*

Water Table

(all distances in ft)

Water Table Status	Vertices (x, y)
Enabled	(-120, 637) (-110, 637) (-100, 637) (-97, 637) (-93, 637) (-90, 637) (-70, 637)

Water Regimes

(potentials in ft, pressures in psf (lb/ft²))

(No water regime defined)

Materials

(unit weights (weight densities) in pcf (lb/ft³), strengths in psf (lb/ft²), angles in degrees, datum level in ft, undrained strength gradient in psf (lb/ft²)/ft)

Mohr-Coulomb Material(s)

Key	Name	Unit Weight (Saturated Unit Weight)	Drainage Behaviour	c' (ϕ')	c_u (datum) (gradient) (grid)
	Topsoil	95 (110)	Drained/undrained	200* (20*)	2000 (0) (0) (-)
	S MC	120 (135)	Drained/undrained	100* (24*)	1000 (0) (0) (-)
	MST MC	120 (135)	Drained/undrained	120* (26*)	1200 (0) (0) (-)
	L F-C S-G	125 (150)	Always drained	10* (30*)	100 (0) (0) (-)
	MD M-C S-G	120 (145)	Always drained	10* (30*)	100 (0) (0) (-)

	Slope Protection	130 (150)	Always drained	10* (40*)	0 (0) (0) (-)
	VL-L M-C S-G	120 (135)	Always drained	115* (24*)	1150 (0) (0) (-)
	Bankrun	120 (135)	Always drained	10* (32*)	0 (0) (0) (-)
	Toe Protection	130 (140)	Always drained	10* (45*)	0 (0) (0) (-)

**Property used in Scenario 1 (described in this report).*

Partial Factors

Factor	Unity*			
Unfavourable: permanent	1			
Unfavourable: variable	1			
Unfavourable: accidental	1			
Favourable: permanent	1			
Favourable: variable	1			
Favourable: accidental	1			
c'	1			
tanϕ'	1			
c_u	1			

**These partial factors were used in Scenario 1 (described in this report).*

Loads

(normal and shear loads in psf (lb/ft²))

Solid Objects

Loaded Object	Type	Loading Type	Adequacy?
S12	Permanent (unfactored self weight: 95 pcf (lb/ft³))	neutral	true
S15	Permanent (unfactored self weight: 120 pcf (lb/ft³))	neutral	true
S17	Permanent (unfactored self weight: 120 pcf (lb/ft³))	neutral	true
S23	Permanent (unfactored self weight: 150 pcf (lb/ft³))	neutral	true
S25	Permanent (unfactored self weight: 120 pcf (lb/ft³))	neutral	true
S40	Permanent (unfactored self weight: 130 pcf (lb/ft³))	neutral	true
S41	Permanent (unfactored self weight: 135 pcf (lb/ft³))	neutral	true
S42	Permanent (unfactored self weight: 135 pcf (lb/ft³))	neutral	true
S43	Permanent (unfactored self weight: 120 pcf (lb/ft³))	neutral	true
S44	Permanent (unfactored self weight: 140 pcf (lb/ft³))	neutral	true
S45	Permanent (unfactored self weight: 130 pcf (lb/ft³))	neutral	true

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The software utilizes the Discontinuity Layout Optimization (DLO) procedure to obtain a solution (Smith and Gilbert 2007). The main steps involved are: (i) distribution of nodes across the problem domain; (ii) connection of every node to every other node with potential discontinuities (e.g. slip-lines); (iii) application of rigorous optimization techniques to identify the critical subset of potential discontinuities, and hence also the critical failure mechanism and margin of safety.

The accuracy of the DLO solution is controlled by the specified nodal density. Within the set of all possible discontinuities linking pairs of nodes, all potential translational failure mechanisms are considered, whether anticipated or not by the engineer. Failure mechanisms involving rotations along the edges of solid bodies in the problem can also be identified. Thus in this case the solution identified by the DLO procedure is guaranteed to be the most critical solution for the problem posed. This means that there is no need to prescribe any aspect of the collapse mechanism prior to an analysis, or to separately consider different failure modes. The critical mechanism and collapse load factor are determined according to the well established upper bound theorem of plasticity.

LimitState:GEO reports the solution to a problem both visually as a collapse mechanism and numerically in terms of an Adequacy Factor, which is defined as the factor by which specified loads must be increased, or material strengths decreased, in order for the system under consideration to reach a collapse state.

REFERENCE

Smith, C.C. and Gilbert, M. (2007) Application of discontinuity layout optimization to plane plasticity problems, Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences, Vol. 463, 2086, pp 2461-2484.

Summary

Name	Date of Analysis	Name of Engineer	Organization
CUVA Bank Stabilization	Tue Aug 8 2023	GPD User	GPD Group

Reference #	Location	Map Reference	Tags
2022281.00	Tow Path Trail Mile Marker 20, Sagamore Hills Township, Summit County, Ohio		

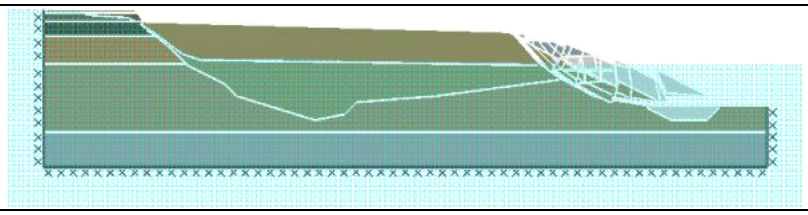
Comments
STA 642+57 ST Rapid Drawdown

Target Nodal Density	Nodal Spacing Scale Factor	Water	Model Translational Failures?	Model Rotational Failures?	Seismic Accelerations: Horiz. / Vert. (g)
Fine (1000 nodes)	1.4083	Enabled	True	Along edges	None

Scenario	Partial Factor Set	Short / Long Term?**	Analysis Type	Adequacy Factor
1*	**Unity**	**Short Term**	**Factor Strength(s)**	**1.748**

**This report provides details of this scenario, which has been identified as the most critical.*

***For Mohr Coulomb materials with Drainage Behaviour specified as 'drained/undrained', undrained properties are used in a short term analysis, and drained properties are used in a long term analysis.*

Failure Mechanism (Scenario 1)


Analysis Options

Factor Strength(s)

Solution Tolerance (%)	Automatic Adequacy on Load(s)	Factor on Load(s)	Artificial Cohesion (kN/m² (kPa))
1	True	1	0.1

Geometry

(all distances in ft)

All Geometrical Objects

No. of Vertices (V)	No. of Boundaries (B)	No. of Solids (S)
42	55	9

Boundary Objects

ID	Start Vertex ID (x, y)	End Vertex ID (x, y)	Baseline Nodal Spacing	Support Type	Material(s)
B1	V1 (-111.549, 623.36)	V3 (9.84252, 623.36)	1.64042	Fixed	-
B2	V3 (9.84252, 623.36)	V29 (9.84252, 623.36)	1.64042	Fixed	-
B3	V2 (9.84252, 623.36)	V73 (2.00131, 623.36)	1.64042	Free	-
B6	V6 (-65.6168, 623.36)	V11 (-78.7402, 623.36)	1.64042	Free	-
B7	V5 (-95.1444, 656.168)	V7 (-111.549, 656.168)	1.64042	Free	-
B8	V1 (-111.549, 623.36)	V28 (-111.549, 623.36)	1.64042	Fixed	-
B10	V8 (-91.8635, 656.168)	V91 (-91.8635, 656.168)	1.64042	Free	-
B11	V9 (-85.3018, 623.36)	V12 (-88.5827, 656.168)	1.64042	Free	-
B12	V10 (-78.7402, 623.36)	V9 (-85.3018, 623.36)	1.64042	Free	-
B14	V12 (-88.5827, 656.168)	V19 (-91.8635, 656.168)	1.64042	Free	-
B15	V14 (-111.549, 656.168)	V89 (-101.706, 656.168)	1.64042	Free	-

B16	V14 (-111.549, 656.168)	V7 (-111.549, 656.168)	1.64042	Fixed	-
B17	V15 (-95.1444, 656.168)	V5 (-95.1444, 656.168)	1.64042	Free	-
B18	V16 (-111.549, 656.168)	V88 (-95.1444, 656.168)	1.64042	Free	-
B19	V16 (-111.549, 656.168)	V14 (-111.549, 656.168)	1.64042	Fixed	-
B20	V17 (-91.8635, 656.168)	V15 (-95.1444, 656.168)	1.64042	Free	-
B21	V18 (-111.549, 656.168)	V19 (-91.8635, 656.168)	1.64042	Free	-
B22	V18 (-111.549, 656.168)	V16 (-111.549, 656.168)	1.64042	Fixed	-
B23	V19 (-91.8635, 656.168)	V8 (-91.8635, 656.168)	1.64042	Free	-
B29	V11 (-78.7402, 623.36)	V10 (-78.7402, 623.36)	1.64042	Free	-
B30	V28 (-111.549, 623.36)	V29 (9.84252, 623.36)	1.64042	Free	-
B31	V28 (-111.549, 623.36)	V30 (-111.549, 623.36)	1.64042	Fixed	-
B32	V29 (9.84252, 623.36)	V2 (9.84252, 623.36)	1.64042	Fixed	-
B33	V9 (-85.3018, 623.36)	V30 (-111.549, 623.36)	1.64042	Free	-
B34	V30 (-111.549, 623.36)	V18 (-111.549, 656.168)	1.64042	Fixed	-
B64	V68 (-59.0551, 623.36)	V6 (-65.6168, 623.36)	1.64042	Free	-
B65	V69 (-59.0551, 623.36)	V68 (-59.0551, 623.36)	1.64042	Free	-
B66	V70 (-45.9318, 623.36)	V69 (-59.0551, 623.36)	1.64042	Free	-
B67	V71 (-5.90551, 623.36)	V72 (-20.0131, 623.36)	1.64042	Free	-
B68	V72 (-20.0131, 623.36)	V70 (-45.9318, 623.36)	1.64042	Free	-
B69	V73 (2.00131, 623.36)	V74 (0, 623.36)	1.64042	Free	-
B70	V74 (0, 623.36)	V71 (-5.90551, 623.36)	1.64042	Free	-
B71	V17 (-91.8635, 656.168)	V77 (-32.8084, 656.168)	1.64042	Free	-
B72	V75 (-27.8871, 656.168)	V79 (-21.6535, 623.36)	1.64042	Free	-
B73	V76 (-3.93701, 623.36)	V73 (2.00131, 623.36)	1.64042	Free	-
B74	V72 (-20.0131, 623.36)	V92 (-23.294, 623.36)	1.64042	Free	-
B75	V77 (-32.8084, 656.168)	V75 (-27.8871, 656.168)	1.64042	Free	-
B76	V78 (-26.9029, 623.36)	V79 (-21.6535, 623.36)	1.64042	Free	-
B77	V78 (-26.9029, 623.36)	V77 (-32.8084, 656.168)	1.64042	Free	-
B78	V79 (-21.6535, 623.36)	V96 (-17.7165, 623.36)	1.64042	Free	-
B88	V88 (-95.1444, 656.168)	V17 (-91.8635, 656.168)	1.64042	Free	-
B89	V89 (-101.706, 656.168)	V15 (-95.1444, 656.168)	1.64042	Free	-
B90	V7 (-111.549, 656.168)	V89 (-101.706, 656.168)	0.82021	Free	-
B91	V90 (-95.1444, 656.168)	V88 (-95.1444, 656.168)	0.82021	Free	-
B92	V89 (-101.706, 656.168)	V90 (-95.1444, 656.168)	0.82021	Free	-
B93	V91 (-91.8635, 656.168)	V17 (-91.8635, 656.168)	1.64042	Free	-

B94	V88 (-95.1444, 656.168)	V91 (-91.8635, 656.168)	0.82021	Free	-
B95	V92 (-23.294, 623.36)	V78 (-26.9029, 623.36)	1.64042	Free	-
B96	V91 (-91.8635, 656.168)	V93 (-91.8635, 656.168)	0.82021	Free	-
B97	V93 (-91.8635, 656.168)	V94 (-88.5827, 623.36)	0.82021	Free	-
B98	V94 (-88.5827, 623.36)	V95 (-85.3018, 623.36)	0.82021	Free	-
B99	V95 (-85.3018, 623.36)	V92 (-23.294, 623.36)	0.82021	Free	-
B100	V96 (-17.7165, 623.36)	V76 (-3.93701, 623.36)	1.64042	Free	-
B101	V92 (-23.294, 623.36)	V97 (-19.0289, 623.36)	0.82021	Free	-
B102	V97 (-19.0289, 623.36)	V96 (-17.7165, 623.36)	0.82021	Free	-

** Loaded boundary.*

Solid Objects

ID	Vertex IDs (x, y)	Boundary IDs	Baseline Nodal Spacing (x / y)	Material(s)/Water Regime(s)
S23*	V28 (-111.549,623.36) V1 (-111.549,623.36) V3 (9.84252,623.36) V29 (9.84252,623.36)	B8 B1 B2 B30	3.28084 / 3.28084	L F-C S-G
S25*	V9 (-85.3018,623.36) V12 (-88.5827,656.168) V19 (-91.8635,656.168) V18 (-111.549,656.168) V30 (-111.549,623.36)	B11 B14 B21 B34 B33	3.28084 / 3.28084	MD M-C S-G
S40*	V78 (-26.9029,623.36) V77 (-32.8084,656.168) V75 (-27.8871,656.168) V79 (-21.6535,623.36)	B77 B75 B72 B76	3.28084 / 3.28084	Slope Protection
S35*	V30 (-111.549,623.36) V28 (-111.549,623.36) V29 (9.84252,623.36) V2 (9.84252,623.36) V73 (2.00131,623.36) V74 (0,623.36) V71 (-5.90551,623.36) V72 (-20.0131,623.36) V70 (-45.9318,623.36) V69 (-59.0551,623.36) V68 (-59.0551,623.36) V6 (-65.6168,623.36) V11 (-78.7402,623.36) V10 (-78.7402,623.36) V9 (-85.3018,623.36)	B31 B30 B32 B3 B69 B70 B67 B68 B66 B65 B64 B6 B29 B12 B33	3.28084 / 3.28084	VL-L M-C S-G
S12*	V15 (-95.1444,656.168) V5 (-95.1444,656.168) V7 (-111.549,656.168) V14 (-111.549,656.168) V89 (-101.706,656.168)	B17 B7 B16 B15 B89	3.28084 / 3.28084	Topsoil
S15*	V17 (-91.8635,656.168) V15 (-95.1444,656.168) V89 (-101.706,656.168) V14 (-111.549,656.168) V16 (-111.549,656.168) V88 (-95.1444,656.168)	B20 B89 B15 B19 B18 B88	3.28084 / 3.28084	S MC
S17*	V19 (-91.8635,656.168) V8 (-91.8635,656.168) V91 (-91.8635,656.168)	B23 B10 B93	3.28084 / 3.28084	MST MC

	V17 (-91.8635,656.168) V88 (-95.1444,656.168) V16 (-111.549,656.168) V18 (-111.549,656.168)	B88 B18 B22 B21		
S38	V72 (-20.0131,623.36) V70 (-45.9318,623.36) V69 (-59.0551,623.36) V68 (-59.0551,623.36) V6 (-65.6168,623.36) V11 (-78.7402,623.36) V10 (-78.7402,623.36) V9 (-85.3018,623.36) V12 (-88.5827,656.168) V19 (-91.8635,656.168) V8 (-91.8635,656.168) V91 (-91.8635,656.168) V17 (-91.8635,656.168) V77 (-32.8084,656.168) V78 (-26.9029,623.36) V92 (-23.294,623.36)	B68 B66 B65 B64 B6 B29 B12 B11 B14 B23 B10 B93 B71 B77 B95 B74	3.28084 / 3.28084	Bankrun
S39	V79 (-21.6535,623.36) V96 (-17.7165,623.36) V76 (-3.93701,623.36) V73 (2.00131,623.36) V74 (0,623.36) V71 (-5.90551,623.36) V72 (-20.0131,623.36) V92 (-23.294,623.36) V78 (-26.9029,623.36)	B78 B100 B73 B69 B70 B67 B74 B95 B76	3.28084 / 3.28084	Toe Protection

** Loaded solid (self weight).*

Water Table

(all distances in ft)

Water Table Status	Vertices (x, y)
Enabled	(-110, 646) (-96, 645) (-94, 644) (-91, 642) (-87, 639) (-84, 638) (-19, 637)

Water Regimes

(potentials in ft, pressures in psf (lb/ft²))

(No water regime defined)

Materials

(unit weights (weight densities) in pcf (lb/ft³), strengths in psf (lb/ft²), angles in degrees, datum level in ft, undrained strength gradient in psf (lb/ft²)/ft)

Mohr-Coulomb Material(s)

Key	Name	Unit Weight (Saturated Unit Weight)	Drainage Behaviour	c' (ϕ')	c_u (datum) (gradient) (grid)
	L F-C S-G	125 (150)	Always drained	10* (30*)	100 (0) (0) (-)
	MD M-C S-G	120 (145)	Always drained	10* (30*)	100 (0) (0) (-)
	Slope Protection	130 (150)	Always drained	10* (40*)	0 (0) (0) (-)
	VL-L M-C S-G	120 (135)	Always drained	115* (24*)	1150 (0) (0) (-)
	Topsoil	95 (110)	Drained/undrained	200 (20)	2000* (0*) (0*) (-)
	S MC	120 (135)	Drained/undrained	100 (24)	1000* (0*) (0*) (-)
	MST MC	120 (135)	Drained/undrained	120 (26)	1200* (0*) (0*) (-)
	Bankrun	120 (135)	Always drained	10* (32*)	0 (0) (0) (-)
	Toe Protection	130 (140)	Always drained	10* (45*)	0 (0) (0) (-)

**Property used in Scenario 1 (described in this report).*

Partial Factors

Factor	Unity*			
Unfavourable: permanent	1			
Unfavourable: variable	1			
Unfavourable: accidental	1			
Favourable: permanent	1			
Favourable: variable	1			
Favourable: accidental	1			
c'	1			
tanϕ'	1			
c_u	1			

**These partial factors were used in Scenario 1 (described in this report).*

Loads

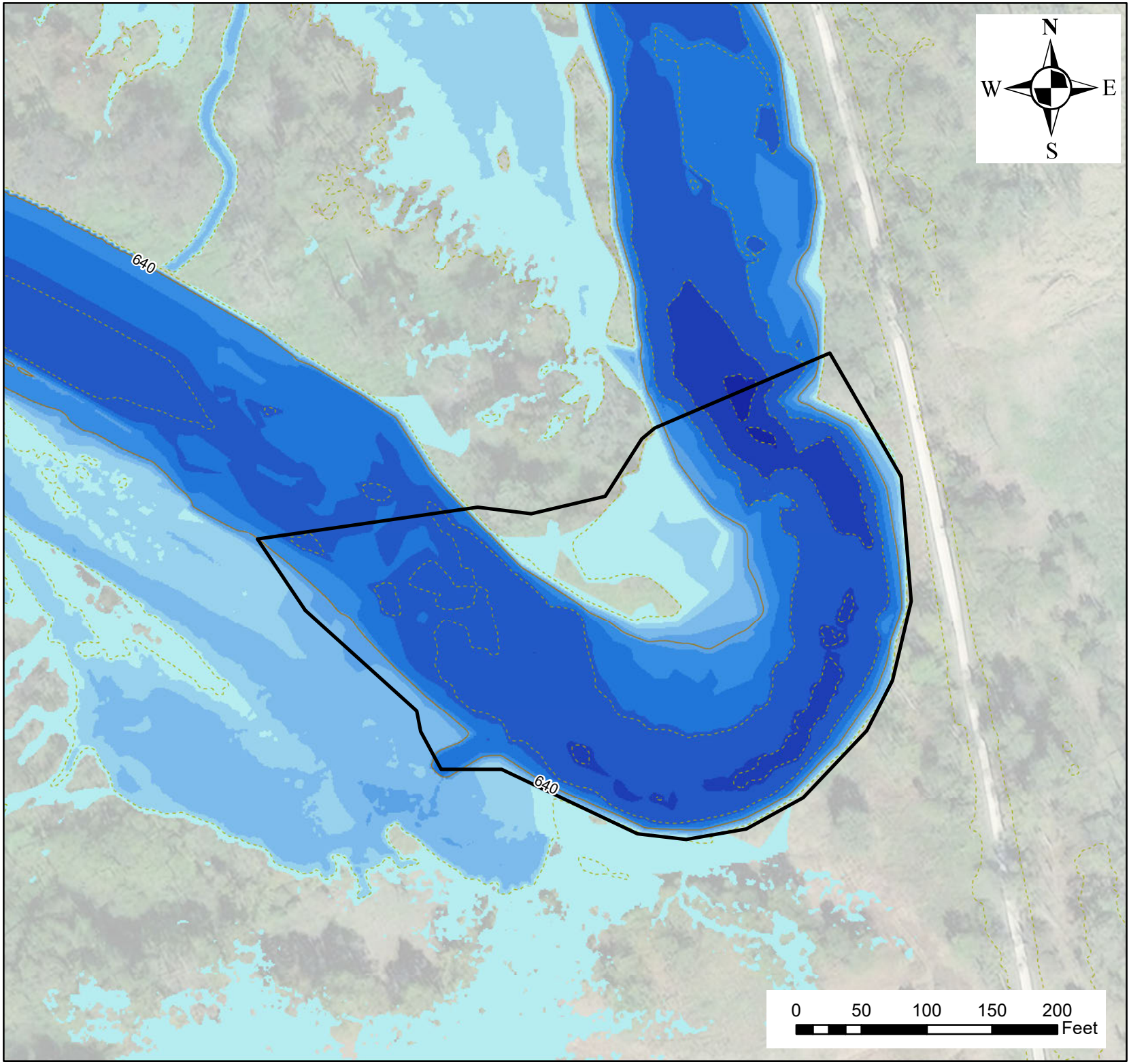
(normal and shear loads in psf (lb/ft²))

Solid Objects

Loaded Object	Type	Loading Type	Adequacy?
S23	Permanent (unfactored self weight: 150 pcf (lb/ft³))	neutral	true
S25	Permanent (unfactored self weight: 145 pcf (lb/ft³))	neutral	true
S40	Permanent (unfactored self weight: 130 pcf (lb/ft³))	neutral	true
S35	Permanent (unfactored self weight: 135 pcf (lb/ft³))	neutral	true
S46	Permanent (unfactored self weight: 110 pcf (lb/ft³))	neutral	true

S47	Permanent (unfactored self weight: 95 pcf (lb/ft³))	neutral	true
S48	Permanent (unfactored self weight: 135 pcf (lb/ft³))	neutral	true
S49	Permanent (unfactored self weight: 120 pcf (lb/ft³))	neutral	true
S50	Permanent (unfactored self weight: 135 pcf (lb/ft³))	neutral	true
S51	Permanent (unfactored self weight: 120 pcf (lb/ft³))	neutral	true
S52	Permanent (unfactored self weight: 135 pcf (lb/ft³))	neutral	true
S53	Permanent (unfactored self weight: 120 pcf (lb/ft³))	neutral	true
S54	Permanent (unfactored self weight: 140 pcf (lb/ft³))	neutral	true
S55	Permanent (unfactored self weight: 130 pcf (lb/ft³))	neutral	true

APPENDIX IV H&H MODELING DATA



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Existing Conditions
1-year Design Storm
Depth Map

