TECHNICAL ENGINEERING REPORT
LITTLE RIVER EROSION CONTROL



Sponsored by:
University of Tennessee-Knoxville
Tickle College of Engineering
Department of Civil and Environmental Engineering

LPBD
LITTLE PROJECTS
BIG DESIGNS
INC

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Senior Design Project Experience Fall 2022-Spring 2023

Mission Statement

Little Projects Big Designs (LPBD) Incorporated aims to provide our clients and community with sustainable, reliable engineering solutions. The LPBD team is committed to personalized solutions offering restoration and improvement to urban infrastructure, as guided by the NAE Grand Challenges. LPBD is a team of engineers motivated by teamwork, leadership, professional attitudes, and lifelong learning and guided by professional and ethical responsibilities, as outlined by the professional outcomes within the ASCE Body of Knowledge. At LPBD, we understand the complex global, cultural, social, environmental, and economic factors that affect our clients, and we develop solutions that take all these factors into consideration to produce a comprehensive design.



Disclaimer Statement

The following document contains design recommendations for private property along Little River. The designs enclosed were developed by students at the University of Tennessee under mentorship by local engineers and professors. The students and mentors do not assume personal liability for implementation of these recommendations. All work enclosed in this document is provided for conceptual information only and shall not be used without prior consultation with a professional engineer.

Acknowledgements

We acknowledge that this technical report would not have been made possible without the support of our client, mentors, and professors at the University of Tennessee. Dr. Jennifer Retherford, Distinguished Lecturer at the University of Tennessee Tickle College of Engineering, served as LPBD's faculty advisor. She provided feedback on intermediate deadlines and connected the team with the other advisors and mentors that assisted with this project. David Reece, a licensed professional engineer with 50 years' experience, served as one of the team's technical mentors. He assisted the team with technical content and drawings and provided references and templates for LPBD to use. Amy Hathaway, a licensed professional engineer with project experience in stream enhancements, served as the team's other technical mentor. She assisted the team in developing design solutions using her professional experience. Dr. Michael McKinney, a professor of environmental science and urban ecology at the University of Tennessee, served as another advisor. He provided guidance on biological and ecological solutions for this project. Anne Ham, the project client, assisted the team frequently with tasks and suggestions that moved the design process forward.

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Project Introduction

A private property in Louisville, TN situated on the Little River is experiencing bank erosion resulting in loss of physical property for the residential owner. Ms. Anne Ham has owned the property for 3 decades and has noticed an increase in erosion with the last 5 years. Ad-hoc remediation has been attempted by the property owner in recent years with no significant reduction in erosion, which prompted her to seek an engineered design solution. Big Projects Little Designs was commissioned to develop a plan to slow erosion on the client's property.

Background

Anne Ham obtained ownership rights from the Tennessee Valley Authority (TVA) to the peninsula adjacent to her property in April of 2004 to preserve and restore the land. The peninsula remained unmaintained until the year 2020, in which Anne Ham started her project to provide a habitat to the local wildlife. Initially, the aim of Anne's project was to clear out the vegetative overgrowth, invasive species, and fallen trees on the peninsula. Upon completing the initial removal of unwanted vegetation, the erosion damage on the site was prominent, especially at the tip of the peninsula. Anne reached out to a local contractor for a riprap estimate the same year with the intention of restoring and offering protection for the eroded riverbank. The received riprap estimate was over-budget which led to considerations of more economical and potentially more aesthetically pleasing solutions. Anne Ham then reached out to David Reece, a retired environmental engineer and close friend, to seek advice on potential engineered solutions. Upon consulting with David Reece, a combination of engineered and natural bank protection ideas was discussed and the decision to solicit professionals was made. The hiring of a civil engineering team and an expert in environmental science and urban ecology was required to provide technical guidance as design possibilities for the peninsula were determined.

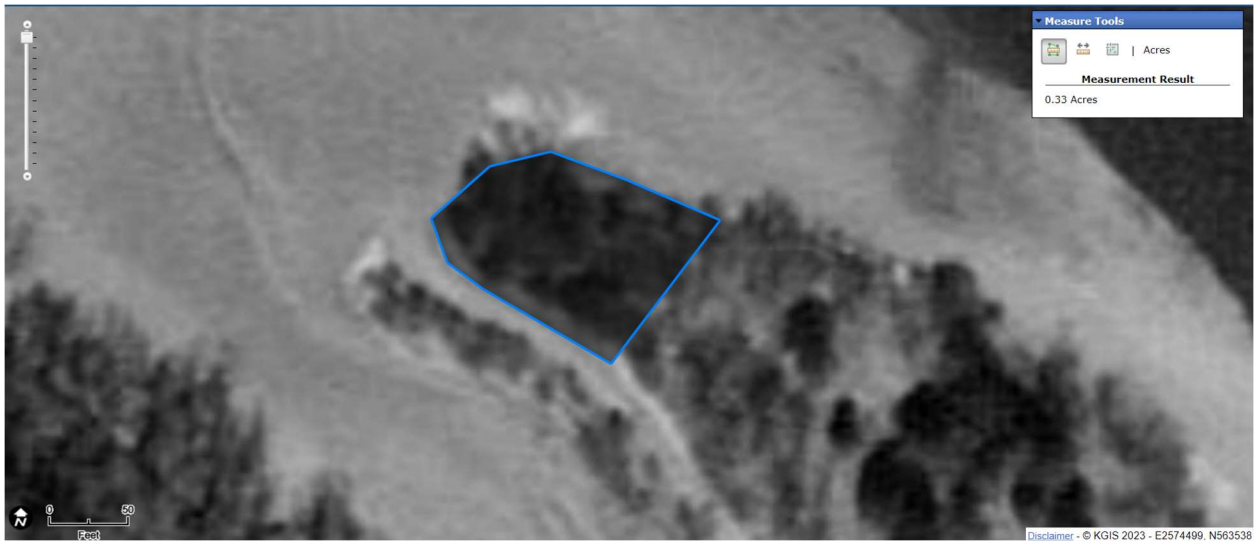




Figure 1: Acreage Estimates from 1985 and 2019.