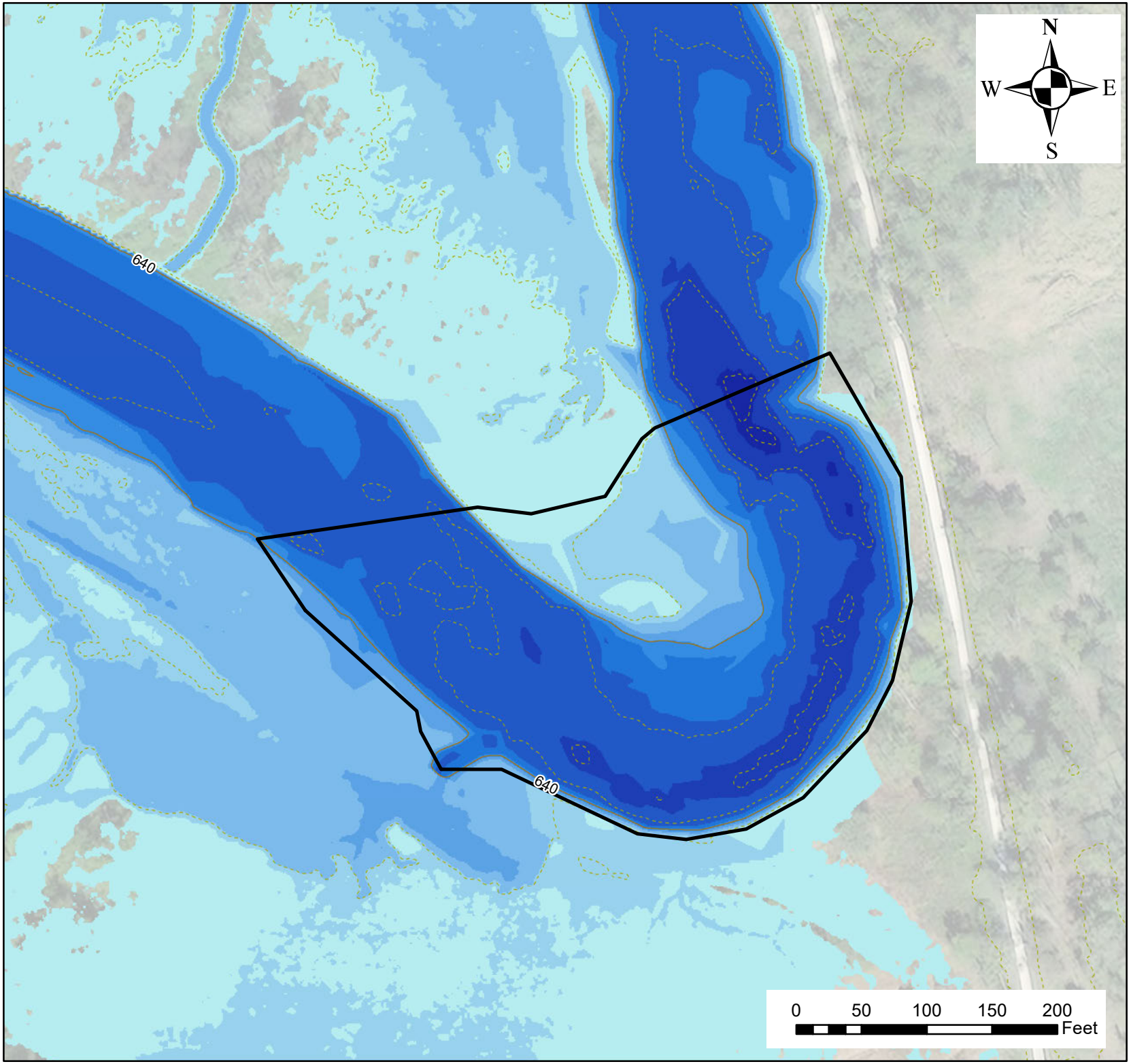
Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Depth:

- 0 - 1 ft
- 1 - 2 ft
- 2 - 4 ft
- 4 - 6 ft
- 6 - 8 ft
- 8 - 10 ft
- 10 - 15 ft
- 15 - 20 ft
- > 20 ft

GPD GROUP



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Existing Conditions
1.5-year Design Storm
Depth Map

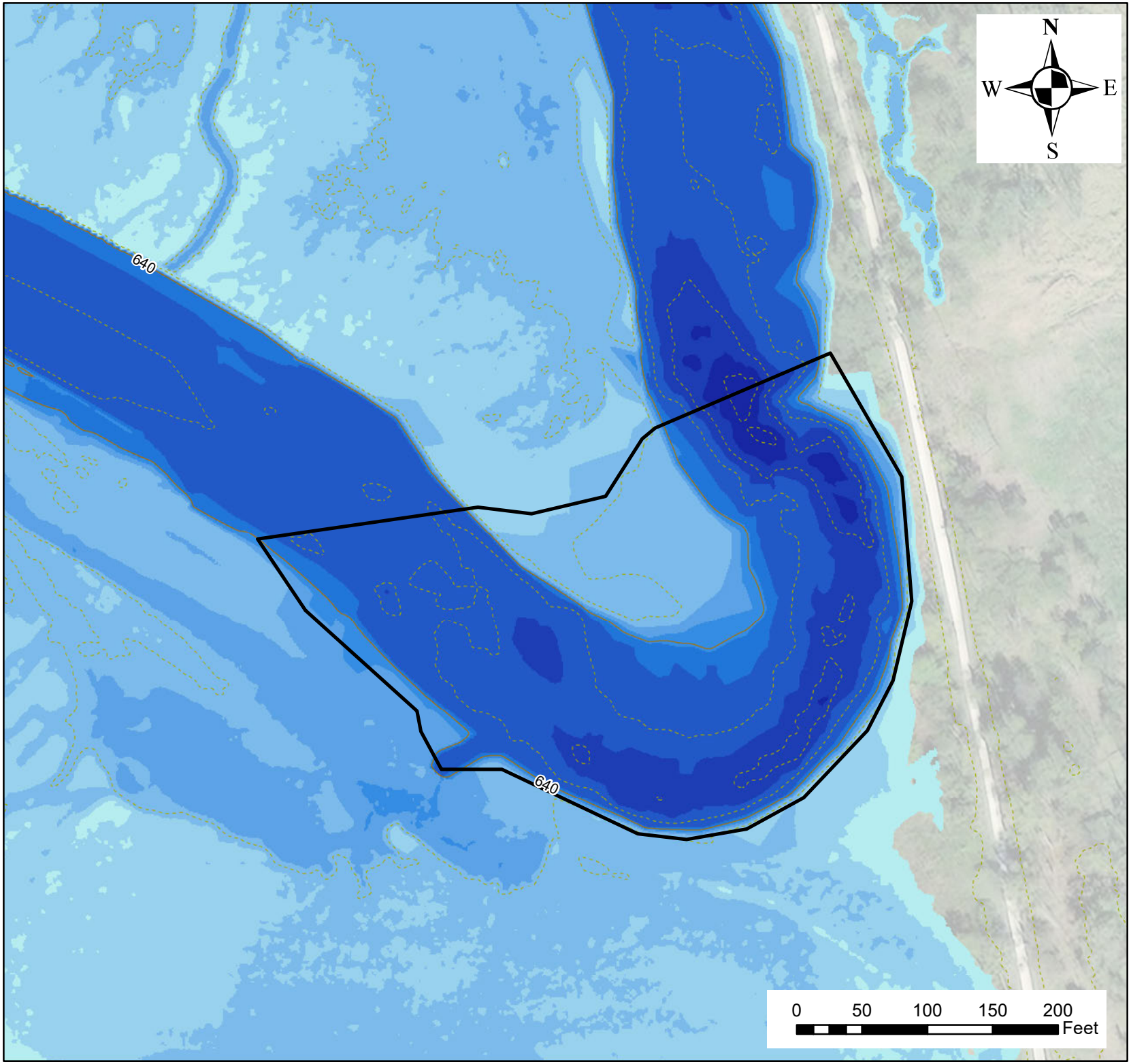
Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Depth:

- 0 - 1 ft
- 1 - 2 ft
- 2 - 4 ft
- 4 - 6 ft
- 6 - 8 ft
- 8 - 10 ft
- 10 - 15 ft
- 15 - 20 ft
- > 20 ft

GPD GROUP



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Existing Conditions
10-year Design Storm
Depth Map

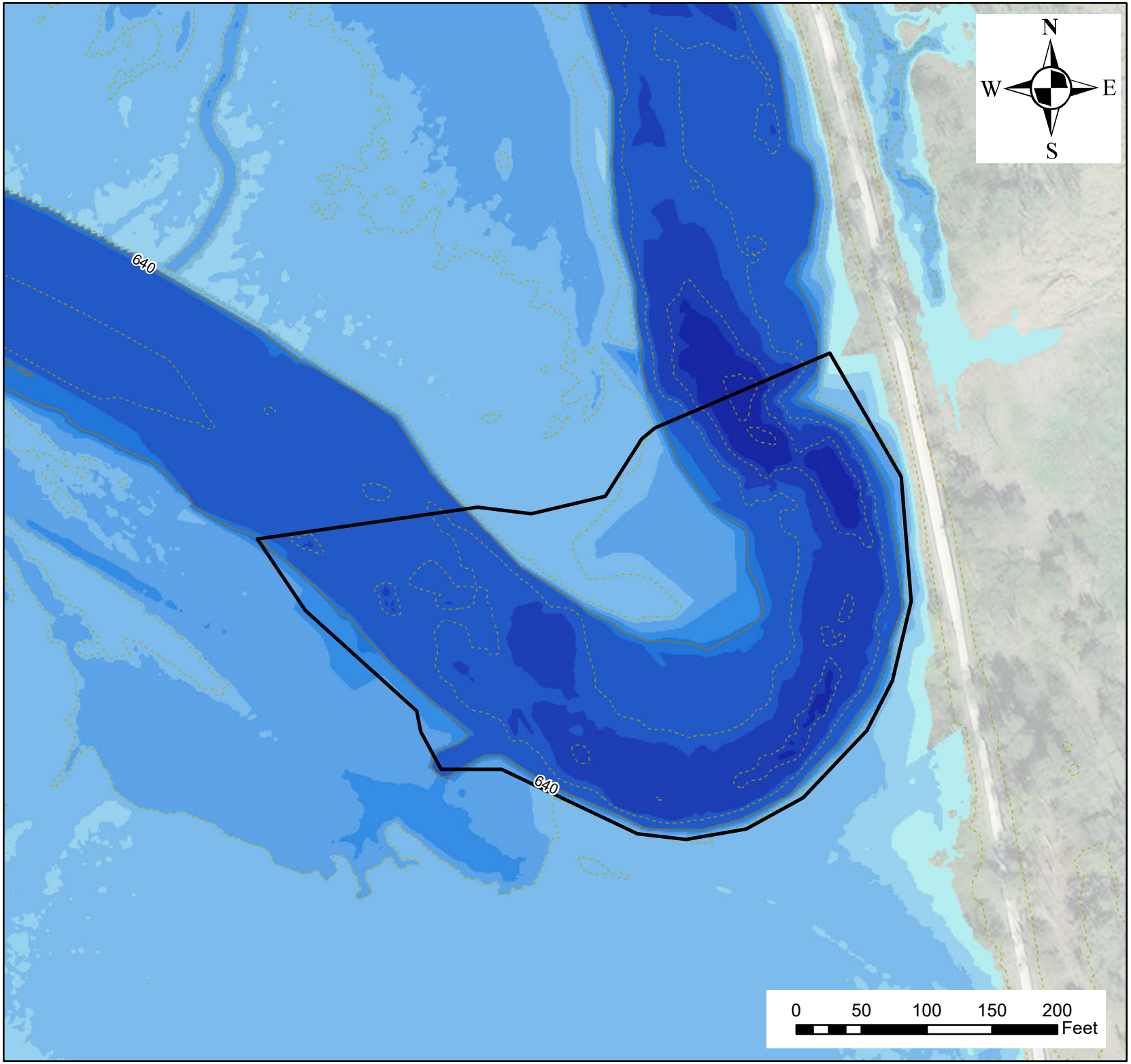
Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Depth:

- 0 - 1 ft
- 1 - 2 ft
- 2 - 4 ft
- 4 - 6 ft
- 6 - 8 ft
- 8 - 10 ft
- 10 - 15 ft
- 15 - 20 ft
- > 20 ft

GPD GROUP



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Existing Conditions
100-year Design Storm
Depth Map

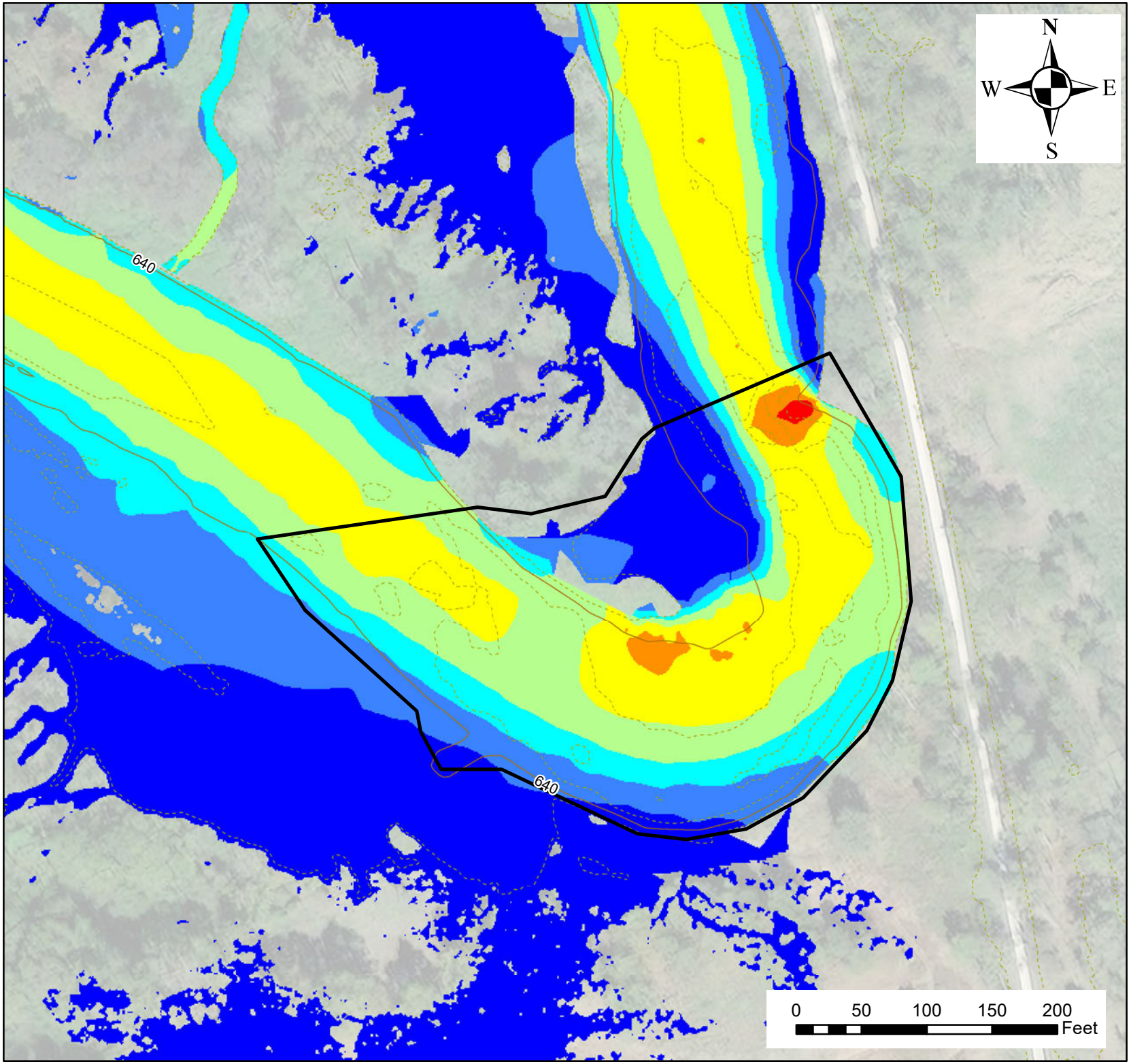
Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Depth:

- 0 - 1 ft
- 1 - 2 ft
- 2 - 4 ft
- 4 - 6 ft
- 6 - 8 ft
- 8 - 10 ft
- 10 - 15 ft
- 15 - 20 ft
- > 20 ft

GPD GROUP



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Existing Conditions
1-year Design Storm
Velocity Map

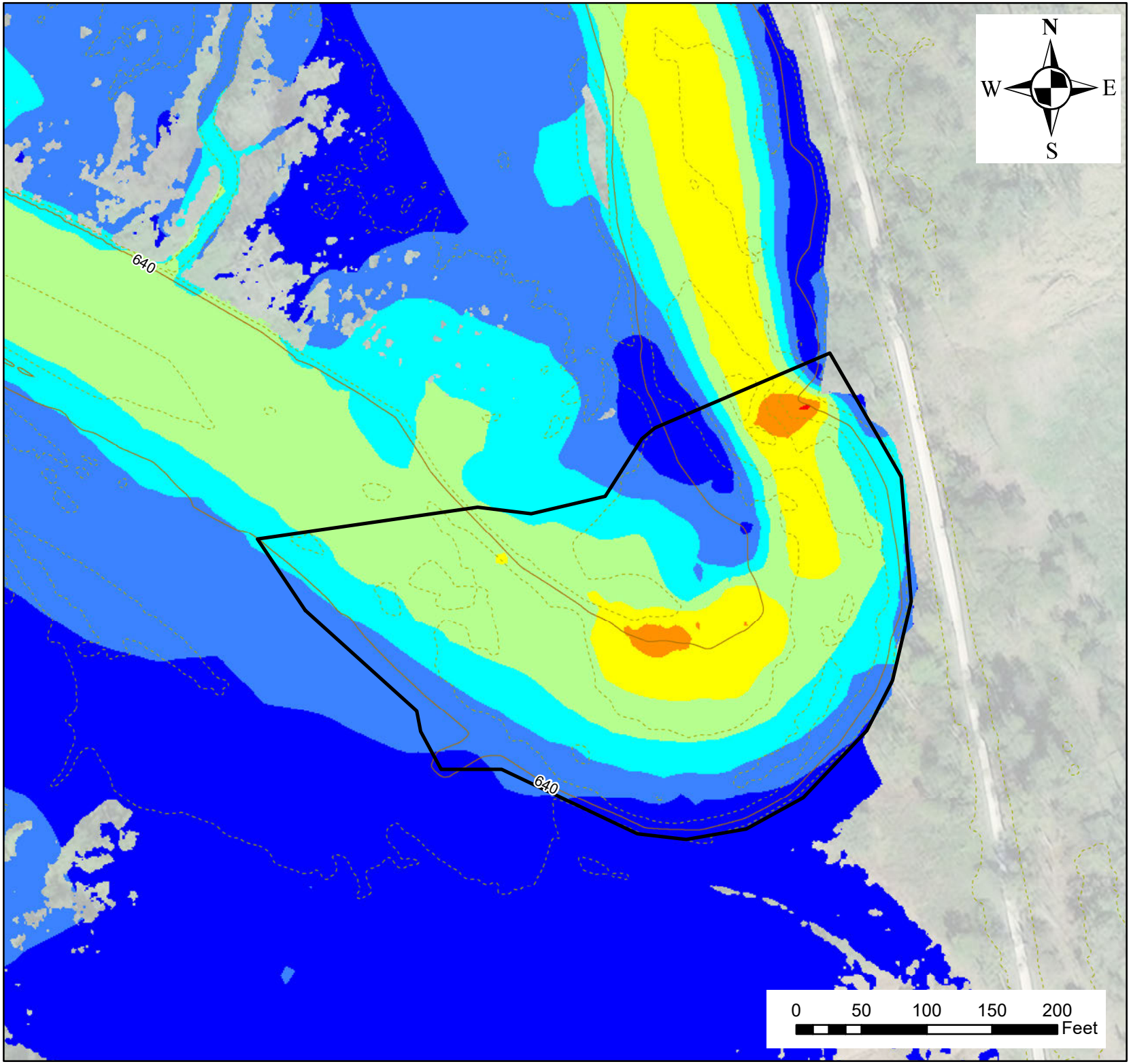
Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Velocity:

- 0 - 1 ft/s
- 1 - 2 ft/s
- 2 - 3 ft/s
- 3 - 4 ft/s
- 4 - 5 ft/s
- 5 - 6 ft/s
- > 6 ft/s

GPD GROUP



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Existing Conditions
1.5-year Design Storm
Velocity Map

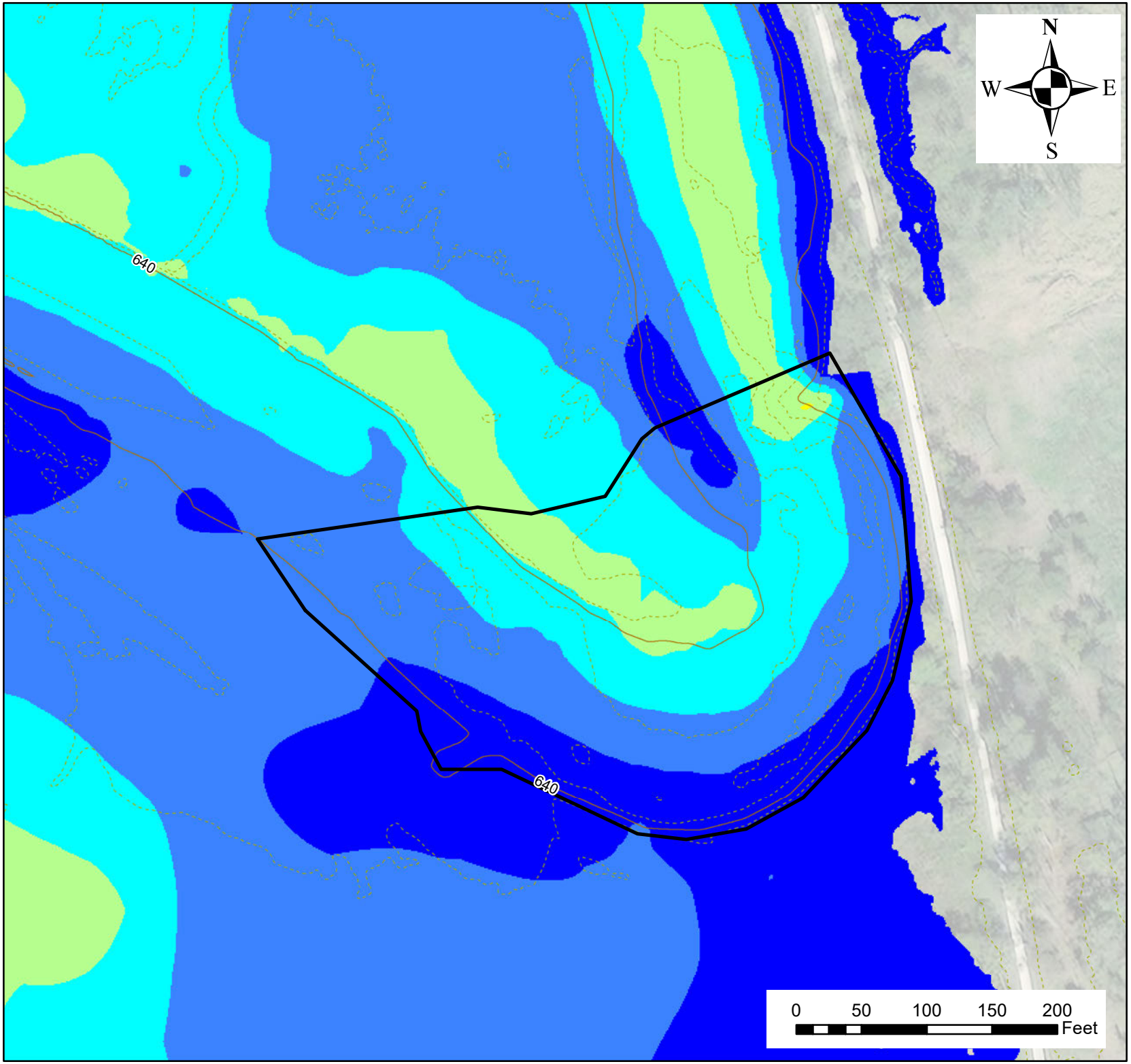
Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Velocity:

- 0 - 1 ft/s
- 1 - 2 ft/s
- 2 - 3 ft/s
- 3 - 4 ft/s
- 4 - 5 ft/s
- 5 - 6 ft/s
- > 6 ft/s

GPD GROUP



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Existing Conditions
10-year Design Storm
Velocity Map

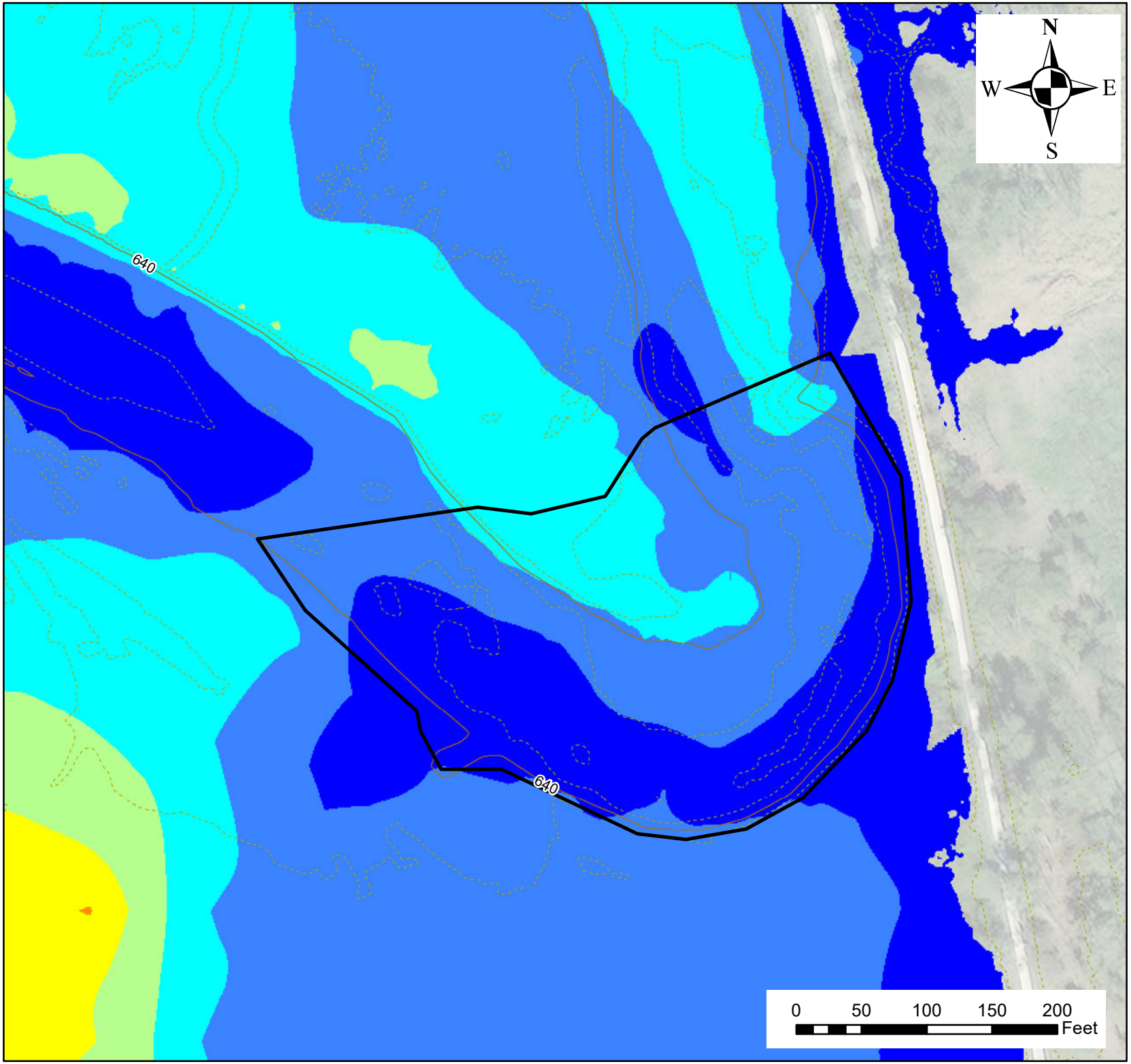
Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Velocity:

- 0 - 1 ft/s
- 1 - 2 ft/s
- 2 - 3 ft/s
- 3 - 4 ft/s
- 4 - 5 ft/s
- 5 - 6 ft/s
- > 6 ft/s

GPD GROUP



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Existing Conditions
100-year Design Storm
Velocity Map

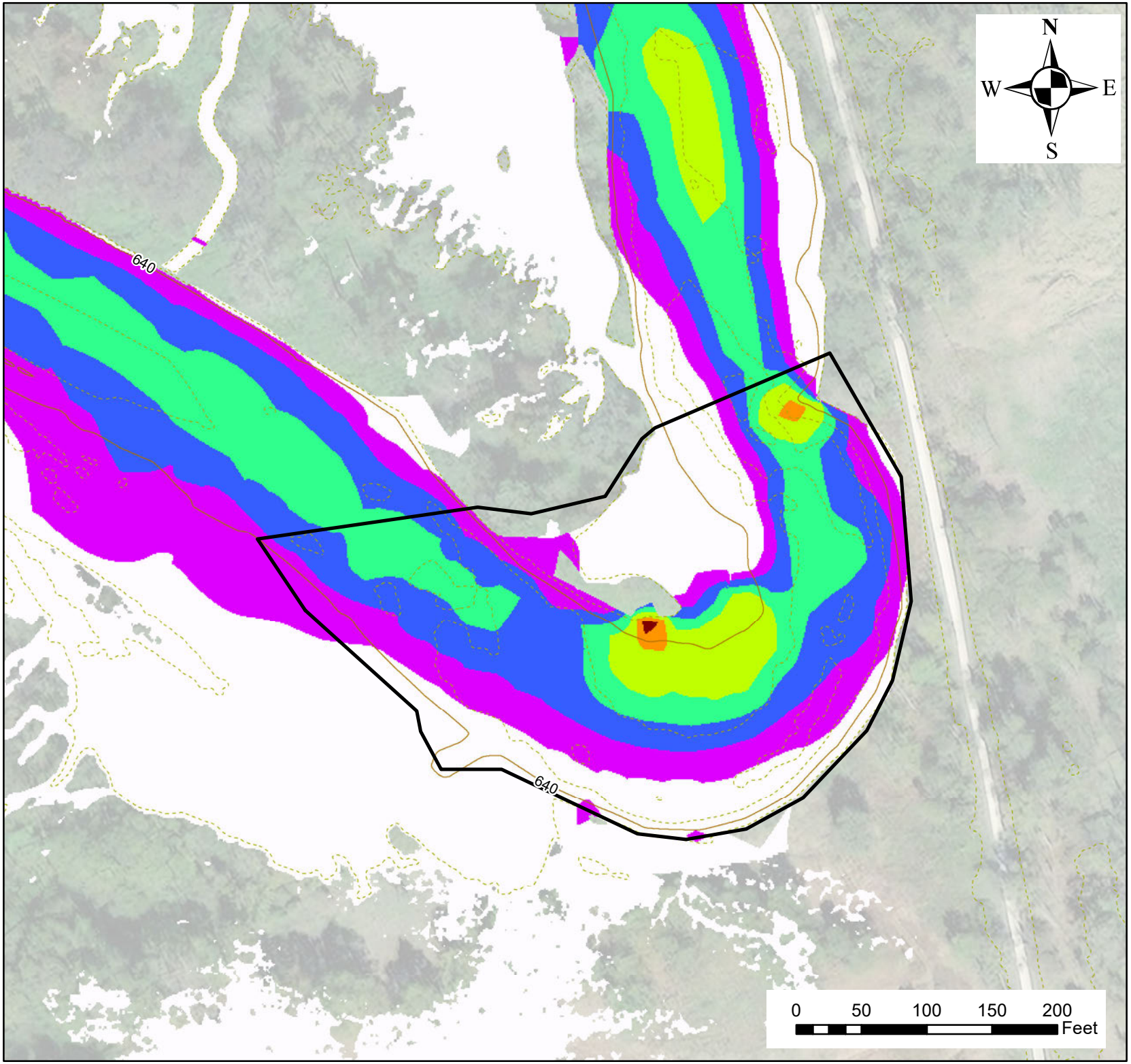
Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Velocity:

- 0 - 1 ft/s
- 1 - 2 ft/s
- 2 - 3 ft/s
- 3 - 4 ft/s
- 4 - 5 ft/s
- 5 - 6 ft/s
- > 6 ft/s

GPD GROUP



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Existing Conditions
1-year Design Storm
Shear Stress Map

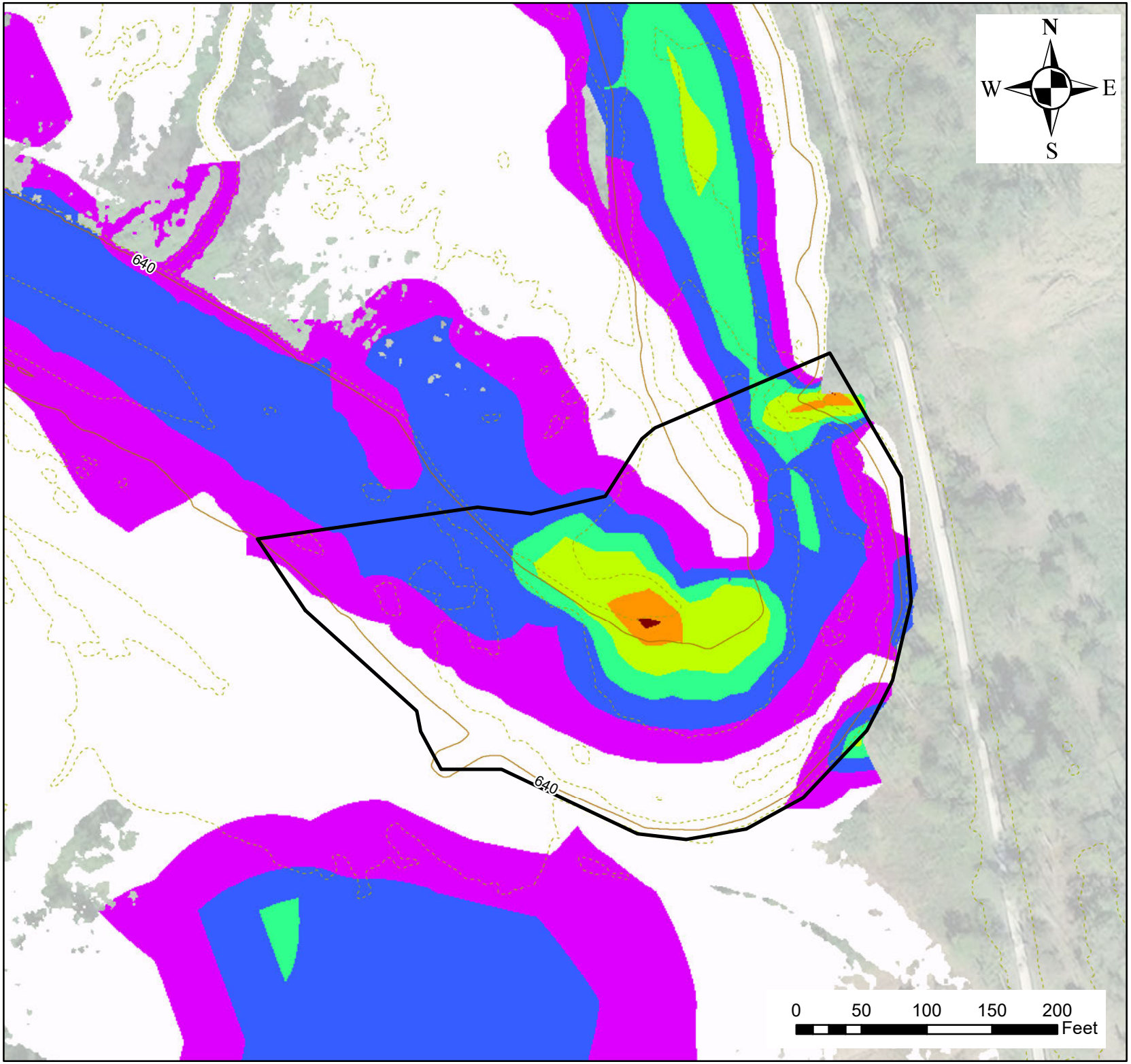
Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Shear Stress:

- 0.0 - 0.1 lb/ft²
- 0.1 - 0.2 lb/ft²
- 0.2 - 0.3 lb/ft²
- 0.3 - 0.4 lb/ft²
- 0.4 - 0.6 lb/ft²
- 0.6 - 0.8 lb/ft²
- > 0.8 lb/ft²

GPD GROUP



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Existing Conditions
1.5-year Design Storm
Shear Stress Map

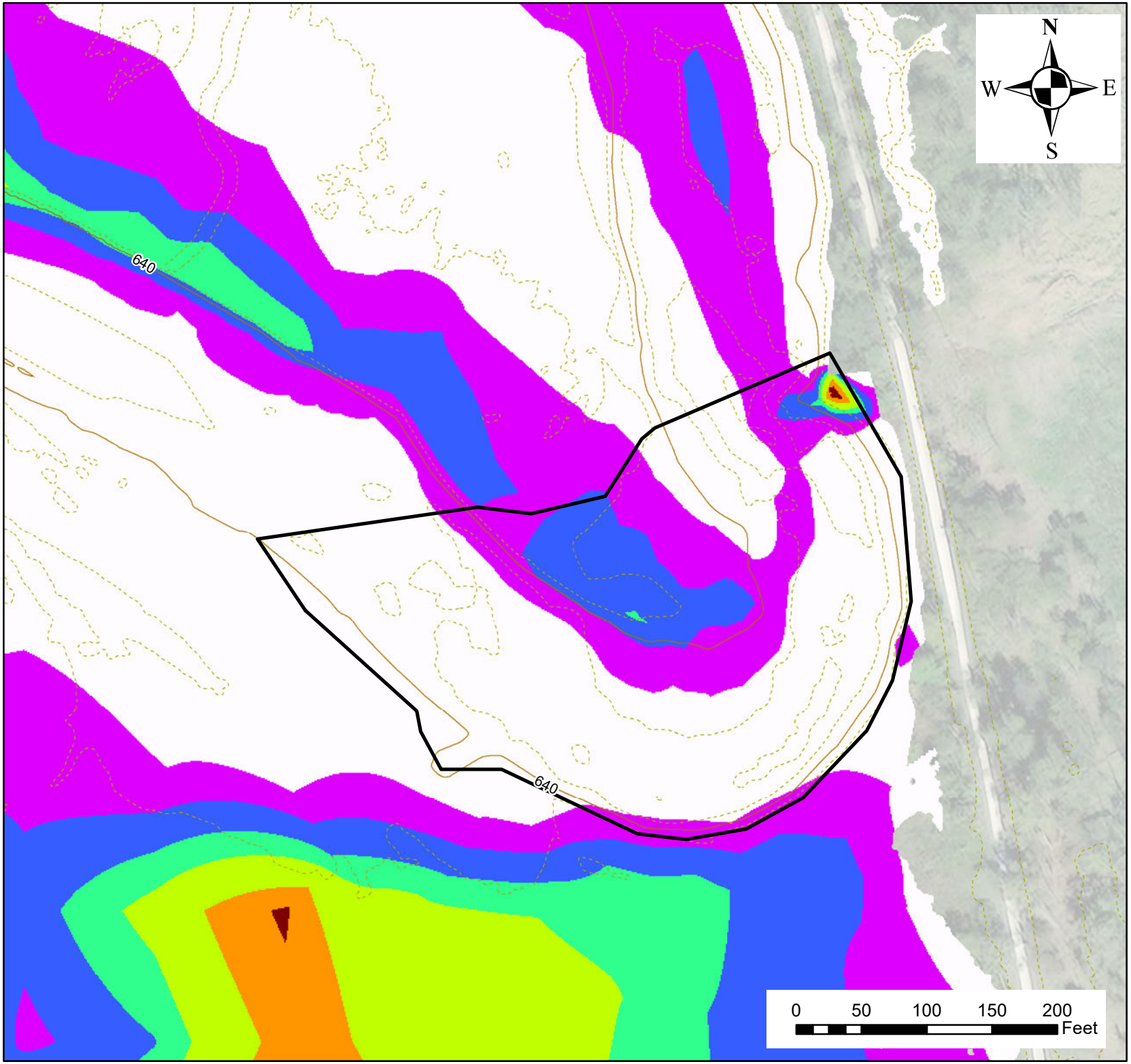
Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Shear Stress:

- 0.0 - 0.1 lb/ft²
- 0.1 - 0.2 lb/ft²
- 0.2 - 0.3 lb/ft²
- 0.3 - 0.4 lb/ft²
- 0.4 - 0.6 lb/ft²
- 0.6 - 0.8 lb/ft²
- > 0.8 lb/ft²

GPD GROUP



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Existing Conditions
10-year Design Storm
Shear Stress Map

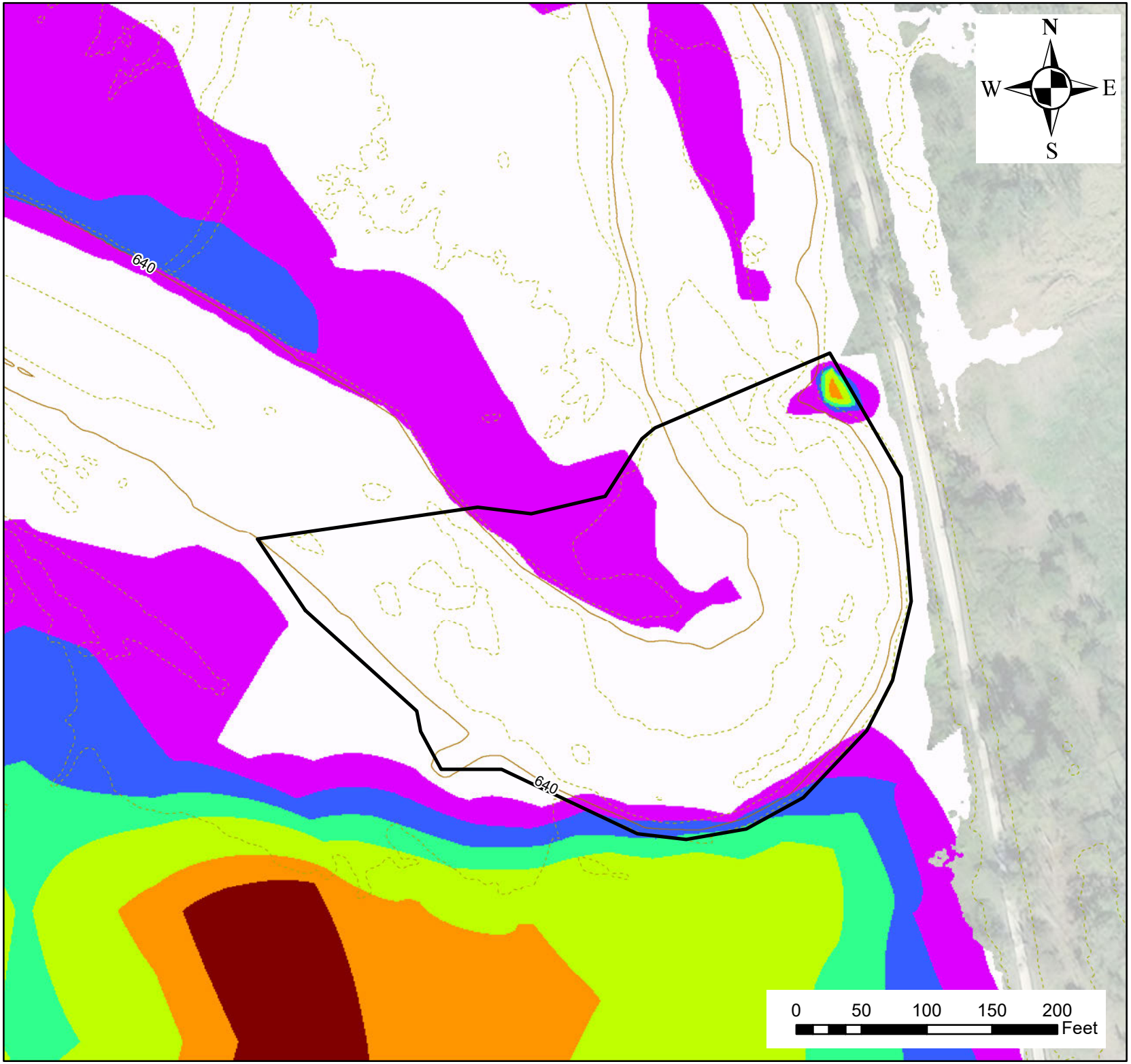
Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Shear Stress:

- 0.0 - 0.1 lb/ft²
- 0.1 - 0.2 lb/ft²
- 0.2 - 0.3 lb/ft²
- 0.3 - 0.4 lb/ft²
- 0.4 - 0.6 lb/ft²
- 0.6 - 0.8 lb/ft²
- > 0.8 lb/ft²

GPD GROUP



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Existing Conditions
100-year Design Storm
Shear Stress Map

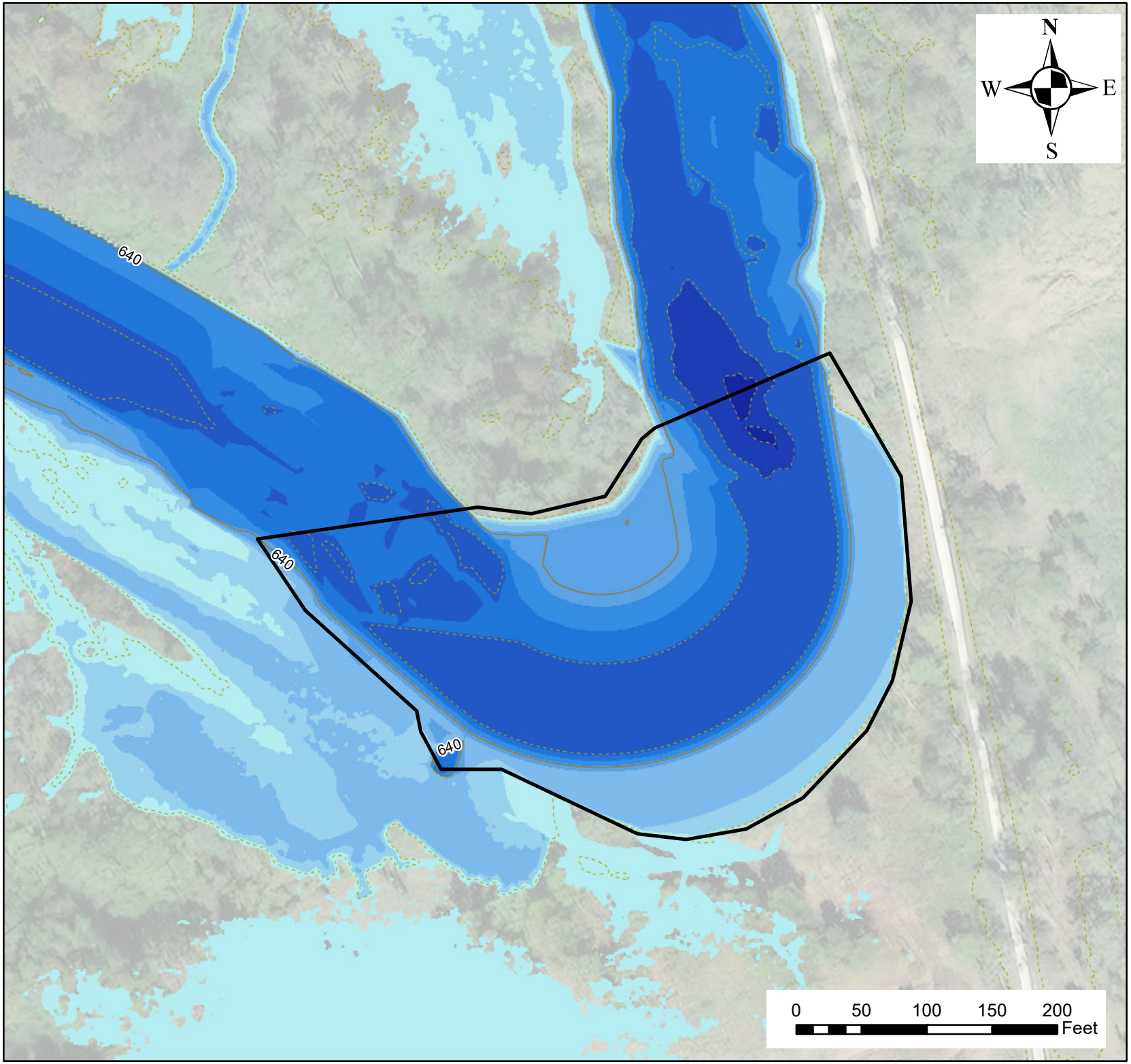
Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Shear Stress:

- 0.0 - 0.1 lb/ft²
- 0.1 - 0.2 lb/ft²
- 0.2 - 0.3 lb/ft²
- 0.3 - 0.4 lb/ft²
- 0.4 - 0.6 lb/ft²
- 0.6 - 0.8 lb/ft²
- > 0.8 lb/ft²

GPD GROUP



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Proposed Conditions
1-year Design Storm
Depth Map

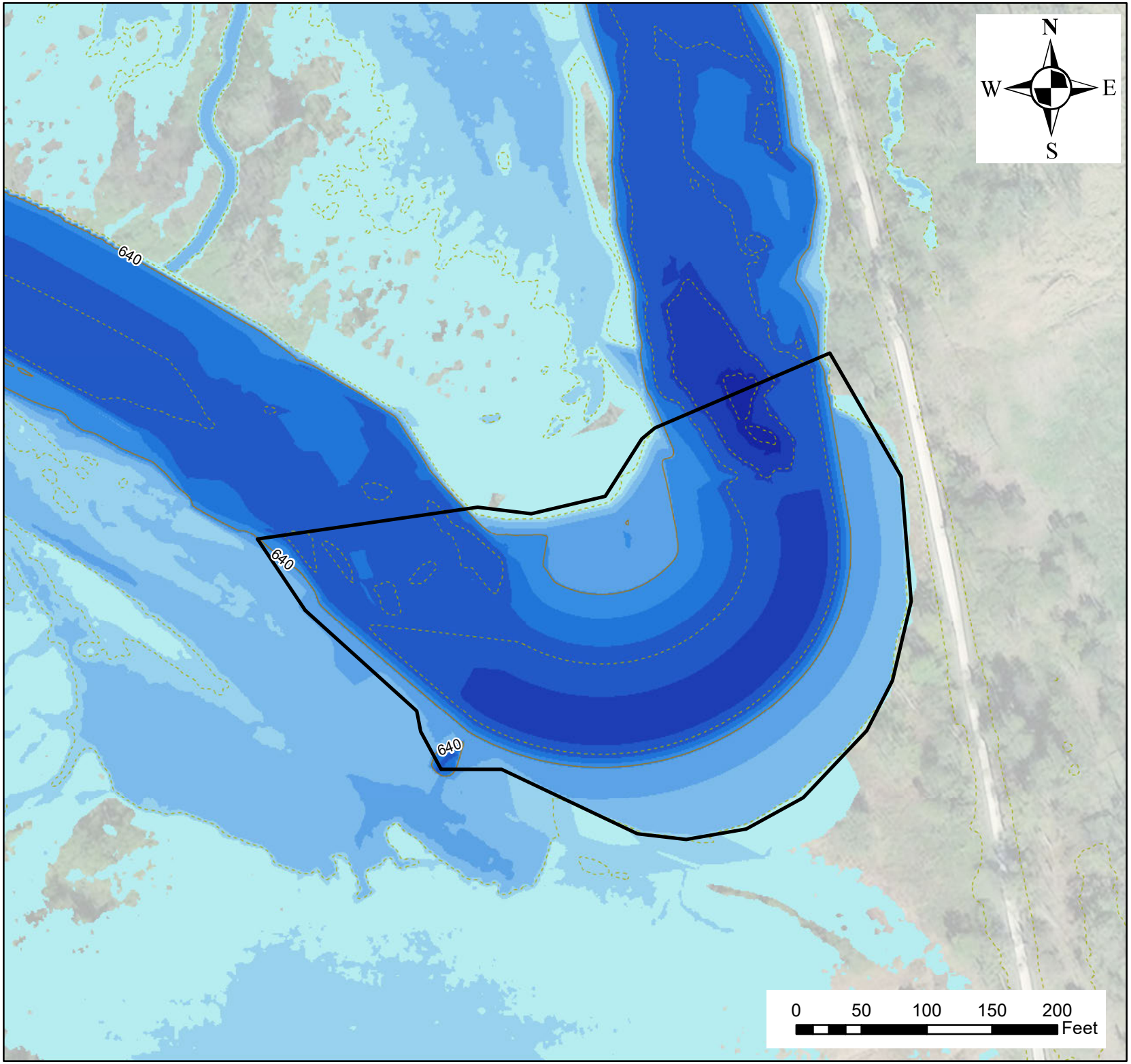
Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Depth:

- 0 - 1 ft
- 1 - 2 ft
- 2 - 4 ft
- 4 - 6 ft
- 6 - 8 ft
- 8 - 10 ft
- 10 - 15 ft
- 15 - 20 ft
- > 20 ft

GPD GROUP



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Proposed Conditions
1.5-year Design Storm
Depth Map

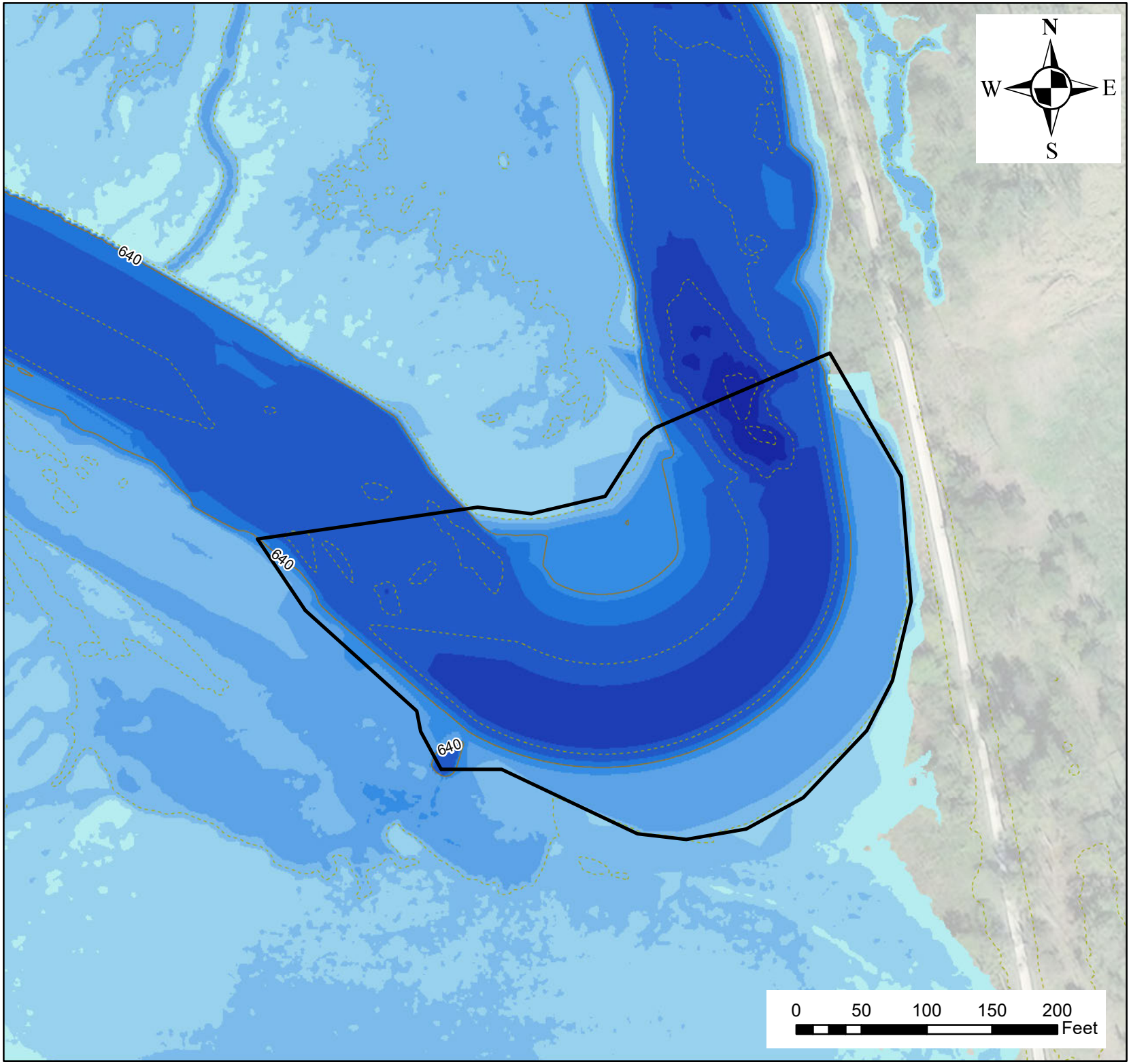
Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Depth:

- 0 - 1 ft
- 1 - 2 ft
- 2 - 4 ft
- 4 - 6 ft
- 6 - 8 ft
- 8 - 10 ft
- 10 - 15 ft
- 15 - 20 ft
- > 20 ft

GPD GROUP



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Proposed Conditions
10-year Design Storm
Depth Map

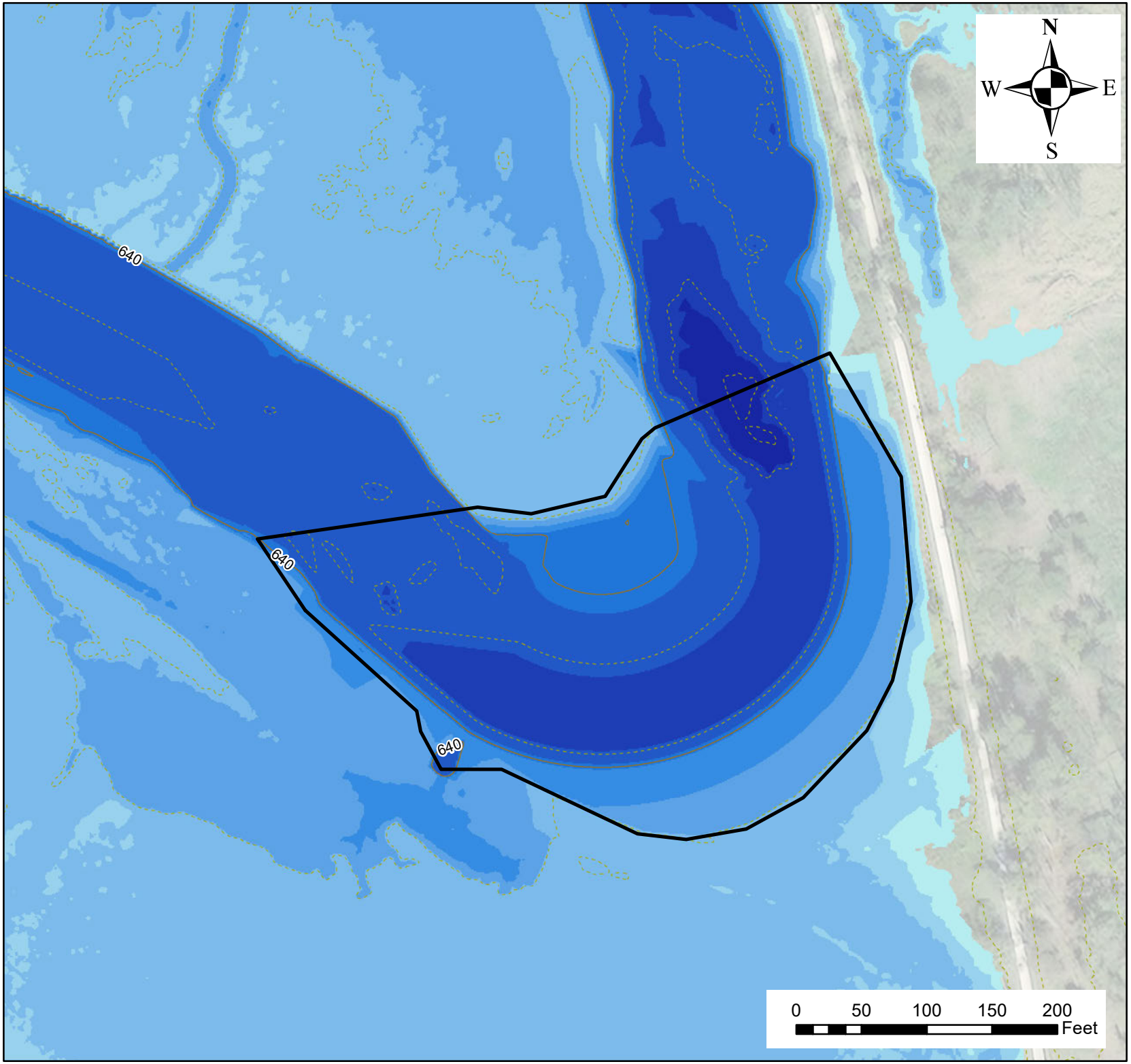
Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Depth:

- 0 - 1 ft
- 1 - 2 ft
- 2 - 4 ft
- 4 - 6 ft
- 6 - 8 ft
- 8 - 10 ft
- 10 - 15 ft
- 15 - 20 ft
- > 20 ft

GPD GROUP



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Proposed Conditions
100-year Design Storm
Depth Map

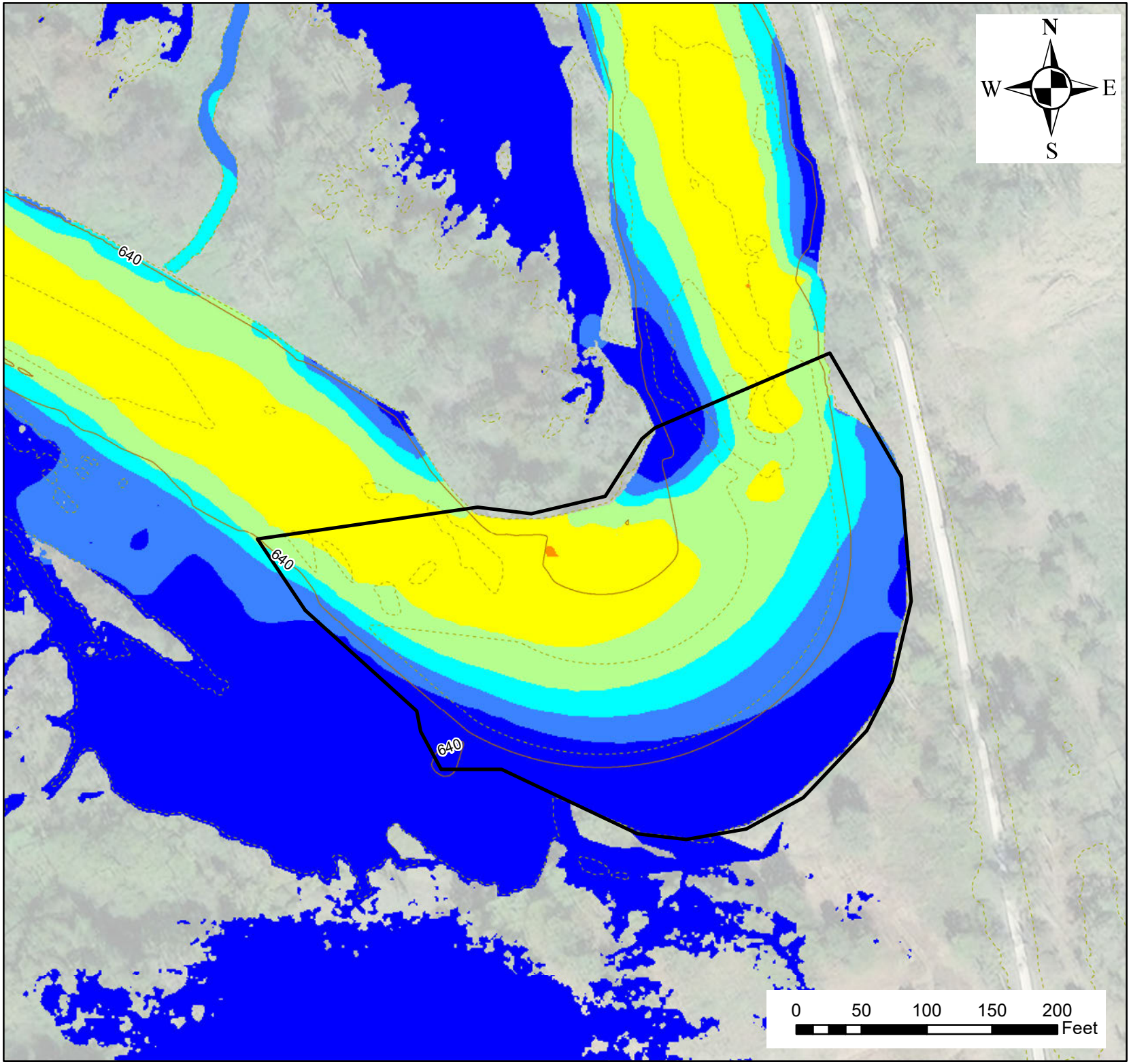
Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Depth:

- 0 - 1 ft
- 1 - 2 ft
- 2 - 4 ft
- 4 - 6 ft
- 6 - 8 ft
- 8 - 10 ft
- 10 - 15 ft
- 15 - 20 ft
- > 20 ft

GPD GROUP



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Proposed Conditions
1-year Design Storm
Velocity Map

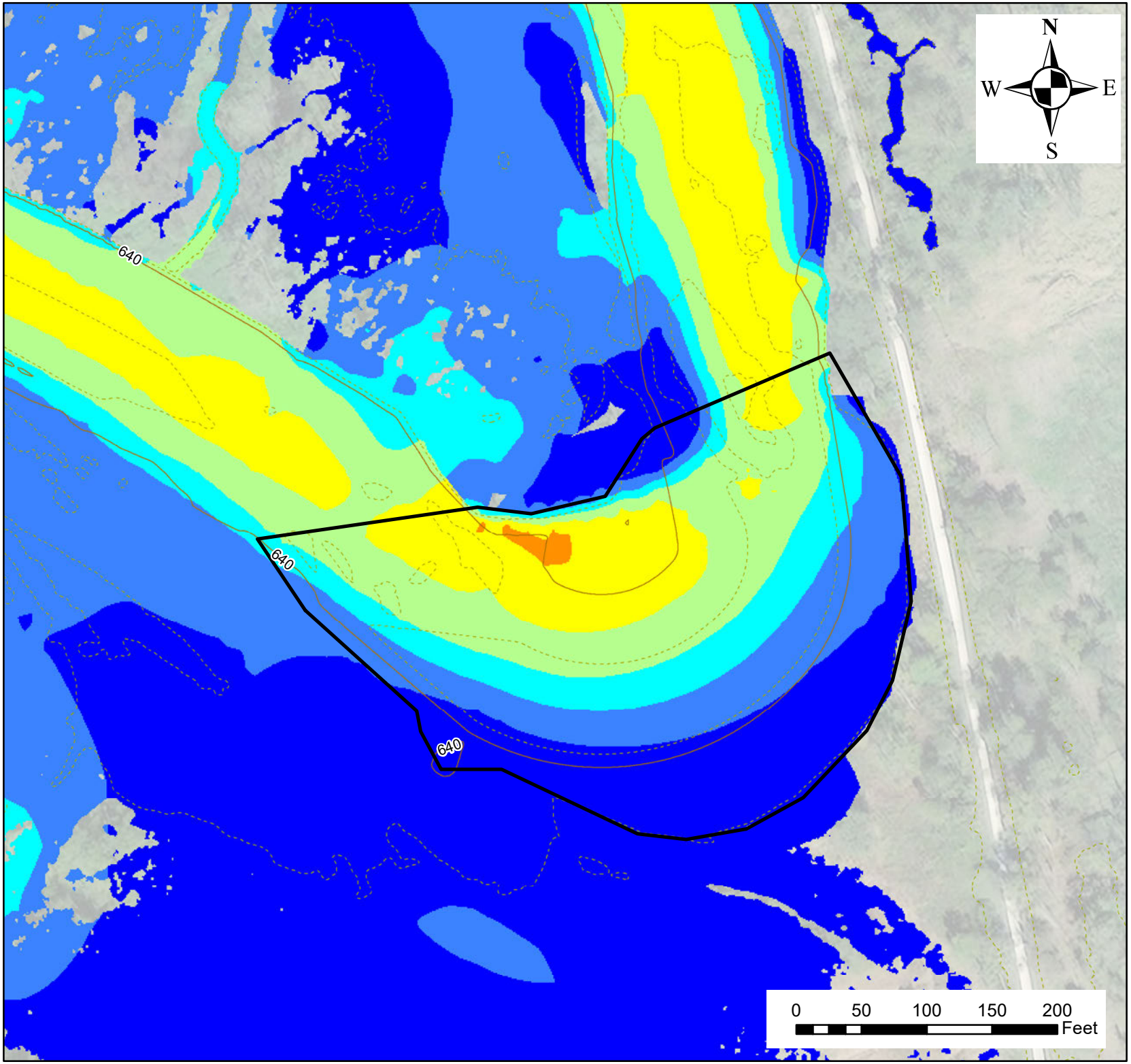
Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Velocity:

- 0 - 1 ft/s
- 1 - 2 ft/s
- 2 - 3 ft/s
- 3 - 4 ft/s
- 4 - 5 ft/s
- 5 - 6 ft/s
- > 6 ft/s

GPD GROUP



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Proposed Conditions
1.5-year Design Storm
Velocity Map

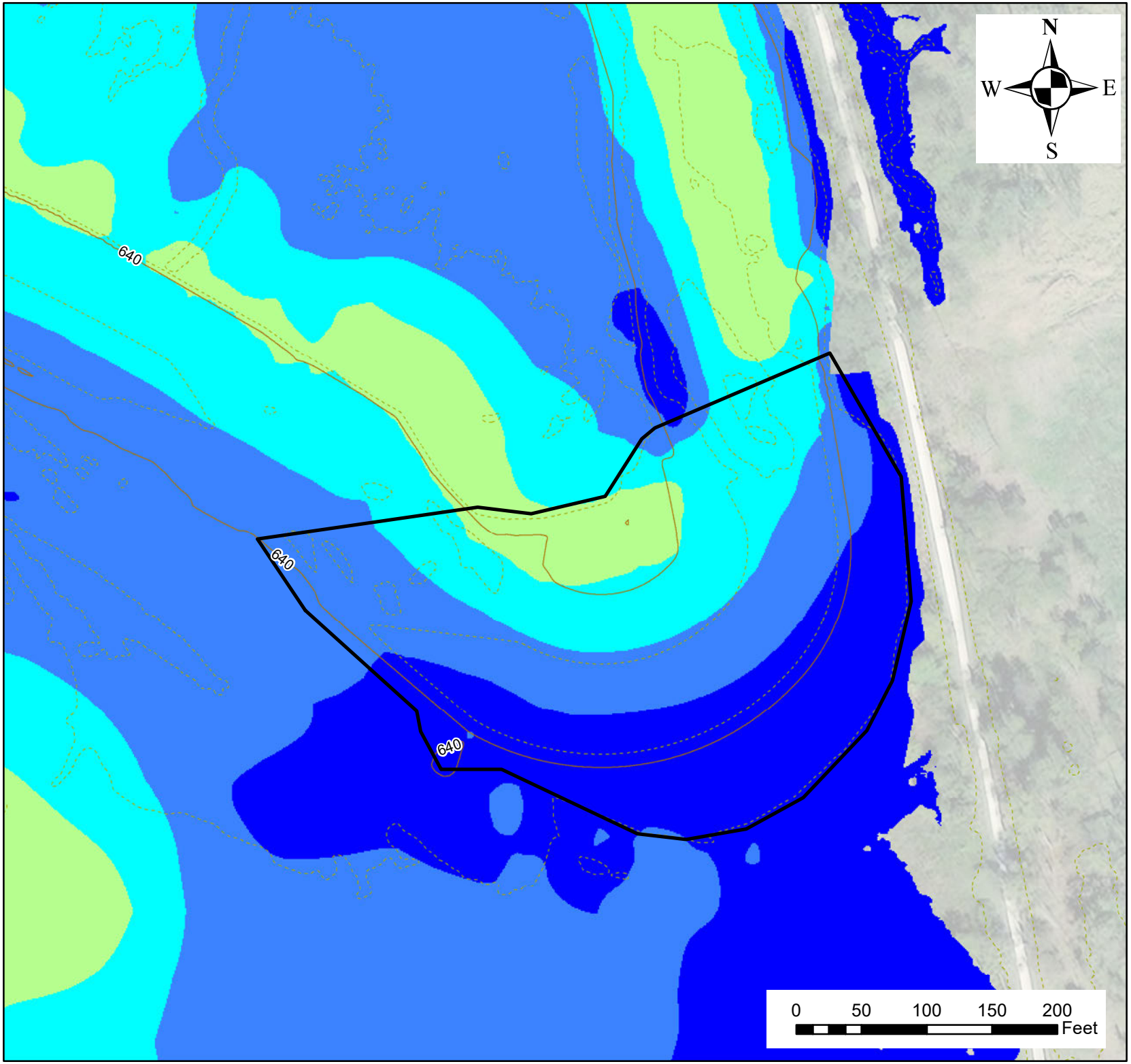
Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Velocity:

- 0 - 1 ft/s
- 1 - 2 ft/s
- 2 - 3 ft/s
- 3 - 4 ft/s
- 4 - 5 ft/s
- 5 - 6 ft/s
- > 6 ft/s

GPD GROUP



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Proposed Conditions
10-year Design Storm
Velocity Map

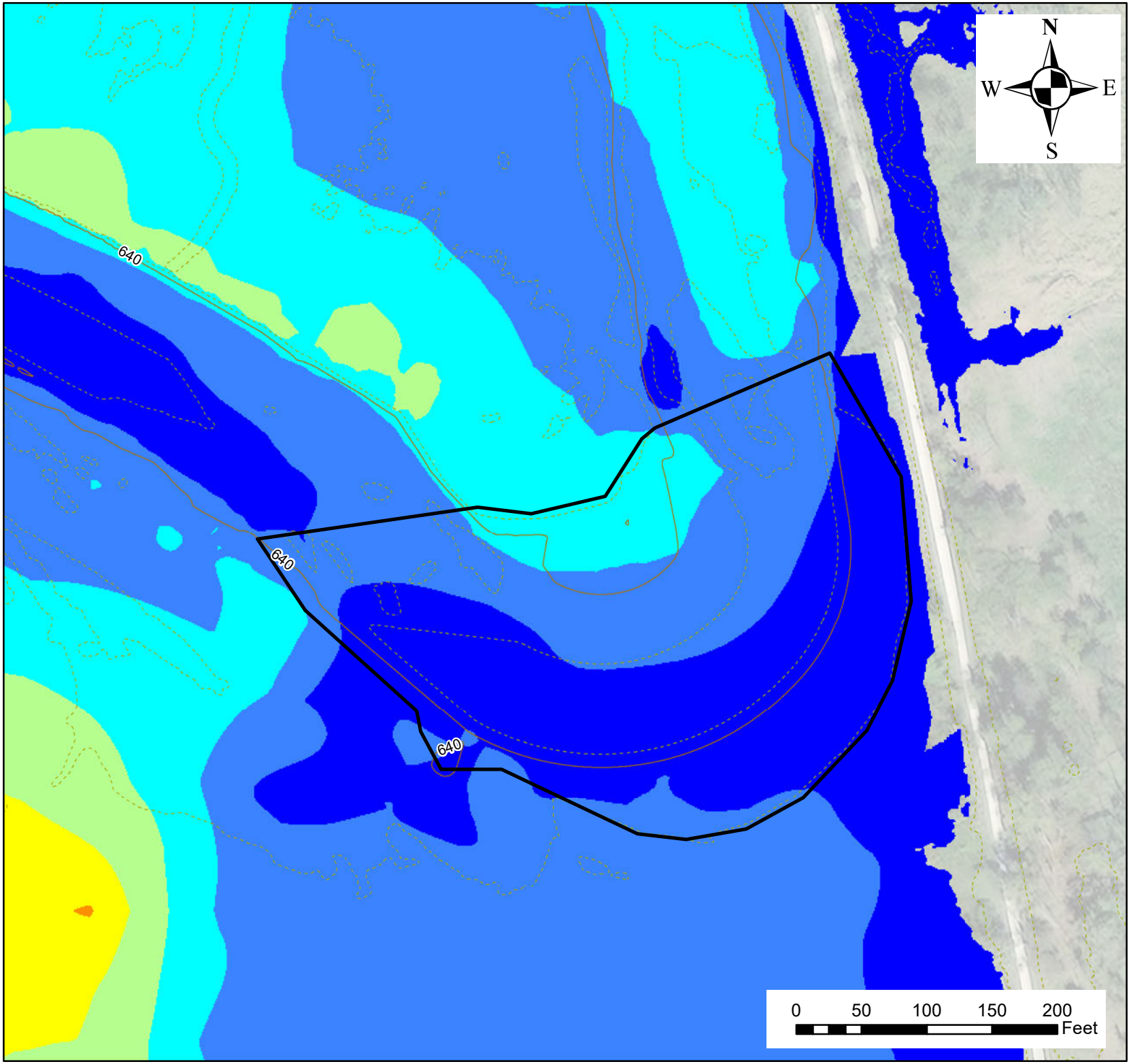
Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Velocity:

- 0 - 1 ft/s
- 1 - 2 ft/s
- 2 - 3 ft/s
- 3 - 4 ft/s
- 4 - 5 ft/s
- 5 - 6 ft/s
- > 6 ft/s

GPD GROUP



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Proposed Conditions
100-year Design Storm
Velocity Map

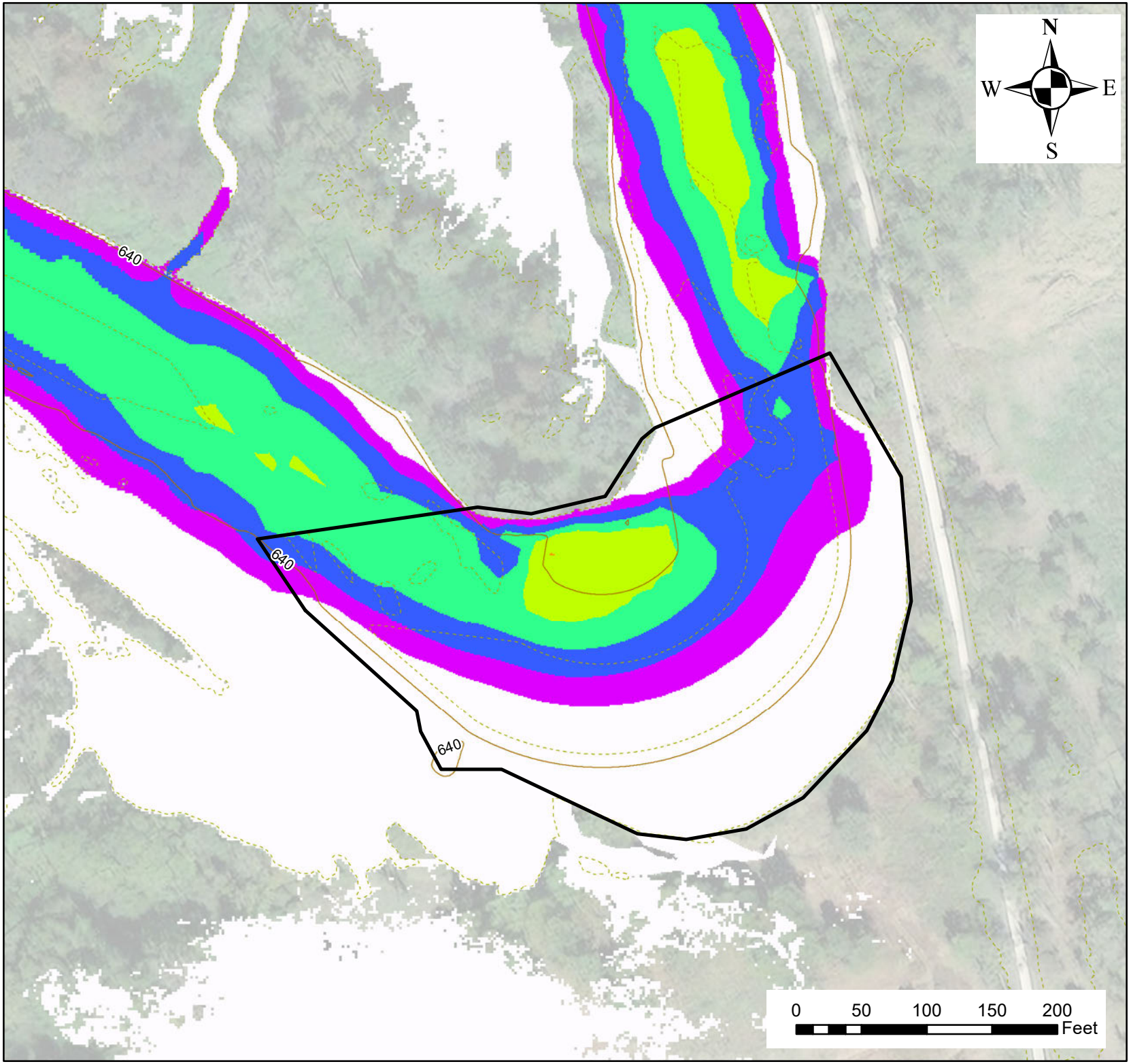
Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Velocity:

- 0 - 1 ft/s
- 1 - 2 ft/s
- 2 - 3 ft/s
- 3 - 4 ft/s
- 4 - 5 ft/s
- 5 - 6 ft/s
- > 6 ft/s

GPD GROUP



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Proposed Conditions
1-year Design Storm
Shear Stress Map

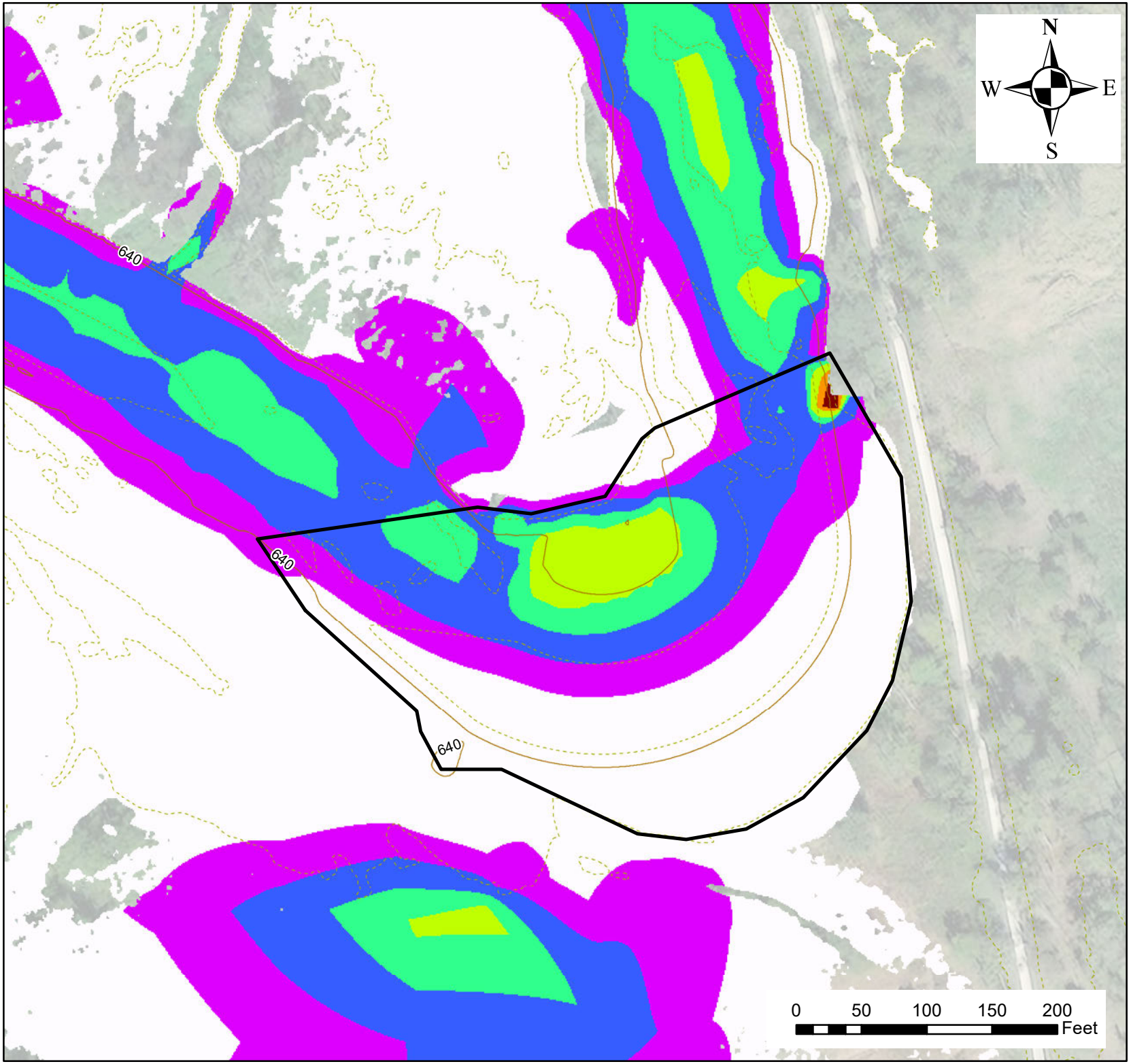
Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Shear Stress:

- 0.0 - 0.1 lb/ft²
- 0.1 - 0.2 lb/ft²
- 0.2 - 0.3 lb/ft²
- 0.3 - 0.4 lb/ft²
- 0.4 - 0.6 lb/ft²
- 0.6 - 0.8 lb/ft²
- > 0.8 lb/ft²

GPD GROUP



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Proposed Conditions
1.5-year Design Storm
Shear Stress Map

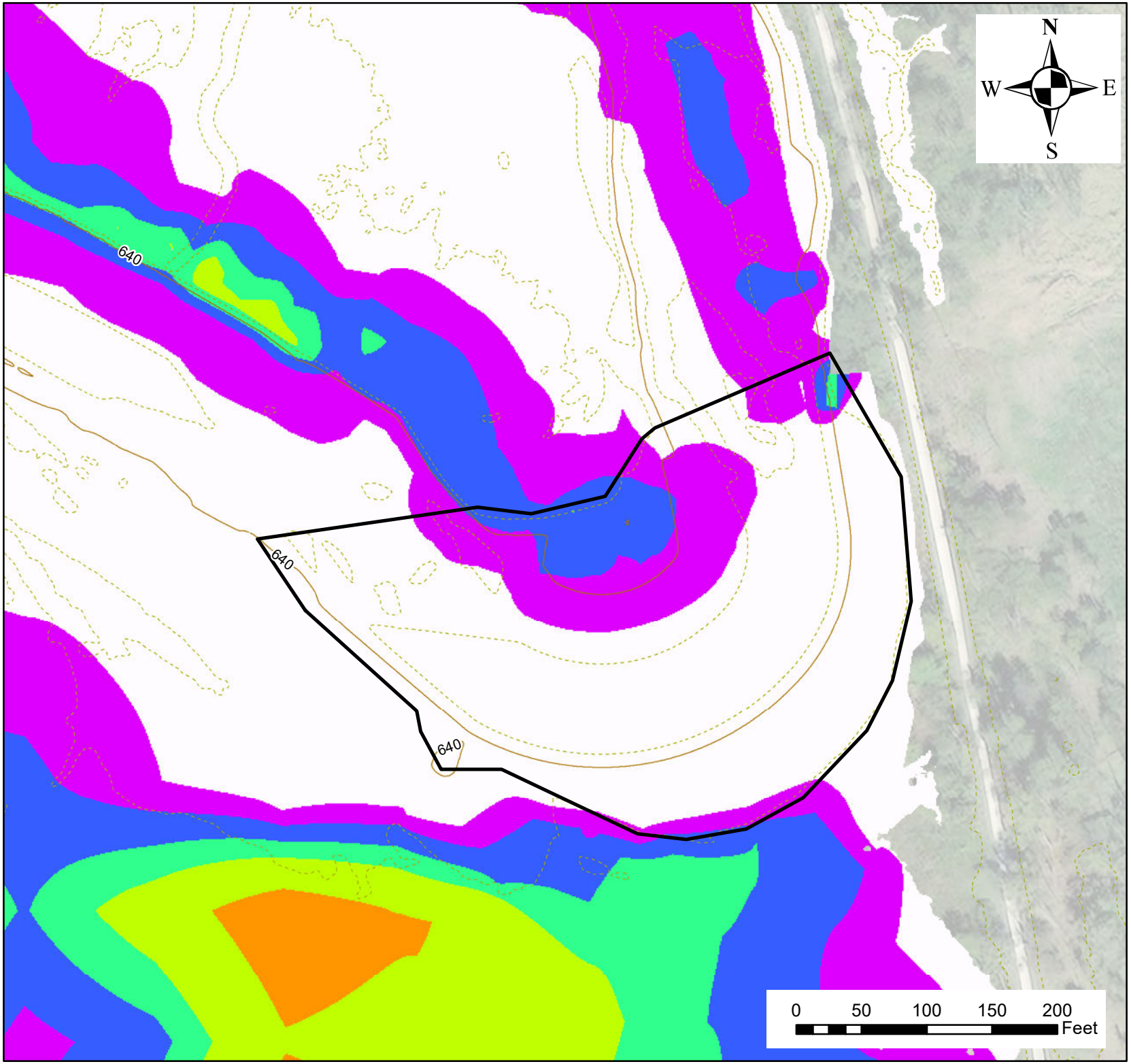
Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Shear Stress:

- 0.0 - 0.1 lb/ft²
- 0.1 - 0.2 lb/ft²
- 0.2 - 0.3 lb/ft²
- 0.3 - 0.4 lb/ft²
- 0.4 - 0.6 lb/ft²
- 0.6 - 0.8 lb/ft²
- > 0.8 lb/ft²

GPD GROUP



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Proposed Conditions
10-year Design Storm
Shear Stress Map

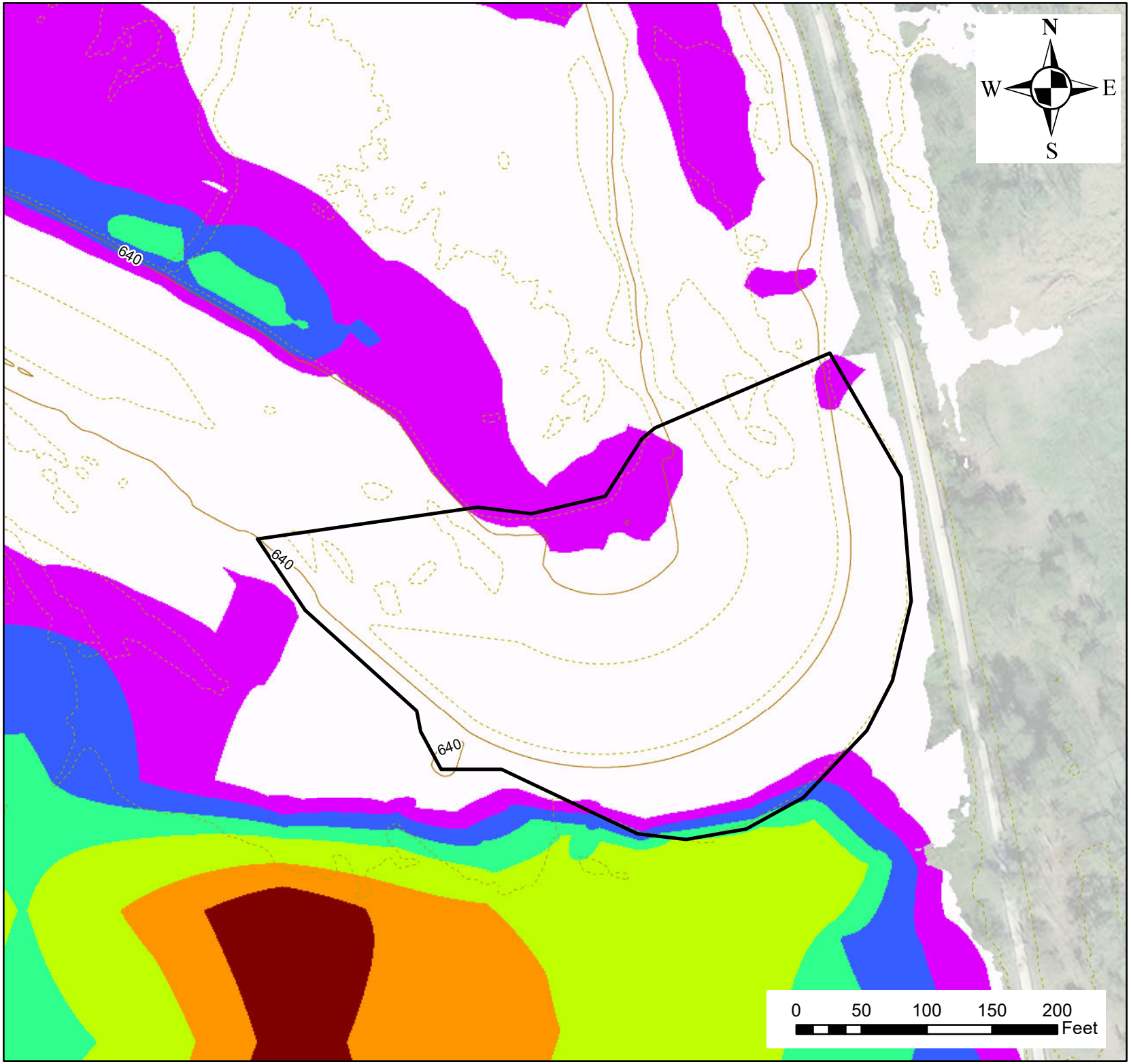
Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Shear Stress:

- 0.0 - 0.1 lb/ft²
- 0.1 - 0.2 lb/ft²
- 0.2 - 0.3 lb/ft²
- 0.3 - 0.4 lb/ft²
- 0.4 - 0.6 lb/ft²
- 0.6 - 0.8 lb/ft²
- > 0.8 lb/ft²

GPD GROUP



Cuyahoga Valley National Park Riverbank Stabilization

Design Development
August 14, 2023

Towpath Mile Marker 20 South

Proposed Conditions
100-year Design Storm
Shear Stress Map

Legend

- Work Limits
- 20 ft. Contours
- 5 ft. Contours

Shear Stress:

- 0.0 - 0.1 lb/ft²
- 0.1 - 0.2 lb/ft²
- 0.2 - 0.3 lb/ft²
- 0.3 - 0.4 lb/ft²
- 0.4 - 0.6 lb/ft²
- 0.6 - 0.8 lb/ft²
- > 0.8 lb/ft²

GPD GROUP

APPENDIX V

SCOUR & MATERIAL CALCULATION WORKSHEETS

Calculation By = APM | **Checked By =** AL
Date = 8/3/23 | **Date =** 8/7/23

Input Value | Scour Site: Towpath MM20 S.
Calculated Value | Upstream Site: US Towpath MM20 S.