Site Conditions

The project site contains a peninsula located on private property along the backwater of Fort Loudon Lake. The peninsula is covered with vegetation such as bushes, trees, and vines. The main channel flows around the northeast portion of the 1000 linear foot shoreline, and a small pool of water is located on the southwest side of the peninsula. Water levels vary in different seasons; thus, the water is higher in warm months and lower in cold months as displayed in Figure 2. The bank height ranges from 1 to 4 feet based on both the natural terrain and erosion which has caused undercutting along most of the peninsula.



Figure 2: Summer Shoreline Elevation (Left) and Winter Shoreline Elevation (Right)

Team Introduction

The Little River Project team is composed of four University of Tennessee at Knoxville (UTK) Civil Engineering students, two UTK professors, two local engineers, and a local environmental restoration advocate to build a comprehensive solution to shoreline erosion along the Little River. Little Projects Big Designs Inc. design team consists of undergraduate students in the UTK Civil and Environmental Engineering program (Figure 3). Natalie Hester has completed two internships in the construction industry with Denham-Blythe Company Inc. and James McHugh Construction Co. and has gained experience in geotechnical engineering through research with Dr. Khalid Alshibli. Isaac Macon interned at a local design firm, Fulghum, Macindoe, and Associates where he learned MicroStation and interned in the TDOT construction office where he gained valuable construction experience. Libby Vanderloo has experience in various civil engineering projects and environmental permitting through a co-op with Tennessee Valley Authority. Steven Tremayne has eight years of experience in building information modeling software such as AutoCAD, Inventor, Revit, Civil 3D, and Navisworks. Little Projects Big Designs Inc. partnered with external associates to recognize the required technical scope of work and develop decisions satisfying the needs of the project (Table 1). Dr. Mike McKinney is a UTK professor in the Earth and Planetary Science Department with research interests in biodiversity and environmental restoration and acts as a consultant on the compatibility between environmental biology and engineering solutions. Dr. Jennifer Retherford is a UTK professor in the Civil and Environmental Engineering department and serves as the senior design professor, project advisor, and technical mentor. David Reece is a licensed professional engineer and has his M.S. in Environmental Engineering from UTK, has 50 years' experience in environmental engineering, and serves as the lead technical mentor. Amy Hathaway is a licensed professional engineer, earned her B.S. and M.S. degrees from North Carolina State University, has project experience in stream enhancements, green infrastructure, watershed master planning, and municipal stormwater programs, and serves as a technical mentor. Anne Ham is the Little River Project property owner and wildlife and shoreline restoration advocate. The team worked collaboratively on this project (Figure 4) and performed engineering services aligned with their previous experience and professional interests to develop engineered solutions.



Figure 3: Little Projects Big Designs Inc.

Table 1: Team Members Affiliations and Contact Information

Team Member	**Affiliation**	**Contact**
Anne Ham	Community Partner Project Lead	anneham@gmail.com
David Reece	Technical Mentor	dareece13@gmail.com
Amy Hathaway	Technical Mentor	ahathaway@wkdickson.com
Dr. Mike McKinney	Technical Mentor	mmckinne@utk.edu
Natalie Hester	UTK Senior Student	nhester2@vols.utk.edu
Isaac Macon	UTK Senior Student	imacon@vols.utk.edu
Libby Vanderloo	UTK Senior Student	evanderl@vols.utk.edu
Steven Tremayne	UTK Senior Student	Stremayn@vols.utk.edu
Dr. Jennifer Retherford	Civil and Environmental Engineering Professor	jqretherford@utk.edu



Figure 4: Team Organizational Graphic

Technical Scope of Work

Site improvement designs at Anne Ham's private property aimed to restore the eroded shoreline, hinder further erosion, and improve bank stability. Soil classification, shear stress calculations, and bank stability and toe erosion modeling were performed to select bank stabilization methods appropriate for the distinct characteristics of the shoreline's existing conditions. Environmental services included assembly of required technical information for permits and selection of appropriate riparian plantings for the riverbank. Construction services included developing an estimate of probable cost and creating a construction schedule.

Bank Stabilization

The peninsula on Anne Ham's property exhibited unique zonal responses to erosion and called for a design solution specific to the regions of the peninsula shoreline. The existing conditions of the site were evaluated through soil classification, critical shear stress calculations, erodibility coefficient calculations, and drone LiDAR surveying. The cause of deteriorating bank stability and the current degree of stability were analyzed through applied shear stress calculations, wave characteristics identification, and BSTEM modeling. Wave action and soil cohesion analyses were performed to design bank remediation options of rock armor and increased plant density for distinct bank cross-sections requiring varying levels of protection.

The existing conditions of the peninsula were characterized by drone LiDAR survey, soil classification, and coefficient calculations. A drone LiDAR survey was obtained for contour data,

specifically bank geometry dimensions, to identify unique bank profiles and divide the peninsula into zones (see complementary engineering drawings set). A USDA Soil Report was obtained to classify the soil on the site. Nine soil samples were collected from the site on February 6th, 2023 to confirm the classification of the soil type from the USDA Soil Report. The soil samples were dried and tested through a hydrometer and mechanical sieve analysis, all in accordance with the following ASTMs: C117, D422, D6913, D7928, and C136. The soil was classified as silty clay loam and silt loam according to the USDA Soil Texture Triangle, as seen in Figure 5. The critical shear stress of the soil was calculated by Smerdon and Beasley's empirical relationship between the plasticity index and critical shear stress of cohesive soils (Table 2). The critical shear stress of the soil was confirmed by the FHWA Channel Linings report. The design critical shear stress value was determined by selecting the lower value from Smerdon and Beasley's relationship and the FHWA Channel Linings report. The erodibility coefficient of the unsaturated bank surface was calculated using Hanson and Simon's empirical relationship and the erodibility coefficient of the saturated bank toe was calculated using the Arulandan et. al. relationship (Appendix A).

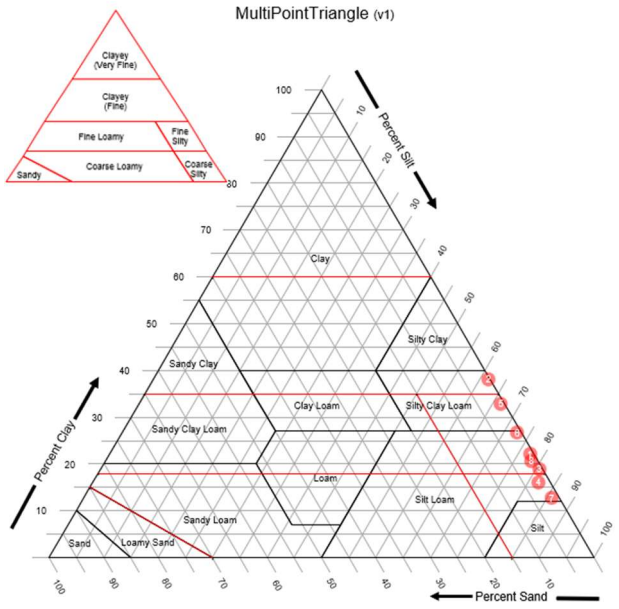


Figure 5: USDA Soil Texture Triangle: Results for the Nine Soil Samples (red circles; right side of triangle)

Table 2: Summary Design Criteria Values

Soil Design Parameters		Value
Smerdon and Beasley's Critical shear stress (design value)		$0.006\ \frac{lb}{ft^2}$
FHWA Channel Linings' Critical shear stress		$0.037\text{-}0.95\ \frac{lb}{ft^2}$
Erodibility Coefficient Parameters	Plasticity Index of Site Soil (I_w)	2.000
	Critical Shear Stress of Site Soil (τ_c)	$0.006\ \frac{lb}{ft^2}$
	Erodibility Coefficient of Bank (k)	$0.102\ \frac{in^3}{lb*s}$
	Erodibility Coefficient of Bank Toe (k)	$0.051\ \frac{in^3}{lb*s}$

Analysis of the current bank instability and cause of deterioration was determined through BTSEM modeling, applied shear stress calculations, and wave characterization. BSTEM models of the existing condition were analyzed to determine the erosion risk level by section. Sections were divided by average bank profile conditions along the shoreline. Section 1 is perpendicular to wave path from boating, parallel to the flow of Little River, and has maximum bank height of 1ft. Section 2 and 3 are parallel to the wave path, perpendicular to the flow, and have a bank height of 4ft. Section 4 is excluded from wave action and flow analysis because section 4 is in an extremely shallow (1ft bank height) inlet area inaccessible to motorized boating and blocked from the natural flow path. Bank sections 1, 2, and 3 have higher estimates of lateral retreat over a one-year time span when compared to bank section 4 (Appendix A). The applied shear stress from the flow of Little River was calculated by Newton's law of Viscosity. From the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) report, river velocities were obtained for the 1-percent annual chance of a flood. The river velocity gradient was calculated from the velocities obtained along eleven cross sections of Little River ranging 0.47 miles to 7.6 miles upstream from the mouth. The client's property is at 4.2 miles upstream the mouth of the river. The velocity gradients were multiplied by the water viscosity to obtain the applied shear stress value. The peak and low water temperatures for the Summer 2022 TVA operating elevations were found from the USGS water data website. The shear stress applied from the water is significantly less than the permissible shear stress of the soil type indicating the 1-percent annual chance flow would not cause erosion along the shoreline (Appendix A). The wave action from recreational boating was characterized using the visual cues description in the Beaufort Scale and estimated to be 2 feet, Beaufort number 3.

Bank remediation unique to each shoreline zone was designed for using rock armor and plantings based on wave action and soil cohesion analysis. Protection against the wave action from recreational boating along Little River was designed for using the US Army Corp of Engineers Design Manual for Coastal Revetments, Seawalls, and Bulkheads (Table 3). The armor unit selected was smooth rounded. For each distinct bank profile section, rock armor will be placed to the full height of the bank and will extend to a length of at least twice the bank height to achieve a 2:1 rock armor slope (see complementary engineering drawings set). BSTEM models were produced for each of the bank sections to analyze proposed bank stability design solutions. The additional cohesion provided by the proposed plantings was calculated in accordance with the RipRoot Model. Minimum root depths of each plant species were acquired from the USDA Plant Database and used to develop the RipRoot model for each bank section. Bank sections 1 and 2 were analyzed using models incorporating a bank stability approach of riprap, sycamore trees, river birch trees, and black willow trees. Bank section 3 was analyzed for a bank stability design of riprap in combination with river birch trees, sycamore trees, black willow trees, silky dogwood shrubs, fox sedges, and green bulrushes. The design solution corresponding to bank section 4 incorporated a combination of silky dogwood shrubs, fox sedges, and green bulrushes. The lateral retreat estimates from the proposed conditions BSTEM models were compared against the existing conditions models to calculate a percent decrease in estimated lateral retreat per bank section (Table 4).