Data used in Calculations			**Notes and Assumptions**
Assumed substrate density, ρ_b =	160	lbs/ft^3	
Water Density, ρ_w =	62.4	lbs/ft^3	(Assuming water temp of 70° F)
Mean Flow Depth, y =	8.90	ft	(Depth from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Mean Flow Depth above bend, y_u =	10.25	ft	(Depth from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Max depth upstream of bend, y_{max} =	11.60	ft	(Depth from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Max Depth at Bend, y_{mxb} =	16.59	ft	(Depth from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Channel Hydraulic Radius, R =	27.90	ft	(Calculated from 2D results at Profile Line Towpath MM20 S.)
Energy Slope, S_e =	0.00089	ft/ft	(From 2D HEC-RAS output: Towpath MM20 S. Channel Profile Line
D_{50} =	23	mm	(Estimated based on EnviroScience bar pebble counts)
D_{90} =	112	mm	(Estimated based on EnviroScience bar pebble counts)
D_{mean} =	23	mm	(Estimated based on EnviroScience bar pebble counts)
Kinematic Viscostiy, ν =	1.1E-05	ft^2/s	(Assuming water temp of 70° F)
Average Stream Slope, S_{ex} =	0.00135	ft/ft	(From HEC-RAS terrain: Towpath MM20 S. Channel Profile Line)
Design Flow, Q =	4884	ft^3/s	1 year flow at site based on 2D HEC-RAS model
Mannings Roughness, n =	0.038		(Main Channel Roughness, Estimated)
Distance to hard point, L =	5557	ft	(Point where structure or stream material will resist scour, in this case assumed to be nearest roadway bridge)
Chnl. Flow Top Width, w =	162.02	ft	(Calculated from 2D results at Profile Line Towpath MM20 S.)
Avg. Channel Velocity, v =	3.77	ft/s	(Velocity from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Avg. Channel Velocity above bend, v_b =	3.93	ft/s	(Velocity from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Mannings Constant =	1.486		
Gravity, g =	32.2	ft/s^2	
Channel Shear Stress, τ =	0.32	lbs/ft^2	(Shear stress from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Bed particle specific gravity, S_s =	2.564		
Radius of stream bend, r_c =	122.6	ft	(Radius of stream centerline)
Unit Discharge, q =	30.143	cfs/ft	(Total flow / flow top width)
Rel. Submerged Density, ΔS_g =	1.564	lbs/ft^3	

Max Scour Limited by Armoring

Shear Velocity, U_* = 0.506 ft/s

$$U_* = (gyS_e)^{0.5}$$

Particle Reynolds #, R_{E*} = 3628.7

$$Re = \frac{U_* D_{50}}{\nu}$$

Dimensionless Stress, τ_* = 0.043
Shields Critical Stress, θ_c = 0.037
Min. armor size constant, K = 17
Min. armor size constant, a = 1
Min. armor size constant, B = 0

See Table TS14B-4 for values

Table TS14B–4 Constants for computation of minimum armor particle size

Particle Reynolds number $\frac{U_* D_{50}}{\nu}$	K	a	B
≤10	68	1.67	0.67
Between 10 and 500	27	0.86	−0.14
≥500	17	1.0	0.0

Smallest armor particle size, D_x =	0.086	ft	$D_x = K\left(\frac{yS_e}{\Delta S_g}\right)^a\left(\frac{U_*}{\nu}\right)^b$
	26.33	mm	
Are particles present larger than D_x?	Yes		If yes, an armor layer can form
Bed porosity, e =	0.318		$e = 0.245 + \frac{0.0864}{(0.1D_{50})^{0.21}}$
Fraction of Material > D_x, P_x =	0.1		(Value estimated based on proposed substrate)
Active Bed Layer Thickness, T =	1.266	ft	$T = \frac{D_x}{(1-e)P_x}$
Max scour limited by armoring, Z_x =	**1.179**	**ft**	

Max Scour by Equilibrium Slope

By Manning and Shields, S_{eq} =	0.00053	ft/ft	$S_{eq} = \left[\theta_c D_c \Delta S_g\right]^{\frac{10}{7}}\left(\frac{K}{qn}\right)^{\frac{6}{7}}$	Let $D_c = D_{50}$
By Meyer-Peter & Muller, S_{eq} =	0.00173	ft/ft	$S_{eq} = K\frac{(D_{50})^{\frac{10}{7}} n^{\frac{9}{7}}}{(D_{90})^{\frac{5}{14}} q^{\frac{6}{7}}}$	See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
By Henderson, S_{eq} =	0.00045	ft/ft	$S_{eq} = K\,Q_d^{-0.46} D_{50}^{1.15}$	See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
By Schoklitsch, S_{eq} =	0.00142	ft/ft	$S_{eq} = K\left(\frac{D_m}{q}\right)^{\frac{3}{4}}$	See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
Average Eqilibrium slope, S_{eq} =	**0.00103**	**ft/ft**		
Max Scour by Equilibrium Slope, Z_{ad} =	**1.746**	**ft**	$z_{ad} = L(S_{ex} - S_{eq})$	
Equilibrium or Armoring Controls?	**Armoring**			

Compute Bend Scour

By Zeller Equation, Z_{bs} =	**6.192**	**ft**	$Z_{bs} = 0.0685 y_{mxb}^{0.6} V^{0.6} S_e^{-0.3}(2.8w^{0.2} r_c^{-0.2} - 1)$
By Maynord Equation, y_{mxb}/y =	1.856	ft	$\frac{y_{mxb}}{y_u} = 1.8 - 0.051\left(\frac{r_c}{w}\right) + 0.0084\left(\frac{w}{y_u}\right)$
By Maynord Equation, Z_{bs} =	**10.301**	**ft***	

*The Maynord Equation takes bend scour, general scour, and thalweg formation into consideration. Factor of Safety of 1.08 used.

Total Scour Predicted

Factor of Safety, FS =	1.3		FS =
Equilibrium or armoring, Z_{ad} =	1.179	ft	(Long term aggradation or degradation of reach)
Contraction Scour, Z_c =		ft	(Not applicable for this analysis)
Bend Scour, Z_b =	6.192	ft	(By Zeller)
Bedform trough depth, Z_{bf} =		ft	(Not applicable for this analysis)
Local scour at a structure, Z_s =		ft	(Not applicable for this analysis)
Total Scour, Z_t =	**9.582**	**ft**	$z_t = FS[z_{ad} + z_c + z_b + z_{bf} + z_s]$

General Scour Predicted

General Scour by Blodget, Z_t(max) = **8.637** **ft**

$$z_t(\max) = K D_{50}^{-0.11}$$

where K = 6.5

General Scour by Lacey, Z_t = **3.914** **ft**

$$z_t = K Q_d^a W_f^b D_{50}^c$$

General Scour by Blench, Z_t = **7.600** **ft**

Table TS14B–8 Constants for Lacey and Blench relations, U.S. units (D_{50} in mm)

Condition	Lacey				Blench			
	K	a	b	c	K	a	b	c
Straight reach	0.097	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Moderate bend	0.195	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Severe bend	0.292	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Right angle bend	0.389	1/3	0	−1/6	1.105	2/3	−2/3	−0.1092
Vertical rock wall	0.487	1/3	0	−1/6				

Average Predicted Scour

Average Predicted Scour, Z_t = **8.007** **ft**

(Average of Total Scour, Maynord Scour, and General Scour calculations)

Maximum Predicted Scour

Maximum Predicted Scour, Z_{max} = **10.301** **ft**

(Maximum of Total Scour, Maynord Scour, and General Scour calculations)

References

General Scour, Armoring, and Equilibrium Slope

US Department of Agriculture, Natural Resources Conservation Service. 2007. *Stream Restoration Design, Technical Supplement 14B Scour Calculations, National Engineering Handbook NEH 654.* Available at https://policy.nrcs.usda.gov/viewerFS.aspx?id=3491

Zeller Bend Scour

Simon Li & Associates. (1985). Design Manual for Engineering Analysis of Fluvial Systems. Arizona Department of Water Resources.

Maynord Bend Scour

Maynord, S.T. (1996). Toe-Scour Estimation in Stabilized Bendways. Journal of Hydraulic Engineering, 122(8), 460-464.

Calculation By = APM | **Checked By =** AL
Date = 8/3/23 | **Date =** 8/7/23

Input Value | Scour Site: Towpath MM20 S.
Calculated Value | Upstream Site: US Towpath MM20 S.

Data used in Calculations			**Notes and Assumptions**
Assumed substrate density, ρ_b =	160	lbs/ft^3	
Water Density, ρ_w =	62.4	lbs/ft^3	(Assuming water temp of 70° F)
Mean Flow Depth, y =	9.89	ft	(Depth from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Mean Flow Depth above bend, y_u =	11.02	ft	(Depth from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Max depth upstream of bend, y_{max} =	12.48	ft	(Depth from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Max Depth at Bend, y_{mxb} =	17.54	ft	(Depth from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Channel Hydraulic Radius, R =	30.32	ft	(Calculated from 2D results at Profile Line Towpath MM20 S.)
Energy Slope, S_e =	0.00152	ft/ft	(From 2D HEC-RAS output: Towpath MM20 S. Channel Profile Line
D_{50} =	23	mm	(Estimated based on EnviroScience bar pebble counts)
D_{90} =	112	mm	(Estimated based on EnviroScience bar pebble counts)
D_{mean} =	23	mm	(Estimated based on EnviroScience bar pebble counts)
Kinematic Viscostiy, ν =	1.1E-05	ft^2/s	(Assuming water temp of 70° F)
Average Stream Slope, S_{ex} =	0.00135	ft/ft	(From HEC-RAS terrain: Towpath MM20 S. Channel Profile Line)
Design Flow, Q =	4806	ft^3/s	1.5 year flow at site based on 2D HEC-RAS model
Mannings Roughness, n =	0.038		(Main Channel Roughness, Estimated)
Distance to hard point, L =	5557	ft	(Point where structure or stream material will resist scour, in this case assumed to be nearest roadway bridge)
Chnl. Flow Top Width, w =	162.38	ft	(Calculated from 2D results at Profile Line Towpath MM20 S.)
Avg. Channel Velocity, v =	3.41	ft/s	(Velocity from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Avg. Channel Velocity above bend, v_b =	3.51	ft/s	(Velocity from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Mannings Constant =	1.486		
Gravity, g =	32.2	ft/s^2	
Channel Shear Stress, τ =	0.27	lbs/ft^2	(Shear stress from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Bed particle specific gravity, S_s =	2.564		
Radius of stream bend, r_c =	122.6	ft	(Radius of stream centerline)
Unit Discharge, q =	29.596	cfs/ft	(Total flow / flow top width)
Rel. Submerged Density, ΔS_g =	1.564	lbs/ft^3	

Max Scour Limited by Armoring

Shear Velocity, U_* = 0.696 ft/s

$$U_* = (gyS_e)^{0.5}$$

Particle Reynolds #, R_{E*} = 4989.43

$$Re = \frac{U_* D_{50}}{\nu}$$

Dimensionless Stress, τ_* = 0.036
Shields Critical Stress, θ_c = 0.037
Min. armor size constant, K = 17
Min. armor size constant, a = 1
Min. armor size constant, B = 0

See Table TS14B-4 for values

Table TS14B–4 Constants for computation of minimum armor particle size

Particle Reynolds number $\frac{U_* D_{50}}{\nu}$	K	a	B
≤10	68	1.67	0.67
Between 10 and 500	27	0.86	−0.14
≥500	17	1.0	0.0

Smallest armor particle size, D_x =	0.163	ft	$D_x = K\left(\frac{yS_e}{\Delta S_g}\right)^a\left(\frac{U_*}{\nu}\right)^b$
	49.78	mm	
Are particles present larger than D_x?	Yes		If yes, an armor layer can form
Bed porosity, e =	0.318		$e = 0.245 + \frac{0.0864}{(0.1D_{50})^{0.21}}$
Fraction of Material > D_x, P_x =	0.1		(Value estimated based on proposed substrate)
Active Bed Layer Thickness, T =	2.393	ft	$T = \frac{D_x}{(1-e)P_x}$
Max scour limited by armoring, Z_x =	**2.230**	**ft**	

Max Scour by Equilibrium Slope

By Manning and Shields, S_{eq} =	0.00054	ft/ft	$S_{eq} = \left[\theta_c D_c \Delta S_g\right]^{\frac{10}{7}}\left(\frac{K}{qn}\right)^{\frac{6}{7}}$	Let $D_c = D_{50}$
By Meyer-Peter & Muller, S_{eq} =	0.00175	ft/ft	$S_{eq} = K\frac{(D_{50})^{\frac{10}{7}} n^{\frac{9}{7}}}{(D_{90})^{\frac{5}{14}} q^{\frac{6}{7}}}$	See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
By Henderson, S_{eq} =	0.00046	ft/ft	$S_{eq} = K\, Q_d^{-0.46} D_{50}^{1.15}$	See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
By Schoklitsch, S_{eq} =	0.00144	ft/ft	$S_{eq} = K\left(\frac{D_m}{q}\right)^{\frac{3}{4}}$	See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
Average Eqilibrium slope, S_{eq} =	**0.00105**	**ft/ft**		
Max Scour by Equilibrium Slope, Z_{ad} =	**1.664**	**ft**	$z_{ad} = L(S_{ex} - S_{eq})$	
Equilibrium or Armoring Controls?	**Equilibrium**			

Compute Bend Scour

By Zeller Equation, Z_{bs} =	**4.996**	**ft**	$Z_{bs} = 0.0685 y_{mxb}^{0.6} V^{0.6} S_e^{-0.3}(2.8w^{0.2} r_c^{-0.2} - 1)$
By Maynord Equation, y_{mxb}/y =	1.847	ft	$\frac{y_{mxb}}{y_u} = 1.8 - 0.051\left(\frac{r_c}{w}\right) + 0.0084\left(\frac{w}{y_u}\right)$
By Maynord Equation, Z_{bs} =	**10.967**	**ft***	

*The Maynord Equation takes bend scour, general scour, and thalweg formation into consideration. Factor of Safety of 1.08 used.

Total Scour Predicted

Factor of Safety, FS =	1.3		FS =
Equilibrium or armoring, Z_{ad} =	1.664	ft	(Long term aggradation or degradation of reach)
Contraction Scour, Z_c =		ft	(Not applicable for this analysis)
Bend Scour, Z_b =	4.996	ft	(By Zeller)
Bedform trough depth, Z_{bf} =		ft	(Not applicable for this analysis)
Local scour at a structure, Z_s =		ft	(Not applicable for this analysis)
Total Scour, Z_t =	**8.658**	**ft**	$z_t = FS[z_{ad} + z_c + z_b + z_{bf} + z_s]$

General Scour Predicted

General Scour by Blodget, Z_t(max) = **8.637** **ft**

$$z_t(\max) = K D_{50}^{-0.11}$$

where K = 6.5

General Scour by Lacey, Z_t = **3.893** **ft**

$$z_t = K Q_d^a W_f^b D_{50}^c$$

General Scour by Blench, Z_t = **7.507** **ft**

Table TS14B–8 Constants for Lacey and Blench relations, U.S. units (D_{50} in mm)

Condition	Lacey				Blench			
	K	a	b	c	K	a	b	c
Straight reach	0.097	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Moderate bend	0.195	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Severe bend	0.292	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Right angle bend	0.389	1/3	0	−1/6	1.105	2/3	−2/3	−0.1092
Vertical rock wall	0.487	1/3	0	−1/6				

Average Predicted Scour

Average Predicted Scour, Z_t = **7.932** **ft**

(Average of Total Scour, Maynord Scour, and General Scour calculations)

Maximum Predicted Scour

Maximum Predicted Scour, Z_{max} = **10.967** **ft**

(Maximum of Total Scour, Maynord Scour, and General Scour calculations)

References

General Scour, Armoring, and Equilibrium Slope

US Department of Agriculture, Natural Resources Conservation Service. 2007. *Stream Restoration Design, Technical Supplement 14B Scour Calculations, National Engineering Handbook NEH 654.* Available at https://policy.nrcs.usda.gov/viewerFS.aspx?id=3491

Zeller Bend Scour

Simon Li & Associates. (1985). Design Manual for Engineering Analysis of Fluvial Systems. Arizona Department of Water Resources.

Maynord Bend Scour

Maynord, S.T. (1996). Toe-Scour Estimation in Stabilized Bendways. Journal of Hydraulic Engineering, 122(8), 460-464.

Calculation By = APM | **Checked By =** AL
Date = 8/3/23 | **Date =** 8/7/23

Input Value | Scour Site: Towpath MM20 S.
Calculated Value | Upstream Site: US Towpath MM20 S.

Data used in Calculations			**Notes and Assumptions**
Assumed substrate density, ρ_b =	160	lbs/ft^3	
Water Density, ρ_w =	62.4	lbs/ft^3	(Assuming water temp of 70° F)
Mean Flow Depth, y =	11.20	ft	(Depth from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Mean Flow Depth above bend, y_u =	12.17	ft	(Depth from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Max depth upstream of bend, y_{max} =	13.63	ft	(Depth from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Max Depth at Bend, y_{mxb} =	18.75	ft	(Depth from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Channel Hydraulic Radius, R =	31.65	ft	(Calculated from 2D results at Profile Line Towpath MM20 S.)
Energy Slope, S_e =	0.00228	ft/ft	(From 2D HEC-RAS output: Towpath MM20 S. Channel Profile Line
D_{50} =	23	mm	(Estimated based on EnviroScience bar pebble counts)
D_{90} =	112	mm	(Estimated based on EnviroScience bar pebble counts)
D_{mean} =	23	mm	(Estimated based on EnviroScience bar pebble counts)
Kinematic Viscostiy, ν =	1.1E-05	ft^2/s	(Assuming water temp of 70° F)
Average Stream Slope, S_{ex} =	0.00135	ft/ft	(From HEC-RAS terrain: Towpath MM20 S. Channel Profile Line)
Design Flow, Q =	3031	ft^3/s	10 year flow at site based on 2D HEC-RAS model
Mannings Roughness, n =	0.038		(Main Channel Roughness, Estimated)
Distance to hard point, L =	5557	ft	(Point where structure or stream material will resist scour, in this case assumed to be nearest roadway bridge)
Chnl. Flow Top Width, w =	162.38	ft	(Calculated from 2D results at Profile Line Towpath MM20 S.)
Avg. Channel Velocity, v =	1.92	ft/s	(Velocity from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Avg. Channel Velocity above bend, v_b =	1.88	ft/s	(Velocity from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Mannings Constant =	1.486		
Gravity, g =	32.2	ft/s^2	
Channel Shear Stress, τ =	0.09	lbs/ft^2	(Shear stress from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Bed particle specific gravity, S_s =	2.564		
Radius of stream bend, r_c =	122.6	ft	(Radius of stream centerline)
Unit Discharge, q =	18.668	cfs/ft	(Total flow / flow top width)
Rel. Submerged Density, ΔS_g =	1.564	lbs/ft^3	

Max Scour Limited by Armoring

Shear Velocity, U_* = 0.906 ft/s

$$U_* = (gyS_e)^{0.5}$$

Particle Reynolds #, R_{E*} = 6499.13

$$Re = \frac{U_* D_{50}}{\nu}$$

Dimensionless Stress, τ_* = 0.012
Shields Critical Stress, θ_c = 0.037
Min. armor size constant, K = 17
Min. armor size constant, a = 1
Min. armor size constant, B = 0

See Table TS14B-4 for values

Table TS14B–4 Constants for computation of minimum armor particle size

Particle Reynolds number $\frac{U_* D_{50}}{\nu}$	K	a	B
≤10	68	1.67	0.67
Between 10 and 500	27	0.86	−0.14
≥500	17	1.0	0.0

Smallest armor particle size, D_x =	0.277	ft	$D_x = K\left(\frac{yS_e}{\Delta S_g}\right)^a\left(\frac{U_*}{\nu}\right)^b$
	84.46	mm	
Are particles present larger than D_x?	Yes		If yes, an armor layer can form
Bed porosity, e =	0.318		$e = 0.245 + \frac{0.0864}{(0.1D_{50})^{0.21}}$
Fraction of Material > D_x, P_x =	0.1		(Value estimated based on proposed substrate)
Active Bed Layer Thickness, T =	4.060	ft	$T = \frac{D_x}{(1-e)P_x}$
Max scour limited by armoring, Z_x =	**3.783**	**ft**	

Max Scour by Equilibrium Slope

By Manning and Shields, S_{eq} =	0.0008	ft/ft	$S_{eq} = \left[\theta_c D_c \Delta S_g\right]^{\frac{10}{7}}\left(\frac{K}{qn}\right)^{\frac{6}{7}}$	Let $D_c = D_{50}$
By Meyer-Peter & Muller, S_{eq} =	0.0026	ft/ft	$S_{eq} = K\frac{(D_{50})^{\frac{10}{7}} n^{\frac{9}{7}}}{(D_{90})^{\frac{5}{14}} q^{\frac{6}{7}}}$	See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
By Henderson, S_{eq} =	0.00056	ft/ft	$S_{eq} = K\, Q_d^{-0.46} D_{50}^{1.15}$	See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
By Schoklitsch, S_{eq} =	0.00203	ft/ft	$S_{eq} = K\left(\frac{D_m}{q}\right)^{\frac{3}{4}}$	See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
Average Eqilibrium slope, S_{eq} =	**0.0015**	**ft/ft**		
Max Scour by Equilibrium Slope, Z_{ad} =	**4.351**	**ft**	$z_{ad} = L(S_{ex} - S_{eq})$	
Equilibrium or Armoring Controls?	**Armoring**			

Compute Bend Scour

By Zeller Equation, Z_{bs} =	**2.792**	**ft**	$Z_{bs} = 0.0685 y_{mxb}^{0.6} V^{0.6} S_e^{-0.3}(2.8w^{0.2} r_c^{-0.2} - 1)$
By Maynord Equation, y_{mxb}/y =	1.836	ft	$\frac{y_{mxb}}{y_u} = 1.8 - 0.051\left(\frac{r_c}{w}\right) + 0.0084\left(\frac{w}{y_u}\right)$
By Maynord Equation, Z_{bs} =	**11.954**	**ft***	

*The Maynord Equation takes bend scour, general scour, and thalweg formation into consideration. Factor of Safety of 1.08 used.