Table 3: Armor Weight Equation Variables

Variable	Value	Source
Specific Weight of Armor Unit	150-175 pcf	Engineering Geology Field Manual
Monochromatic Wave Height	2 ft	Beaufort Scale
Stability Coefficient	1.2	Table 2-3 of Design Manual
Specific Weight of Water	62.4 pcf	USGS
Cotangent of Structure Slope	1.5-3.0	Table 2-3 of Design Manual
Armor Unit Weight	241 lbs	Equation 2-14 of Design Manual

Table 4: Lateral Retreat Estimates

Bank Section	Existing Conditions Lateral Retreat	Proposed Conditions Lateral Retreat	Percent Decrease
1	15.04 in	0 in	100%
2	13.42 in	0 in	100%
3	14.79 in	0 in	100%
4	10.72 in	$7.87*10^{-4}$ in	99.99%

Environmental Services

Environmental services required identifying requirements for permits and designing riparian plantings. Technical requirements for applicable permits were compiled based on site conditions at the peninsula and erosion control guidelines per TVA and TDEC. Riparian plantings were identified based on the Tennessee Urban Riparian Buffer Handbook for the bank to mitigate erosion and provide habitat for wildlife and pollinators.

Permitting services were completed by identifying the appropriate permits and compiling the required technical information for the applicable permits. The TVA 26a and TDEC regulations were reviewed and the TVA 26a permit for minor facilities and the TDEC Aquatic Resource Alteration Permit (ARAP) were identified as necessary based on project size and extent of disturbance of the waterway. Technical requirements to satisfy permit criteria were identified based on the application criteria unique to each permit. Necessary content to support the permit applications were inventoried and include maps and narratives (summarized in Figure 6) supporting the technical design solutions pursued by the project. To comply with TVA 26a, three specific items were generated. A map of the exact location of the project site was created using existing USGS topographic maps. Project plans and drawings were created and analyzed to ensure compliance. A series of narrative descriptions were generated to define the existing conditions warranting service, express a scope of work capturing the necessary mitigation goals, and identify proposed changes to address the project needs. The narrative description of the existing conditions was written based on soil characteristics and vegetation present on the peninsula (Appendix B). Technical content for the narratives, also including the project rationale, was created based on the identified erosion mitigation needs for the peninsula and based on the extent of riprap and riparian plantings presented in the design solution.

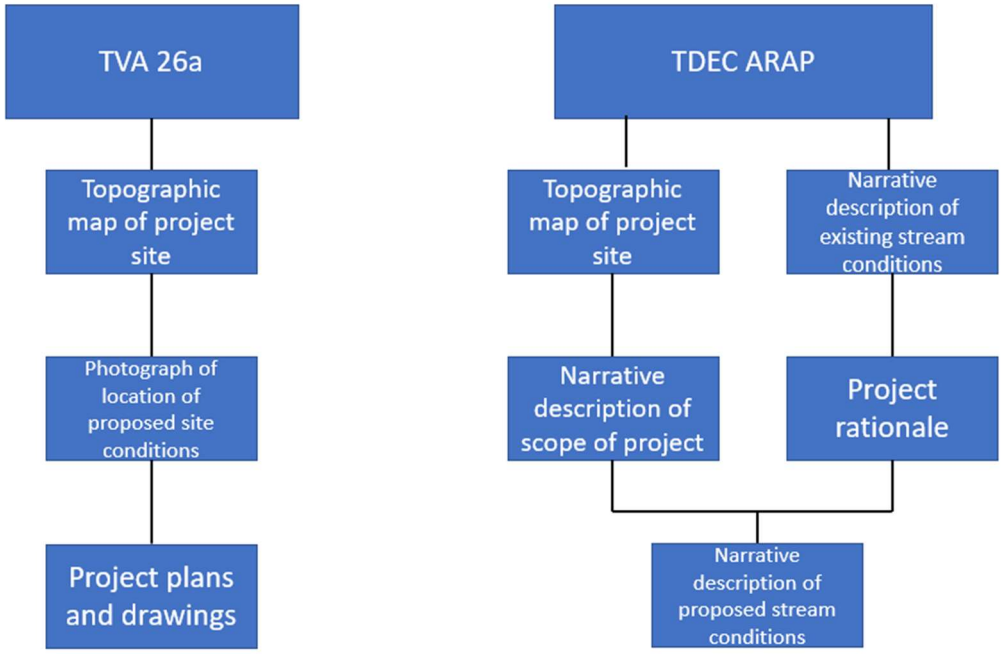


Figure 6: Technical Permit Requirements

Planting services were completed by researching appropriate riparian plantings and selecting plants based on existing bank conditions and plant growth requirements. Riparian plantings native to East Tennessee were researched using the Tennessee Urban Riparian Handbook (Appendix B). The existing bank was characterized and divided into three zones based on sunlight, soil pH, and soil moisture (Table 5). Zone 1 was designed to start at the edge of the tree line on the northeastern side of the peninsula and follow the bank for 135 feet, extending to the winter pool elevation boundary (see complimentary engineering drawing set). Zone 2 was designed to start at the end of Zone 1 and follow the bank for 57 feet along the tip of the peninsula, extending about 60 feet from the bank. Zone 3 was designed to start at the end of Zone 2 and follow the bank for 130 feet along the southwestern side, extending about 30 feet from the bank. Plants for each zone were selected using the Tennessee Urban Riparian Handbook based on light requirements, soil pH, soil moisture, wildlife benefit, and aesthetics (Table 6). The plants chosen for Zones 1 and 2 were river birch, sycamore, and black willow trees. The plants chosen for Zone 3 were silky dogwood shrubs, fox sedges, and green bulrush. Minimum root depth was determined using the USDA Plant Database. Minimum plant spacing was determined using the North Carolina Extension Gardener Plant Toolbox and New Moon Nurseries websites. Quantities for each plant were calculated based on minimum spacing requirements.

Table 5: Plant Zone Existing Conditions

Zone	Light	Soil pH	Soil Moisture
1	Full	Basic	High
2	Partial shade	Basic	High
3	Full	Basic	High

Table 6: Riparian Plantings Selection

Plant Selected	Type of Plant	Location of Plant on Bank	Minimum Root Depth	Minimum Spacing	Quantity
River Birch	Canopy tree	1, 2	20”	10’	19
Sycamore	Canopy tree	1, 2	30”	24’	18
Black Willow	Canopy tree	1, 2	32”	24’	19
Silky dogwood	Shrub	3	16”	3’	49
Fox sedge	Grass/Sedge	3	16”	3’	49
Green Bulrush	Grass/Sedge	3	12”	3’	49

Construction Services

Construction services included developing an estimate of probable cost and generating a construction schedule based on the proposed design solution. Task durations were determined based on regional trends and a project schedule was created using the Critical Path Method. An estimate of probable cost was generated by developing a material takeoff, selecting construction equipment, and identifying unit prices.

A schedule was formed using the Critical Path Method to introduce tasks, define task sequence, and determine task duration. Pre-construction, construction, and post-construction tasks were identified based on the proposed design solutions presented in the engineering drawing set. A project breakdown was conducted to determine critical activities and sequence. The tasks were grouped into 4 families including preconstruction activities, procurement of materials and equipment, material installation and restoration activities. The sequence of tasks was determined based on a comparable, regional project and common order of construction activities. A project start was selected during low water season to accommodate construction and planting activities at the project work site along the Ham property shoreline. The seasonal lake drawdowns were determined to end on April 1st according to the TVA, therefore, a start date of Monday, February 27th was designated. Durations of tasks were determined based on calculations, documents, and drawings located in Appendix C. The duration for the surveying necessary for the project was determined considerate of the 1000 linear foot size of the project extents as outlined in the drawings and an anticipated two-person skilled survey crew. The duration for developing and processing permits necessary for the project was decided in agreement with a schedule from a comparable, regional project. Local vendors were identified by defining a 50-mile radius around the project site to minimize hauling effort for procurement of gravel, plantings, and construction equipment needed to develop the proposed bank cross-section remediations. A haul timing was calculated to accommodate travel from Vulcan materials, anticipated to be the supplier for the riprap necessary for the proposed streambank stabilization solutions. Procurement times were calculated based on website information offering basic ordering information and availability of the geotextile fabric required for our design solutions based on phone calls with vendor representatives. Mobilization time of equipment was determined based on distance from vendor to the project site. The working time of a 6-person labor crew consisting of a foreman, 2 unskilled laborers, 2 skilled laborers, and an operator was selected as 8 hours per day in accordance with OSHA regulations. The duration of clearing for the project site was determined based on the extent of invasive vegetation highlighted in the drawings, the size of the work crew, and the selected clearing equipment. Clearing equipment was

chosen based on the type of invasive plants such as vines and brush located on the site. The placement time of graded rock was determined from a production rate calculated from tonnage of rock and crew size. Tonnage quantity of riprap was determined from calculating the volume of varying bank heights and lengths around the peninsula in cubic yards and converting into tons. The planting tasks were selected to occur during construction tasks by designating the unskilled laborers to planting tasks, while the remainder of the crew completes riprap installation. The duration of planting was determined from the quantity of plants and labor crew size. The duration of restoration and reseeding was determined from the size of the area disturbed by the contractor. The duration of de-mobilization was determined from the amount of construction vehicles left on site. A Bobcat mini excavator was selected as the most efficient construction vehicle for the project due to its light weight and quantity of rock. Clean up duration was determined based on the amount of leftover materials. The overall duration was calculated by summing task durations on the critical path (Table 7).

Table 7: Summary of Construction Durations

Task	Duration (days)
Preconstruction	5
Procurement	8
Installation	5
Restoration	1
CPM Total	18

Costs were estimated by calculating material quantities, selecting construction equipment, and determining labor. The estimated cost of riprap was determined based on tonnage and a recent riprap cost estimate located in Appendix C. Riprap tonnage was determined by calculating volume around the bank in designated riprap areas and selecting size of riprap. Riprap class A-1 was selected from the Tennessee Department of Transportation's standard construction specifications due to the bank height varying from 1 to 4 feet. Volume was calculated from determining length, width, and depth in the designated riprap areas that are highlighted in the details of the project drawing set. The estimated cost of geotextile fabric was determined by calculating the quantity of fabric. Quantity of fabric was determined by calculating the area underneath riprap and the temporary construction entrance. The estimated cost of gravel was determined by calculating the volume of the specified temporary construction entrance highlighted in the drawing set. Costs of plants were estimated by contacting local nurseries. The estimated cost of seeding was determined using a comparable project's seeding price and calculating the disturbed area of the construction path, laydown yard, and temporary construction entrance. Costs of construction vehicles and equipment were determined from an online site containing construction vehicle rental prices, and duration of tasks such as graded rock placement and clearing. Labor rates were determined based on skill level, activity duration in hours, and a contractor's wage rate sheet. Activity duration was determined based on the project schedule. The skill level of laborers was determined based on their level of certification. The final cost was estimated in Table 8.