Total Scour Predicted

Factor of Safety, FS =	1.3		FS =
Equilibrium or armoring, Z_{ad} =	3.783	ft	(Long term aggradation or degradation of reach)
Contraction Scour, Z_c =		ft	(Not applicable for this analysis)
Bend Scour, Z_b =	2.792	ft	(By Zeller)
Bedform trough depth, Z_{bf} =		ft	(Not applicable for this analysis)
Local scour at a structure, Z_s =		ft	(Not applicable for this analysis)
Total Scour, Z_t =	**8.547**	**ft**	$z_t = FS[z_{ad} + z_c + z_b + z_{bf} + z_s]$

General Scour Predicted

General Scour by Blodget, Z_t(max) = **8.637** **ft**

$$z_t(\max) = K D_{50}^{-0.11}$$

where K = 6.5

General Scour by Lacey, Z_t = **3.338** **ft**

$$z_t = K Q_d^a W_f^b D_{50}^c$$

General Scour by Blench, Z_t = **5.522** **ft**

Table TS14B–8 Constants for Lacey and Blench relations, U.S. units (D_{50} in mm)

Condition	Lacey				Blench			
	K	a	b	c	K	a	b	c
Straight reach	0.097	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Moderate bend	0.195	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Severe bend	0.292	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Right angle bend	0.389	1/3	0	−1/6	1.105	2/3	−2/3	−0.1092
Vertical rock wall	0.487	1/3	0	−1/6				

Average Predicted Scour

Average Predicted Scour, Z_t = **7.600** **ft**

(Average of Total Scour, Maynord Scour, and General Scour calculations)

Maximum Predicted Scour

Maximum Predicted Scour, Z_{max} = **11.954** **ft**

(Maximum of Total Scour, Maynord Scour, and General Scour calculations)

References

General Scour, Armoring, and Equilibrium Slope

US Department of Agriculture, Natural Resources Conservation Service. 2007. *Stream Restoration Design, Technical Supplement 14B Scour Calculations, National Engineering Handbook NEH 654.* Available at https://policy.nrcs.usda.gov/viewerFS.aspx?id=3491

Zeller Bend Scour

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Maynord Bend Scour

Maynord, S.T. (1996). Toe-Scour Estimation in Stabilized Bendways. Journal of Hydraulic Engineering, 122(8), 460-464.

Calculation By = APM | **Checked By =** AL
Date = 8/3/23 | **Date =** 8/7/23

Input Value | Scour Site: Towpath MM20 S.
Calculated Value | Upstream Site: US Towpath MM20 S.

Data used in Calculations			**Notes and Assumptions**
Assumed substrate density, ρ_b =	160	lbs/ft^3	
Water Density, ρ_w =	62.4	lbs/ft^3	(Assuming water temp of 70° F)
Mean Flow Depth, y =	12.21	ft	(Depth from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Mean Flow Depth above bend, y_u =	13.13	ft	(Depth from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Max depth upstream of bend, y_{max} =	14.60	ft	(Depth from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Max Depth at Bend, y_{mxb} =	19.73	ft	(Depth from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Channel Hydraulic Radius, R =	32.67	ft	(Calculated from 2D results at Profile Line Towpath MM20 S.)
Energy Slope, S_e =	0.00299	ft/ft	(From 2D HEC-RAS output: Towpath MM20 S. Channel Profile Line
D_{50} =	23	mm	(Estimated based on EnviroScience bar pebble counts)
D_{90} =	112	mm	(Estimated based on EnviroScience bar pebble counts)
D_{mean} =	23	mm	(Estimated based on EnviroScience bar pebble counts)
Kinematic Viscostiy, ν =	1.1E-05	ft^2/s	(Assuming water temp of 70° F)
Average Stream Slope, S_{ex} =	0.00135	ft/ft	(From HEC-RAS terrain: Towpath MM20 S. Channel Profile Line)
Design Flow, Q =	2127	ft^3/s	100 year flow at site based on 2D HEC-RAS model
Mannings Roughness, n =	0.038		(Main Channel Roughness, Estimated)
Distance to hard point, L =	5557	ft	(Point where structure or stream material will resist scour, in this case assumed to be nearest roadway bridge)
Chnl. Flow Top Width, w =	162.38	ft	(Calculated from 2D results at Profile Line Towpath MM20 S.)
Avg. Channel Velocity, v =	1.22	ft/s	(Velocity from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Avg. Channel Velocity above bend, v_b =	0.85	ft/s	(Velocity from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Mannings Constant =	1.486		
Gravity, g =	32.2	ft/s^2	
Channel Shear Stress, τ =	0.04	lbs/ft^2	(Shear stress from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Bed particle specific gravity, S_s =	2.564		
Radius of stream bend, r_c =	122.6	ft	(Radius of stream centerline)
Unit Discharge, q =	13.099	cfs/ft	(Total flow / flow top width)
Rel. Submerged Density, ΔS_g =	1.564	lbs/ft^3	

Max Scour Limited by Armoring

Shear Velocity, U_* =	1.083	ft/s	$U_* = (gyS_e)^{0.5}$
Particle Reynolds #, R_{E*} =	7771.753		$Re = \frac{U_* D_{50}}{\nu}$
Dimensionless Stress, τ_* =	0.005		
Shields Critical Stress, θ_c =	0.037		
Min. armor size constant, K =	17		See Table TS14B-4 for values
Min. armor size constant, a =	1		
Min. armor size constant, B =	0		

Table TS14B–4 Constants for computation of minimum armor particle size

Particle Reynolds number $\frac{U_* D_{50}}{\nu}$	K	a	B
≤10	68	1.67	0.67
Between 10 and 500	27	0.86	–0.14
≥500	17	1.0	0.0

Smallest armor particle size, D_x =	0.396	ft	$D_x = K\left(\frac{yS_e}{\Delta S_g}\right)^a\left(\frac{U_*}{\nu}\right)^b$
	120.78	mm	
Are particles present larger than D_x?	**No**		If yes, an armor layer can form
Bed porosity, e =	0.318		$e = 0.245 + \frac{0.0864}{(0.1D_{50})^{0.21}}$
Fraction of Material > D_x, P_x =	0.1		(Value estimated based on proposed substrate)
Active Bed Layer Thickness, T =	5.806	ft	$T = \frac{D_x}{(1-e)P_x}$
Max scour limited by armoring, Z_x =	**No**	**ft**	

Max Scour by Equilibrium Slope

By Manning and Shields, S_{eq} =	0.00109	ft/ft	$S_{eq} = \left[\theta_c D_c \Delta S_g\right]^{\frac{10}{7}}\left(\frac{K}{qn}\right)^{\frac{6}{7}}$	Let $D_c = D_{50}$
By Meyer-Peter & Muller, S_{eq} =	0.00353	ft/ft	$S_{eq} = K\frac{(D_{50})^{\frac{10}{7}} n^{\frac{9}{7}}}{(D_{90})^{\frac{5}{14}} q^{\frac{6}{7}}}$	See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
By Henderson, S_{eq} =	0.00066	ft/ft	$S_{eq} = K\, Q_d^{-0.46} D_{50}^{1.15}$	See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
By Schoklitsch, S_{eq} =	0.00265	ft/ft	$S_{eq} = K\left(\frac{D_m}{q}\right)^{\frac{3}{4}}$	See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
Average Eqilibrium slope, S_{eq} =	**0.00198**	**ft/ft**		
Max Scour by Equilibrium Slope, Z_{ad} =	**3.796**	**ft**	$z_{ad} = L(S_{ex} - S_{eq})$	
Equilibrium or Armoring Controls?	**Equilibrium**			

Compute Bend Scour

By Zeller Equation, Z_{bs} =	**1.410**	**ft**	$Z_{bs} = 0.0685 y_{mxb}^{0.6} V^{0.6} S_e^{-0.3}(2.8w^{0.2} r_c^{-0.2} - 1)$
By Maynord Equation, y_{mxb}/y =	1.827	ft	$\frac{y_{mxb}}{y_u} = 1.8 - 0.051\left(\frac{r_c}{w}\right) + 0.0084\left(\frac{w}{y_u}\right)$
By Maynord Equation, Z_{bs} =	**12.784**	**ft***	

*The Maynord Equation takes bend scour, general scour, and thalweg formation into consideration. Factor of Safety of 1.08 used.

Total Scour Predicted

Factor of Safety, FS =	1.3		FS =
Equilibrium or armoring, Z_{ad} =	3.796	ft	(Long term aggradation or degradation of reach)
Contraction Scour, Z_c =		ft	(Not applicable for this analysis)
Bend Scour, Z_b =	1.410	ft	(By Zeller)
Bedform trough depth, Z_{bf} =		ft	(Not applicable for this analysis)
Local scour at a structure, Z_s =		ft	(Not applicable for this analysis)
Total Scour, Z_t =	**6.768**	**ft**	$z_t = FS[z_{ad} + z_c + z_b + z_{bf} + z_s]$

General Scour Predicted

General Scour by Blodget, Z_t(max) = **8.637** **ft**

$$z_t(\max) = K D_{50}^{-0.11}$$ where K = 6.5

General Scour by Lacey, Z_t = **2.967** **ft**

$$z_t = K Q_d^a W_f^b D_{50}^c$$

General Scour by Blench, Z_t = **4.360** **ft**

Table TS14B–8 Constants for Lacey and Blench relations, U.S. units (D_{50} in mm)

Condition	Lacey				Blench			
	K	a	b	c	K	a	b	c
Straight reach	0.097	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Moderate bend	0.195	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Severe bend	0.292	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Right angle bend	0.389	1/3	0	−1/6	1.105	2/3	−2/3	−0.1092
Vertical rock wall	0.487	1/3	0	−1/6				

Average Predicted Scour

Average Predicted Scour, Z_t = **7.103** **ft** (Average of Total Scour, Maynord Scour, and General Scour calculations)

Maximum Predicted Scour

Maximum Predicted Scour, Z_{max} = **12.784** **ft** (Maximum of Total Scour, Maynord Scour, and General Scour calculations)

References

General Scour, Armoring, and Equilibrium Slope

US Department of Agriculture, Natural Resources Conservation Service. 2007. *Stream Restoration Design, Technical Supplement 14B Scour Calculations, National Engineering Handbook NEH 654.* Available at https://policy.nrcs.usda.gov/viewerFS.aspx?id=3491

Zeller Bend Scour

Simon Li & Associates. (1985). Design Manual for Engineering Analysis of Fluvial Systems. Arizona Department of Water Resources.

Maynord Bend Scour

Maynord, S.T. (1996). Toe-Scour Estimation in Stabilized Bendways. Journal of Hydraulic Engineering, 122(8), 460-464.

Calculation By = APM | **Checked By =** AL
Date = 8/3/23 | **Date =** 8/7/23

Input Value | Scour Site: Towpath MM20 S.
Calculated Value | Upstream Site: US Towpath MM20 S.

Data used in Calculations			**Notes and Assumptions**
Assumed substrate density, ρ_b =	160	lbs/ft^3	
Water Density, ρ_w =	62.4	lbs/ft^3	(Assuming water temp of 70° F)
Mean Flow Depth, y =	9.65	ft	(Depth from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Mean Flow Depth above bend, y_u =	10.04	ft	(Depth from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Max depth upstream of bend, y_{max} =	11.38	ft	(Depth from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Max Depth at Bend, y_{mxb} =	14.79	ft	(Depth from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Channel Hydraulic Radius, R =	10.20	ft	(Calculated from 2D results at Profile Line Towpath MM20 S.)
Energy Slope, S_e =	0.00076	ft/ft	(From 2D HEC-RAS output: Towpath MM20 S. Channel Profile Line
D_{50} =	23	mm	(Estimated based on EnviroScience bar pebble counts)
D_{90} =	112	mm	(Estimated based on EnviroScience bar pebble counts)
D_{mean} =	23	mm	(Estimated based on EnviroScience bar pebble counts)
Kinematic Viscostiy, ν =	1.1E-05	ft^2/s	(Assuming water temp of 70° F)
Average Stream Slope, S_{ex} =	0.00125	ft/ft	(From HEC-RAS terrain: Towpath MM20 S. Channel Profile Line)
Design Flow, Q =	3718	ft^3/s	1 year flow at site based on 2D HEC-RAS model
Mannings Roughness, n =	0.038		(Main Channel Roughness, Estimated)
Distance to hard point, L =	5557	ft	(Point where structure or stream material will resist scour, in this case assumed to be nearest roadway bridge)
Chnl. Flow Top Width, w =	139.29	ft	(Calculated from 2D results at Profile Line Towpath MM20 S.)
Avg. Channel Velocity, v =	3.04	ft/s	(Velocity from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Avg. Channel Velocity above bend, v_b =	4.18	ft/s	(Velocity from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Mannings Constant =	1.486		
Gravity, g =	32.2	ft/s^2	
Channel Shear Stress, τ =	0.20	lbs/ft^2	(Shear stress from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Bed particle specific gravity, S_s =	2.564		
Radius of stream bend, r_c =	138.6	ft	(Radius of stream centerline)
Unit Discharge, q =	26.693	cfs/ft	(Total flow / flow top width)
Rel. Submerged Density, ΔS_g =	1.5641	lbs/ft^3	

Max Scour Limited by Armoring

Shear Velocity, U_* = 0.488 ft/s

$$U_* = (gyS_e)^{0.5}$$

Particle Reynolds #, R_{E*} = 3497.19

$$Re = \frac{U_* D_{50}}{\nu}$$

Dimensionless Stress, τ_* = 0.0277
Shields Critical Stress, θ_c = 0.037
Min. armor size constant, K = 17
Min. armor size constant, a = 1
Min. armor size constant, B = 0

See Table TS14B-4 for values

Table TS14B–4 Constants for computation of minimum armor particle size

Particle Reynolds number $\frac{U_* D_{50}}{\nu}$	K	a	B
≤10	68	1.67	0.67
Between 10 and 500	27	0.86	−0.14
≥500	17	1.0	0.0

Smallest armor particle size, D_x =	0.0802	ft	$D_x = K\left(\frac{yS_e}{\Delta S_g}\right)^a\left(\frac{U_*}{\nu}\right)^b$
	24.46	mm	
Are particles present larger than D_x?	Yes		If yes, an armor layer can form
Bed porosity, e =	0.318		$e = 0.245 + \frac{0.0864}{(0.1D_{50})^{0.21}}$
Fraction of Material > D_x, P_x =	0.1		(Value estimated based on proposed substrate)
Active Bed Layer Thickness, T =	1.176	ft	$T = \frac{D_x}{(1-e)P_x}$
Max scour limited by armoring, Z_x =	**1.095**	**ft**	

Max Scour by Equilibrium Slope

By Manning and Shields, S_{eq} =	0.00059	ft/ft	$S_{eq} = \left[\theta_c D_c \Delta S_g\right]^{\frac{10}{7}}\left(\frac{K}{qn}\right)^{\frac{6}{7}}$	Let $D_c = D_{50}$
By Meyer-Peter & Muller, S_{eq} =	0.00192	ft/ft	$S_{eq} = K\frac{(D_{50})^{\frac{10}{7}} n^{\frac{9}{7}}}{(D_{90})^{\frac{5}{14}} q^{\frac{6}{7}}}$	See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
By Henderson, S_{eq} =	0.00051	ft/ft	$S_{eq} = K\,Q_d^{-0.46} D_{50}^{1.15}$	See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
By Schoklitsch, S_{eq} =	0.00156	ft/ft	$S_{eq} = K\left(\frac{D_m}{q}\right)^{\frac{3}{4}}$	See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
Average Eqilibrium slope, S_{eq} =	**0.00114**	**ft/ft**		
Max Scour by Equilibrium Slope, Z_{ad} =	**0.567**	**ft**	$z_{ad} = L(S_{ex} - S_{eq})$	
Equilibrium or Armoring Controls?	**Equilibrium**			

Compute Bend Scour

By Zeller Equation, Z_{bs} =	**5.528**	**ft**	$Z_{bs} = 0.0685 y_{mxb}^{0.6} V^{0.6} S_e^{-0.3}(2.8w^{0.2} r_c^{-0.2} - 1)$
By Maynord Equation, y_{mxb}/y =	1.840	ft	$\frac{y_{mxb}}{y_u} = 1.8 - 0.051\left(\frac{r_c}{w}\right) + 0.0084\left(\frac{w}{y_u}\right)$
By Maynord Equation, Z_{bs} =	**9.908**	**ft***	

*The Maynord Equation takes bend scour, general scour, and thalweg formation into consideration. Factor of Safety of 1.08 used.

Total Scour Predicted

Factor of Safety, FS =	1.3		FS =
Equilibrium or armoring, Z_{ad} =	0.567	ft	(Long term aggradation or degradation of reach)
Contraction Scour, Z_c =		ft	(Not applicable for this analysis)
Bend Scour, Z_b =	5.528	ft	(By Zeller)
Bedform trough depth, Z_{bf} =		ft	(Not applicable for this analysis)
Local scour at a structure, Z_s =		ft	(Not applicable for this analysis)
Total Scour, Z_t =	**7.923**	**ft**	$z_t = FS[z_{ad} + z_c + z_b + z_{bf} + z_s]$

General Scour Predicted

General Scour by Blodget, Z_t(max) = **8.637** **ft**

$$z_t(\max) = K D_{50}^{-0.11}$$

where K = 6.5

General Scour by Lacey, Z_t = **3.574** **ft**

$$z_t = K Q_d^a W_f^b D_{50}^c$$

General Scour by Blench, Z_t = **7.008** **ft**

Table TS14B–8 Constants for Lacey and Blench relations, U.S. units (D_{50} in mm)

Condition	Lacey				Blench			
	K	a	b	c	K	a	b	c
Straight reach	0.097	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Moderate bend	0.195	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Severe bend	0.292	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Right angle bend	0.389	1/3	0	−1/6	1.105	2/3	−2/3	−0.1092
Vertical rock wall	0.487	1/3	0	−1/6				

Average Predicted Scour

Average Predicted Scour, Z_t = **7.410** **ft** (Average of Total Scour, Maynord Scour, and General Scour calculations)

Maximum Predicted Scour

Maximum Predicted Scour, Z_{max} = **9.908** **ft** (Maximum of Total Scour, Maynord Scour, and General Scour calculations)

References

General Scour, Armoring, and Equilibrium Slope

US Department of Agriculture, Natural Resources Conservation Service. 2007. *Stream Restoration Design, Technical Supplement 14B Scour Calculations, National Engineering Handbook NEH 654.* Available at https://policy.nrcs.usda.gov/viewerFS.aspx?id=3491

Zeller Bend Scour

Simon Li & Associates. (1985). Design Manual for Engineering Analysis of Fluvial Systems. Arizona Department of Water Resources.

Maynord Bend Scour

Maynord, S.T. (1996). Toe-Scour Estimation in Stabilized Bendways. Journal of Hydraulic Engineering, 122(8), 460-464.

Calculation By = APM | **Checked By =** AL
Date = 8/3/23 | **Date =** 8/7/23

Input Value | Scour Site: Towpath MM20 S.
Calculated Value | Upstream Site: US Towpath MM20 S.

Data used in Calculations			**Notes and Assumptions**
Assumed substrate density, ρ_b =	160	lbs/ft^3	
Water Density, ρ_w =	62.4	lbs/ft^3	(Assuming water temp of 70° F)
Mean Flow Depth, y =	10.71	ft	(Depth from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Mean Flow Depth above bend, y_u =	10.94	ft	(Depth from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Max depth upstream of bend, y_{max} =	12.40	ft	(Depth from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Max Depth at Bend, y_{mxb} =	15.83	ft	(Depth from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Channel Hydraulic Radius, R =	11.23	ft	(Calculated from 2D results at Profile Line Towpath MM20 S.)
Energy Slope, S_e =	0.00157	ft/ft	(From 2D HEC-RAS output: Towpath MM20 S. Channel Profile Line
D_{50} =	23	mm	(Estimated based on EnviroScience bar pebble counts)
D_{90} =	112	mm	(Estimated based on EnviroScience bar pebble counts)
D_{mean} =	23	mm	(Estimated based on EnviroScience bar pebble counts)
Kinematic Viscostiy, ν =	1.1E-05	ft^2/s	(Assuming water temp of 70° F)
Average Stream Slope, S_{ex} =	0.00125	ft/ft	(From HEC-RAS terrain: Towpath MM20 S. Channel Profile Line)
Design Flow, Q =	3864	ft^3/s	1.5 year flow at site based on 2D HEC-RAS model
Mannings Roughness, n =	0.038		(Main Channel Roughness, Estimated)
Distance to hard point, L =	5557	ft	(Point where structure or stream material will resist scour, in this case assumed to be nearest roadway bridge)
Chnl. Flow Top Width, w =	139.29	ft	(Calculated from 2D results at Profile Line Towpath MM20 S.)
Avg. Channel Velocity, v =	2.92	ft/s	(Velocity from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Avg. Channel Velocity above bend, v_b =	3.87	ft/s	(Velocity from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Mannings Constant =	1.486		
Gravity, g =	32.2	ft/s^2	
Channel Shear Stress, τ =	0.18	lbs/ft^2	(Shear stress from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Bed particle specific gravity, S_s =	2.564		
Radius of stream bend, r_c =	138.6	ft	(Radius of stream centerline)
Unit Discharge, q =	27.741	cfs/ft	(Total flow / flow top width)
Rel. Submerged Density, ΔS_g =	1.5641	lbs/ft^3	

Max Scour Limited by Armoring

Shear Velocity, U_* = 0.737 ft/s

$$U_* = (gyS_e)^{0.5}$$

Particle Reynolds #, R_{E*} = 5285.4

$$Re = \frac{U_* D_{50}}{\nu}$$

Dimensionless Stress, τ_* = 0.0250
Shields Critical Stress, θ_c = 0.037
Min. armor size constant, K = 17
Min. armor size constant, a = 1
Min. armor size constant, B = 0

See Table TS14B-4 for values

Table TS14B–4 Constants for computation of minimum armor particle size

Particle Reynolds number $\frac{U_* D_{50}}{\nu}$	K	a	B
≤10	68	1.67	0.67
Between 10 and 500	27	0.86	−0.14
≥500	17	1.0	0.0

Smallest armor particle size, D_x =	0.1833	ft	$D_x = K\left(\frac{yS_e}{\Delta S_g}\right)^a\left(\frac{U_*}{\nu}\right)^b$
	55.86	mm	
Are particles present larger than D_x?	Yes		If yes, an armor layer can form
Bed porosity, e =	0.318		$e = 0.245 + \frac{0.0864}{(0.1D_{50})^{0.21}}$
Fraction of Material > D_x, P_x =	0.1		(Value estimated based on proposed substrate)
Active Bed Layer Thickness, T =	2.685	ft	$T = \frac{D_x}{(1-e)P_x}$
Max scour limited by armoring, Z_x =	**2.502**	**ft**	

Max Scour by Equilibrium Slope

By Manning and Shields, S_{eq} =	0.00057	ft/ft	$S_{eq} = \left[\theta_c D_c \Delta S_g\right]^{\frac{10}{7}}\left(\frac{K}{qn}\right)^{\frac{6}{7}}$	Let $D_c = D_{50}$
By Meyer-Peter & Muller, S_{eq} =	0.00185	ft/ft	$S_{eq} = K\frac{(D_{50})^{\frac{10}{7}} n^{\frac{9}{7}}}{(D_{90})^{\frac{5}{14}} q^{\frac{6}{7}}}$	See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
By Henderson, S_{eq} =	0.0005	ft/ft	$S_{eq} = K\,Q_d^{-0.46} D_{50}^{1.15}$	See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
By Schoklitsch, S_{eq} =	0.00151	ft/ft	$S_{eq} = K\left(\frac{D_m}{q}\right)^{\frac{3}{4}}$	See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
Average Eqilibrium slope, S_{eq} =	**0.00111**	**ft/ft**		
Max Scour by Equilibrium Slope, Z_{ad} =	**0.754**	**ft**	$z_{ad} = L(S_{ex} - S_{eq})$	
Equilibrium or Armoring Controls?	**Equilibrium**			

Compute Bend Scour

By Zeller Equation, Z_{bs} =	**4.360**	**ft**	$Z_{bs} = 0.0685 y_{mxb}^{0.6} V^{0.6} S_e^{-0.3}(2.8w^{0.2} r_c^{-0.2} - 1)$
By Maynord Equation, y_{mxb}/y =	1.830	ft	$\frac{y_{mxb}}{y_u} = 1.8 - 0.051\left(\frac{r_c}{w}\right) + 0.0084\left(\frac{w}{y_u}\right)$
By Maynord Equation, Z_{bs} =	**10.687**	**ft***	

*The Maynord Equation takes bend scour, general scour, and thalweg formation into consideration. Factor of Safety of 1.08 used.