Table 8: Final Cost Estimate

Payable Items	Estimation of Probable Cost
Construction Materials	$8,294.52
Vegetation	$9,569.61
Equipment	$3,120.00
Labor	$4,467.28
Total	$25,451.41

Conclusion

Shoreline stabilization designs on Anne Ham's peninsula are expected to restore the eroded shoreline and prevent future erosion, improve aesthetics, and create natural wildlife habitats at a reasonable price. Zones around the peninsula were classified based on existing deteriorated conditions and four unique design conditions were developed based on bank stability modeling and soil cohesion analysis. Documents supporting required permits were drafted and plants were selected for the proposed design scenarios according to TVA 26a and TDEC ARAP guidelines. A cost was estimated based on the recommended improvements spanning the 200-foot perimeter of the peninsula and a construction schedule to implement the rock armament and plantings. The designs address the property owner's concerns regarding land preservation, nature beautification, and wildlife habitation, and should be economically feasible.

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Bank Stabilization

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Appendix A: Bank Stabilization Services

Custom Soil Resource Report
Soil Map



Map Scale: 1:1,820 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0 25 50 100 150

Feet: 0 50 100 200 300

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 17N WGS84

Physical Soil Properties–Blount County Area, Tennessee														
Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensibility	Organic matter	Erosion factors			Wind erodibility group	Wind erodibility index
										Kw	Kf	T		
	In	*Pct*	*Pct*	*Pct*	*g/cc*	*micro m/sec*	*In/In*	*Pct*	*Pct*					
Sd—Sequatchie silt loam														
Sequatchie	0-12	-29-	-53-	10-18- 25	1.50-1.58-1.65	4.23-9.17-14.11	0.12-0.15-0.18	0.0- 1.5- 2.9	1.0- 2.5-3.0	.24	.37	5	6	48
	12-36	-34-	-37-	22-29- 35	1.55-1.63-1.70	4.23-9.17-14.11	0.15-0.18-0.20	0.0- 1.5- 2.9	0.2- 0.8-0.9	.20	.32			
	36-60	-34-	-37-	18-29- 35	1.55-1.63-1.70	4.23-23.29-42.34	0.09-0.12-0.14	0.0- 1.5- 2.9	0.0- 0.2-0.4	.17	.32			
Sg—Sequoia silty clay loam, eroded sloping phase														
Sequoia	0-5	-19-	-45-	27-36- 45	1.35-1.43-1.50	4.23-9.17-14.11	0.15-0.17-0.19	3.0- 4.5- 5.9	0.5- 0.8-1.0	.32	.32	3	4	86
	5-36	- 6-	-47-	35-48- 60	1.35-1.45-1.55	1.41-2.82-4.23	0.08-0.12-0.16	3.0- 4.5- 5.9	0.2- 0.5-0.9	.17	.28			
	36-70	—	—	—	—	0.00-0.71-1.41	—	—	—					
W—Water														
Water	—	—	—	—	—	—	—	—	—					

Engineering Properties–Blount County Area, Tennessee														
Map unit symbol and soil name	Pct. of map unit	Hydrologic group	Depth	USDA texture	Classification		Pct Fragments		Percentage passing sieve number—				Liquid limit	Plasticity index
					Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
			In				*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*
Na—Neubert loam														
Neubert	100	B	0-15	Loam	CL, CL-ML, ML, SM	A-4	0- 0- 0	0- 3- 5	90-95-100	85-93-100	60-73-85	45-60-75	20-25-30	2-6 -10
			15-60	Loam, fine sandy loam	CL, CL-ML, ML, SM	A-4	0- 0- 0	0- 3- 5	90-95-100	85-93-100	60-73-85	45-60-75	20-25-30	2-6 -10
Sd—Sequatchie silt loam														
Sequatchie	100	B	0-12	Gravelly silt loam	CL, CL-ML, ML, SM	A-2, A-4	0- 0- 0	0- 5- 10	85-93-100	75-88-100	65-80-95	30-50-70	15-21-27	2-6 -10
			12-36	Gravelly clay loam, loam, silt loam	CL, CL-ML	A-4, A-6	0- 0- 0	0- 5- 10	85-93-100	75-88-100	65-80-95	55-70-85	20-26-32	5-10-15
			36-60	Gravelly clay loam, sandy loam, loam, fine sandy loam	CL, CL-ML, ML, SM	A-2, A-4	0- 0- 0	0- 8- 15	75-88-100	65-83-100	45-65-85	25-45-65	15-20-25	2-6 -10
Sg—Sequoia silty clay loam, eroded sloping phase														
Sequoia	100	C	0-5	Silty clay loam	CH, CL	A-6, A-7	0- 0- 0	0- 0- 0	95-98-100	95-98-100	90-95-100	85-90-95	35-50-65	12-24-35
			5-36	Channery silty clay, clay	CH, CL, MH	A-7	0- 0- 0	0- 0- 0	70-85-100	65-83-100	60-80-100	55-75-95	43-59-74	20-30-40
			36-70	Bedrock	—	—	—	—	—	—	—	—	—	—

TN811 LOCATE REQUEST

TICKET NUMBER:	**230315053**	OLD TICKET NUM:	
Message Type:	Normal	For Code:	NA
Hours Notice:	72	Seq Num:	NA
Prepared By:	jordan.7109	Taken Date:	01/31/23 3:53 PM

Response Status As Of Monday, February 06, 2023 12:58 PM

STATUS	CODE	NAME	FACILITIES
Closed	ALU	Alcoa Utilities - Electric - ALU • **February 01, 2023 1:13 PM** || Clear - No Conflict : No Conflict Overhead,	Electric
Closed	ALW	Alcoa Utilities - Water/Sewer - ALW • **February 03, 2023 12:13 PM** || Located - Facilities Marked : Facilities Marked	Water, Sewer
Closed	U07	Atmos Energy (United Cities Gas) - Maryville - U07 • **February 03, 2023 2:00 PM** || Located - Facilities Marked : Facilities Marked Marked service for 20 ft.	Gas
Closed	B01	ATT/D-(270) 791-2182 - B01 • **February 03, 2023 5:58 AM** || Located - Facilities Marked : Facilities Marked	Phone
Closed	CK4	Charter Communications - Alcoa - CK4 • **February 03, 2023 5:58 AM** || Clear - No Conflict : No Conflict	Cable
Closed	CM	Maryville Utilities, City of - CM • **February 03, 2023 5:58 AM** || Clear - No Conflict : No Conflict	Electric
Closed	CM	Maryville Utilities, City of - CM • **February 04, 2023 7:51 AM** || Clear - No Conflict : No Conflict • **February 03, 2023 6:36 AM** || Locate Delayed : Locate Delayed • **February 03, 2023 5:58 AM** || Locate Delayed : Locate Delayed	Water
Closed	CM	Maryville Utilities, City of - CM • **February 03, 2023 5:58 AM** || Clear - No Conflict : No Conflict	Sewer
Closed	MCI	MCI - MCI • **January 31, 2023 3:55 PM** || Clear - No Conflict : No Conflict	Phone

Excavator Information

Excavator:	NATALIE HESTER	Excavator Phone:	(615) 653-1724
Address:	2020 CITY VISTA WAY APT 2108	Caller:	NATALIE HESTER
City, St, Zip:	KNOXVILLE, TN 37290	Caller Phone:	(615) 653-1724
Contact Fax:		Contact:	NATALIE HESTER
Contact Email:		Contact Phone:	(615) 653-1724
Call Back:			

Work Information

State:	TN	Work To Begin:	02/03/23 AT 3:45 PM
County:	BLOUNT	Update Date:	02/14/23
Place:	LOUISVILLE	Expire Date:	02/18/23
Address:	4806 WHEELER RD		
Intersection:	MANOR WAY		
Latitude:	35.861688	Longitude:	-83.956103
Secondary Lat:	35.864948	Secondary Long:	-83.952047
Work Type:	OTHER /SEE REMARKS	Explosives: No	WhitePaint: No
Done For:	ANN HAM	Directional Boring:	No
Extent:		Add'l Addr In Remarks:	No

Location Information (DIRECTION)

PROP IS APPX 1000FT IN DEPTH...

Location Information (REMARKS)

SOIL SAMPLES - MARK REAR OF PROP @ TIP OF PENINSULA

GRIDS:9A, 9B, 9G, 9H

Utilities Notified:

Code	Name	Added Manually?
MCI	MCI - MCI	False
ALU	Alcoa Utilities - Electric - ALU	False
ALW	Alcoa Utilities - Water/Sewer - ALW	False
B01	ATT/D-(270) 791-2182 - B01	False
CK4	Charter Communications - Alcoa - CK4	False
CM	Maryville Utilities, City of - CM	False
U07	Atmos Energy (United Cities Gas) - Maryville - U07	False

Table 3. Summary of Discharges

Flooding Source and Location	Drainage Area (square miles)	Peak Discharges (cubic feet per second) 10-Percent-Annual-Chance	2-Percent-Annual-Chance	1-Percent-Annual-Chance	0.2-Percent-Annual-Chance
Lackey Creek					
Just upstream of mouth	10.5	1,430	2,240	2,610	3,610
Just upstream of Taylor Branch	5.7	880	1,370	1,610	2,220
At Meadowiew Road	3.3	570	890	1,040	1,440
Lackey Creek Tributary					
At mouth	1.2	250	400	460	640
About 1.0 mile upstream of mouth	0.7	160	260	300	420
Laurel Bank Branch					
At mouth	*	*	*	*	*
About 0.46 mile upstream of mouth	*	*	*	2,800	3,640
About 1.09 miles upstream of mouth	*	*	*	3,220	4,230
Upstream of Tennessee Highway 95	*	*	*	3,850	5,110
About 0.49 mile upstream of Big Springs Road	*	*	*	3,980	5,300
Little River					
At Mouth	379	27,000	39,000	44,500	58,000
About 1.56 miles upstream of State Rte 33	300	25,000	36,000	41,000	54,000
About 11.56 miles upstream of mouth	*	23,100	34,800	40,200	54,300
About 0.89 miles upstream of U.S. Highway 411	*	20,900	31,890	37,030	50,630
At Walland Bridge	*	18,000	28,050	32,850	45,800
About 27.11 miles upstream of mouth	*	15,630	24,920	29,430	41,840
About 0.58 miles downstream of Wear Valley Road	*	14,480	23,030	27,160	38,290
About 27.11 miles upstream of Mill Dam	*	14,100	22,400	26,400	37,100
Pistol Creek					
At mouth	39	3,550	5,100	5,950	8,100
About 2,750 feet upstream of Alcoa Trail	38.5	3,550	5,100	5,950	8,100
At Kelvin Road	*	*	*	3,770	5,150
At Home Street	*	*	*	3,070	4,220

*Data not available

Cross sections were field surveyed at bridges and other strategic locations. All bridges and culverts were surveyed to observe elevation data and structural geometry.