Total Scour Predicted

Factor of Safety, FS =	1.3		FS =
Equilibrium or armoring, Z_{ad} =	0.754	ft	(Long term aggradation or degradation of reach)
Contraction Scour, Z_c =		ft	(Not applicable for this analysis)
Bend Scour, Z_b =	4.360	ft	(By Zeller)
Bedform trough depth, Z_{bf} =		ft	(Not applicable for this analysis)
Local scour at a structure, Z_s =		ft	(Not applicable for this analysis)
Total Scour, Z_t =	**6.649**	**ft**	$z_t = FS[z_{ad} + z_c + z_b + z_{bf} + z_s]$

General Scour Predicted

General Scour by Blodget, Z_t(max) = **8.637** **ft**

$$z_t(\max) = K D_{50}^{-0.11}$$

where K = 6.5

General Scour by Lacey, Z_t = **3.620** **ft**

$$z_t = K Q_d^a W_f^b D_{50}^c$$

General Scour by Blench, Z_t = **7.190** **ft**

Table TS14B–8 Constants for Lacey and Blench relations, U.S. units (D_{50} in mm)

Condition	Lacey				Blench			
	K	a	b	c	K	a	b	c
Straight reach	0.097	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Moderate bend	0.195	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Severe bend	0.292	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Right angle bend	0.389	1/3	0	−1/6	1.105	2/3	−2/3	−0.1092
Vertical rock wall	0.487	1/3	0	−1/6				

Average Predicted Scour

Average Predicted Scour, Z_t = **7.357** **ft** (Average of Total Scour, Maynord Scour, and General Scour calculations)

Maximum Predicted Scour

Maximum Predicted Scour, Z_{max} = **10.687** **ft** (Maximum of Total Scour, Maynord Scour, and General Scour calculations)

References

General Scour, Armoring, and Equilibrium Slope

US Department of Agriculture, Natural Resources Conservation Service. 2007. *Stream Restoration Design, Technical Supplement 14B Scour Calculations, National Engineering Handbook NEH 654.* Available at https://policy.nrcs.usda.gov/viewerFS.aspx?id=3491

Zeller Bend Scour

Simon Li & Associates. (1985). Design Manual for Engineering Analysis of Fluvial Systems. Arizona Department of Water Resources.

Maynord Bend Scour

Maynord, S.T. (1996). Toe-Scour Estimation in Stabilized Bendways. Journal of Hydraulic Engineering, 122(8), 460-464.

Calculation By = APM | **Checked By =** AL
Date = 8/3/23 | **Date =** 8/7/23

Input Value | Scour Site: Towpath MM20 S.
Calculated Value | Upstream Site: US Towpath MM20 S.

Data used in Calculations			**Notes and Assumptions**
Assumed substrate density, ρ_b =	160	lbs/ft^3	
Water Density, ρ_w =	62.4	lbs/ft^3	(Assuming water temp of 70° F)
Mean Flow Depth, y =	12.01	ft	(Depth from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Mean Flow Depth above bend, y_u =	12.15	ft	(Depth from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Max depth upstream of bend, y_{max} =	13.62	ft	(Depth from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Max Depth at Bend, y_{mxb} =	17.08	ft	(Depth from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Channel Hydraulic Radius, R =	12.50	ft	(Calculated from 2D results at Profile Line Towpath MM20 S.)
Energy Slope, S_e =	0.00243	ft/ft	(From 2D HEC-RAS output: Towpath MM20 S. Channel Profile Line
D_{50} =	23	mm	(Estimated based on EnviroScience bar pebble counts)
D_{90} =	112	mm	(Estimated based on EnviroScience bar pebble counts)
D_{mean} =	23	mm	(Estimated based on EnviroScience bar pebble counts)
Kinematic Viscostiy, ν =	1.1E-05	ft^2/s	(Assuming water temp of 70° F)
Average Stream Slope, S_{ex} =	0.00125	ft/ft	(From HEC-RAS terrain: Towpath MM20 S. Channel Profile Line)
Design Flow, Q =	2598	ft^3/s	10 year flow at site based on 2D HEC-RAS model
Mannings Roughness, n =	0.038		(Main Channel Roughness, Estimated)
Distance to hard point, L =	5557	ft	(Point where structure or stream material will resist scour, in this case assumed to be nearest roadway bridge)
Chnl. Flow Top Width, w =	139.29	ft	(Calculated from 2D results at Profile Line Towpath MM20 S.)
Avg. Channel Velocity, v =	1.78	ft/s	(Velocity from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Avg. Channel Velocity above bend, v_b =	2.13	ft/s	(Velocity from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Mannings Constant =	1.486		
Gravity, g =	32.2	ft/s^2	
Channel Shear Stress, τ =	0.07	lbs/ft^2	(Shear stress from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Bed particle specific gravity, S_s =	2.564		
Radius of stream bend, r_c =	138.6	ft	(Radius of stream centerline)
Unit Discharge, q =	18.652	cfs/ft	(Total flow / flow top width)
Rel. Submerged Density, ΔS_g =	1.5641	lbs/ft^3	

Max Scour Limited by Armoring

Shear Velocity, U_* = 0.970 ft/s

$$U_* = (gyS_e)^{0.5}$$

Particle Reynolds #, R_{E*} = 6960.16

$$Re = \frac{U_* D_{50}}{\nu}$$

Dimensionless Stress, τ_* = 0.0091
Shields Critical Stress, θ_c = 0.037
Min. armor size constant, K = 17
Min. armor size constant, a = 1
Min. armor size constant, B = 0

See Table TS14B-4 for values

Table TS14B–4 Constants for computation of minimum armor particle size

Particle Reynolds number $\frac{U_* D_{50}}{\nu}$	K	a	B
≤10	68	1.67	0.67
Between 10 and 500	27	0.86	−0.14
≥500	17	1.0	0.0

Smallest armor particle size, D_x =	0.3178	ft	$D_x = K\left(\frac{yS_e}{\Delta S_g}\right)^a\left(\frac{U_*}{\nu}\right)^b$
	96.87	mm	
Are particles present larger than D_x?	Yes		If yes, an armor layer can form
Bed porosity, e =	0.318		$e = 0.245 + \frac{0.0864}{(0.1D_{50})^{0.21}}$
Fraction of Material > D_x, P_x =	0.1		(Value estimated based on proposed substrate)
Active Bed Layer Thickness, T =	4.657	ft	$T = \frac{D_x}{(1-e)P_x}$
Max scour limited by armoring, Z_x =	**4.339**	**ft**	

Max Scour by Equilibrium Slope

By Manning and Shields, S_{eq} =	0.0008	ft/ft	$S_{eq} = \left[\theta_c D_c \Delta S_g\right]^{\frac{10}{7}}\left(\frac{K}{qn}\right)^{\frac{6}{7}}$	Let $D_c = D_{50}$
By Meyer-Peter & Muller, S_{eq} =	0.0026	ft/ft	$S_{eq} = K\frac{(D_{50})^{\frac{10}{7}} n^{\frac{9}{7}}}{(D_{90})^{\frac{5}{14}} q^{\frac{6}{7}}}$	See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
By Henderson, S_{eq} =	0.00061	ft/ft	$S_{eq} = K\,Q_d^{-0.46} D_{50}^{1.15}$	See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
By Schoklitsch, S_{eq} =	0.00204	ft/ft	$S_{eq} = K\left(\frac{D_m}{q}\right)^{\frac{3}{4}}$	See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
Average Eqilibrium slope, S_{eq} =	**0.00151**	**ft/ft**		
Max Scour by Equilibrium Slope, Z_{ad} =	**3.559**	**ft**	$z_{ad} = L(S_{ex} - S_{eq})$	
Equilibrium or Armoring Controls?	**Equilibrium**			

Compute Bend Scour

By Zeller Equation, Z_{bs} =	**2.482**	**ft**	$Z_{bs} = 0.0685 y_{mxb}^{0.6} V^{0.6} S_e^{-0.3}(2.8w^{0.2} r_c^{-0.2} - 1)$
By Maynord Equation, y_{mxb}/y =	1.820	ft	$\frac{y_{mxb}}{y_u} = 1.8 - 0.051\left(\frac{r_c}{w}\right) + 0.0084\left(\frac{w}{y_u}\right)$
By Maynord Equation, Z_{bs} =	**11.734**	**ft***	

*The Maynord Equation takes bend scour, general scour, and thalweg formation into consideration. Factor of Safety of 1.08 used.

Total Scour Predicted

Factor of Safety, FS =	1.3		FS =
Equilibrium or armoring, Z_{ad} =	3.559	ft	(Long term aggradation or degradation of reach)
Contraction Scour, Z_c =		ft	(Not applicable for this analysis)
Bend Scour, Z_b =	2.482	ft	(By Zeller)
Bedform trough depth, Z_{bf} =		ft	(Not applicable for this analysis)
Local scour at a structure, Z_s =		ft	(Not applicable for this analysis)
Total Scour, Z_t =	**7.853**	**ft**	$z_t = FS[z_{ad} + z_c + z_b + z_{bf} + z_s]$

General Scour Predicted

General Scour by Blodget, Z_t(max) = **8.637** **ft**

$$z_t(\max) = K D_{50}^{-0.11}$$

where K = 6.5

General Scour by Lacey, Z_t = **3.171** **ft**

$$z_t = K Q_d^a W_f^b D_{50}^c$$

General Scour by Blench, Z_t = **5.518** **ft**

Table TS14B–8 Constants for Lacey and Blench relations, U.S. units (D_{50} in mm)

Condition	Lacey				Blench			
	K	a	b	c	K	a	b	c
Straight reach	0.097	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Moderate bend	0.195	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Severe bend	0.292	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Right angle bend	0.389	1/3	0	−1/6	1.105	2/3	−2/3	−0.1092
Vertical rock wall	0.487	1/3	0	−1/6				

Average Predicted Scour

Average Predicted Scour, Z_t = **7.383** **ft** (Average of Total Scour, Maynord Scour, and General Scour calculations)

Maximum Predicted Scour

Maximum Predicted Scour, Z_{max} = **11.734** **ft** (Maximum of Total Scour, Maynord Scour, and General Scour calculations)

References

General Scour, Armoring, and Equilibrium Slope

US Department of Agriculture, Natural Resources Conservation Service. 2007. *Stream Restoration Design, Technical Supplement 14B Scour Calculations, National Engineering Handbook NEH 654.* Available at https://policy.nrcs.usda.gov/viewerFS.aspx?id=3491

Zeller Bend Scour

Simon Li & Associates. (1985). Design Manual for Engineering Analysis of Fluvial Systems. Arizona Department of Water Resources.

Maynord Bend Scour

Maynord, S.T. (1996). Toe-Scour Estimation in Stabilized Bendways. Journal of Hydraulic Engineering, 122(8), 460-464.

Calculation By = APM | **Checked By =** AL
Date = 8/3/23 | **Date =** 8/7/23

Input Value | Scour Site: Towpath MM20 S.
Calculated Value | Upstream Site: US Towpath MM20 S.

Data used in Calculations			**Notes and Assumptions**
Assumed substrate density, ρ_b =	160	lbs/ft^3	
Water Density, ρ_w =	62.4	lbs/ft^3	(Assuming water temp of 70° F)
Mean Flow Depth, y =	13.03	ft	(Depth from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Mean Flow Depth above bend, y_u =	13.14	ft	(Depth from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Max depth upstream of bend, y_{max} =	14.61	ft	(Depth from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Max Depth at Bend, y_{mxb} =	18.09	ft	(Depth from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Channel Hydraulic Radius, R =	13.49	ft	(Calculated from 2D results at Profile Line Towpath MM20 S.)
Energy Slope, S_e =	0.00322	ft/ft	(From 2D HEC-RAS output: Towpath MM20 S. Channel Profile Line
D_{50} =	23	mm	(Estimated based on EnviroScience bar pebble counts)
D_{90} =	112	mm	(Estimated based on EnviroScience bar pebble counts)
D_{mean} =	23	mm	(Estimated based on EnviroScience bar pebble counts)
Kinematic Viscostiy, ν =	1.1E-05	ft^2/s	(Assuming water temp of 70° F)
Average Stream Slope, S_{ex} =	0.00125	ft/ft	(From HEC-RAS terrain: Towpath MM20 S. Channel Profile Line)
Design Flow, Q =	1867	ft^3/s	100 year flow at site based on 2D HEC-RAS model
Mannings Roughness, n =	0.038		(Main Channel Roughness, Estimated)
Distance to hard point, L =	5557	ft	(Point where structure or stream material will resist scour, in this case assumed to be nearest roadway bridge)
Chnl. Flow Top Width, w =	139.29	ft	(Calculated from 2D results at Profile Line Towpath MM20 S.)
Avg. Channel Velocity, v =	1.16	ft/s	(Velocity from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Avg. Channel Velocity above bend, v_b =	0.96	ft/s	(Velocity from 2D HEC-RAS at Profile Line US Towpath MM20 S.)
Mannings Constant =	1.486		
Gravity, g =	32.2	ft/s^2	
Channel Shear Stress, τ =	0.03	lbs/ft^2	(Shear stress from 2D HEC-RAS at Profile Line Towpath MM20 S.)
Bed particle specific gravity, S_s =	2.564		
Radius of stream bend, r_c =	138.6	ft	(Radius of stream centerline)
Unit Discharge, q =	13.401	cfs/ft	(Total flow / flow top width)
Rel. Submerged Density, ΔS_g =	1.5641	lbs/ft^3	

Max Scour Limited by Armoring

Shear Velocity, U_* = 1.162 ft/s

$$U_* = (gyS_e)^{0.5}$$

Particle Reynolds #, R_{E*} = 8335.65

$$Re = \frac{U_* D_{50}}{\nu}$$

Dimensionless Stress, τ_* = 0.0037
Shields Critical Stress, θ_c = 0.037
Min. armor size constant, K = 17
Min. armor size constant, a = 1
Min. armor size constant, B = 0

See Table TS14B-4 for values

Table TS14B–4 Constants for computation of minimum armor particle size

Particle Reynolds number $\frac{U_* D_{50}}{\nu}$	K	a	B
≤10	68	1.67	0.67
Between 10 and 500	27	0.86	–0.14
≥500	17	1.0	0.0

Smallest armor particle size, D_x =	0.4558	ft	$D_x = K\left(\frac{yS_e}{\Delta S_g}\right)^a\left(\frac{U_*}{\nu}\right)^b$
	138.94	mm	
Are particles present larger than D_x?	**No**		If yes, an armor layer can form
Bed porosity, e =	0.318		$e = 0.245 + \frac{0.0864}{(0.1D_{50})^{0.21}}$
Fraction of Material > D_x, P_x =	0.01		(Value estimated based on proposed substrate)
Active Bed Layer Thickness, T =	66.793	ft	$T = \frac{D_x}{(1-e)P_x}$
Max scour limited by armoring, Z_x =	**No**	**ft**	
Max Scour by Equilibrium Slope			
By Manning and Shields, S_{eq} =	0.00107	ft/ft	$S_{eq} = \left[\theta_c D_c \Delta S_g\right]^{\frac{10}{7}}\left(\frac{K}{qn}\right)^{\frac{6}{7}}$ Let $D_c = D_{50}$
By Meyer-Peter & Muller, S_{eq} =	0.00346	ft/ft	$S_{eq} = K\frac{(D_{50})^{\frac{10}{7}} n^{\frac{9}{7}}}{(D_{90})^{\frac{5}{14}} q^{\frac{6}{7}}}$ See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
By Henderson, S_{eq} =	0.0007	ft/ft	$S_{eq} = K\,Q_d^{-0.46} D_{50}^{1.15}$ See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
By Schoklitsch, S_{eq} =	0.00261	ft/ft	$S_{eq} = K\left(\frac{D_m}{q}\right)^{\frac{3}{4}}$ See Table TS14B-7 "Constants for equilibrium slope formuals . . ."
Average Eqilibrium slope, S_{eq} =	**0.00196**	**ft/ft**	
Max Scour by Equilibrium Slope, Z_{ad} =	**3.006**	**ft**	$z_{ad} = L(S_{ex} - S_{eq})$
Equilibrium or Armoring Controls?	**Equilibrium**		
Compute Bend Scour			
By Zeller Equation, Z_{bs} =	**1.250**	**ft**	$Z_{bs} = 0.0685 y_{mxb}^{0.6} V^{0.6} S_e^{-0.3}(2.8w^{0.2} r_c^{-0.2} - 1)$
By Maynord Equation, y_{mxb}/y =	1.813	ft	$\frac{y_{mxb}}{y_u} = 1.8 - 0.051\left(\frac{r_c}{w}\right) + 0.0084\left(\frac{w}{y_u}\right)$
By Maynord Equation, Z_{bs} =	**12.585**	**ft***	

*The Maynord Equation takes bend scour, general scour, and thalweg formation into consideration. Factor of Safety of 1.08 used.

Total Scour Predicted

Factor of Safety, FS =	1.3		FS =
Equilibrium or armoring, Z_{ad} =	3.006	ft	(Long term aggradation or degradation of reach)
Contraction Scour, Z_c =		ft	(Not applicable for this analysis)
Bend Scour, Z_b =	1.250	ft	(By Zeller)
Bedform trough depth, Z_{bf} =		ft	(Not applicable for this analysis)
Local scour at a structure, Z_s =		ft	(Not applicable for this analysis)
Total Scour, Z_t =	**5.533**	**ft**	$z_t = FS[z_{ad} + z_c + z_b + z_{bf} + z_s]$

General Scour Predicted

General Scour by Blodget, Z_t(max) = **8.637** **ft**

$$z_t(\max) = K D_{50}^{-0.11}$$

where K = 6.5

General Scour by Lacey, Z_t = **2.840** **ft**

$$z_t = K Q_d^a W_f^b D_{50}^c$$

General Scour by Blench, Z_t = **4.427** **ft**

Table TS14B–8 Constants for Lacey and Blench relations, U.S. units (D_{50} in mm)

Condition	Lacey				Blench			
	K	a	b	c	K	a	b	c
Straight reach	0.097	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Moderate bend	0.195	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Severe bend	0.292	1/3	0	−1/6	0.530	2/3	−2/3	−0.1092
Right angle bend	0.389	1/3	0	−1/6	1.105	2/3	−2/3	−0.1092
Vertical rock wall	0.487	1/3	0	−1/6				

Average Predicted Scour

Average Predicted Scour, Z_t = **6.804** **ft** (Average of Total Scour, Maynord Scour, and General Scour calculations)

Maximum Predicted Scour

Maximum Predicted Scour, Z_{max} = **12.585** **ft** (Maximum of Total Scour, Maynord Scour, and General Scour calculations)

References

General Scour, Armoring, and Equilibrium Slope

US Department of Agriculture, Natural Resources Conservation Service. 2007. *Stream Restoration Design, Technical Supplement 14B Scour Calculations, National Engineering Handbook NEH 654.* Available at https://policy.nrcs.usda.gov/viewerFS.aspx?id=3491

Zeller Bend Scour

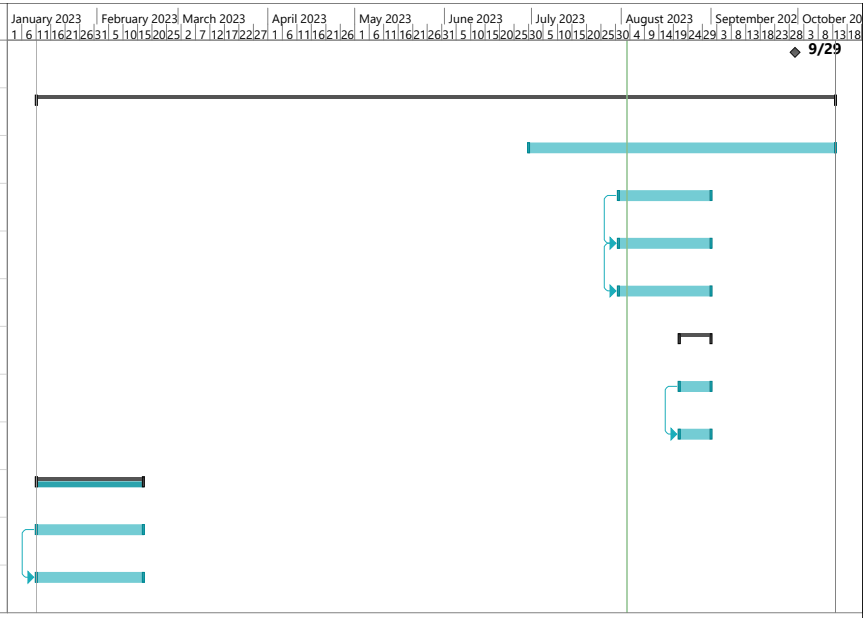
Simon Li & Associates. (1985). Design Manual for Engineering Analysis of Fluvial Systems. Arizona Department of Water Resources.

Maynord Bend Scour

Maynord, S.T. (1996). Toe-Scour Estimation in Stabilized Bendways. Journal of Hydraulic Engineering, 122(8), 460-464.

APPENDIX VI PERMIT SCHEDULE

ID	Task Name	Duration	Start	Finish
1	CUVA 224822- Towpath MM 20 South	0 days	Fri 9/29/23	Fri 9/29/23
2	**EnviroScience**	**198 days**	**Wed 1/11/23**	**Fri 10/13/23**
3	SWPPP MM 20	76 days	Fri 6/30/23	Fri 10/13/23
4	USACE - Nationwide 13/Section 10 Rivers and Harbors Act- Draft Permit to NPS	24 days	Mon 7/31/23	Thu 8/31/23
5	Ohio EPA - Section 401 Water Quality Certification - Draft Permit to NPS	24 days	Mon 7/31/23	Thu 8/31/23
6	Notice to Mariners - Draft Permit to NPS	24 days	Mon 7/31/23	Thu 8/31/23
7	**Floodplain Permit (MM 20)**	**9 days**	**Mon 8/21/23**	**Thu 8/31/23**
8	NPS Provided Written Memorandum	9 days	Mon 8/21/23	Thu 8/31/23
9	Technical Memorandum to Sagamore Hills Township	9 days	Mon 8/21/23	Thu 8/31/23
10	**NPDES NOI (8 Sites) - Complete**	**27 days**	**Wed 1/11/23**	**Thu 2/16/23**
11	GPD to process/NPS to submit NPDES NOI (Submitted)	27 days	Wed 1/11/23	Thu 2/16/23
12	RiverReach co-permitee (8 Sites)	27 days	Wed 1/11/23	Thu 2/16/23



Project: Permit Schedule_DB Te
Date: Thu 8/3/23

Task		Project Summary		Manual Task		Start-only		Deadline	
Split		Inactive Task		Duration-only		Finish-only		Progress	
Milestone		Inactive Milestone		Manual Summary Rollup		External Tasks		Manual Progress	
Summary		Inactive Summary		Manual Summary		External Milestone			

APPENDIX VII

Quality Assurance Worksheets