Locations of selected cross sections used in the hydraulic analyses are shown on the Flood Profiles (Exhibit 1). For stream segments for which a floodway was computed (Section 4.2), selected cross-section locations are also shown on the FIRM (Exhibit 2).

Water-surface elevations of floods of the selected recurrence intervals were computed using the HEC-2 step-backwater computer program (Reference 17). Starting water-surface elevations for Lackey Creek, Lackey Creek Tributary, Pistol Creek, and Taylor Branch were calculated using average elevations from Fort Loudoun Lake. The Tennessee River was started using Fort Loudoun Dam headwater elevations.

Roughness coefficients (Manning's "n") used in the hydraulic computations were determined on the basis of field inspections of the channels and floodplain areas. Roughness values for the channel and overbank areas are shown below:

Table 4. Manning's "n" Values

Stream	Channel "n"	Overbank "n"
Lackey Creek	0.030-0.045	0.060-0.15
Lackey Creek Tributary	0.04	0.080-0.14
Little River	0.030-0.045	0.060-0.15
Pistol Creek	0.035-0.050	0.065-0.10
Taylor Branch	0.035-0.045	0.070-0.15
Tennessee River	0.021-0.045	0.060-0.15

All elevations are referenced to NGVD. Elevation reference marks used in this study are shown on the maps and described in the exhibit labeled Elevation Reference Marks.

Cross section data for the streams in the study area were obtained by field surveys. All bridges and culverts were field surveyed to obtain elevation data and structural geometry. Cross sections were located at close intervals upstream and downstream of bridges and culverts in order to compute significant backwater effects of these strictures. The locations of selected cross sections used in the hydraulic analyses are shown on the Flood Profiles (Exhibit 1). For streams for which a floodway is computed (Section 4.2), selected cross section locations are also shown on the Flood Insurance Rate Map (Exhibit 2).

Water-surface elevations of floods of the selected recurrence intervals on Pistol Creek (RM 3.5-8.8), Unnamed Tributary to Springfield Branch, Culton Creek, and Russell Branch were computed by the Tennessee Valley Authority in June 1989 (Reference 1).

Water-surface elevations of floods of the selected recurrence intervals on Springfield Branch (above RM 1.03), Laurel Bank Branch (within the limits of the City of Maryville), Unnamed Tributary to Laurel Bank Branch, Dunlap Branch (within the limits of the City of Maryville), Brown Creek, Unnamed Tributary to Brown Creek and Duncan Branch were computed by the Tennessee Valley Authority in June 1989 (Reference 4).

Water-surface elevations of floods of the selected recurrence intervals on Pistol Creek (RM 8.8-13.73) within the limits of the City of Maryville were computed by AMEC Earth & Environmental, Inc. in May 2001 (Reference 5).

3.3 Vertical Datum

All FIS reports and FIRMs are referenced to a specific vertical datum. The vertical datum provides a starting point against which flood, ground, and structure elevations can be referenced and compared. Until recently, the standard vertical datum in use for newly created or revised FIS reports and FIRMs was the National Geodetic Vertical Datum of 1929 (NGVD29). With the finalization of the North American Vertical Datum of 1988 (NAVD88), many FIS reports and FIRMs are being prepared using NAVD88 as the referenced vertical datum.

All flood elevations shown in this FIS report and on the FIRM are referenced to NAVD88. Structure and ground elevations in the community must, therefore, be referenced to NAVD88. The datum shift value in Blount County to convert from NGVD29 to NAVD88 is -0.34 feet.

For more information on NAVD88, see the FEMA publication entitled Converting the National Flood Insurance Program to the North American Vertical Datum of 1988 (FEMA, June 1992), or contact the Vertical Network Branch, National Geodetic Survey, Coast and Geodetic Survey, National Oceanic and Atmospheric Administration, Rockville, Maryland 20910 (Internet address http://www.ngs.noaa.gov).

Temporary vertical monuments are often established during the preparation of a flood hazard analysis for the purpose of establishing local vertical control. However, no temporary vertical monuments were established during the preparation of this flood hazard analysis.

4.0 FLOODPLAIN MANAGEMENT APPLICATIONS

The NFIP encourages State and local governments to adopt sound floodplain management programs. Therefore, each FIS provides 1-percent-annual-chance flood elevations and delineations of the 1- and 0.2-percent-annual-chance floodplain boundaries and 1-percent-annual-chance floodway to assist communities in developing floodplain management measures. This information is presented on the FIRM and in many components of the FIS report, including Flood Profiles, Floodway Data table and Summary of Stillwater Elevations Table. Users should reference the data presented in the FIS report as well as additional information that may be available at the local map repository before making flood elevation and/or floodplain boundary determinations.

4.1 Floodplain Boundaries

To provide a national standard without regional discrimination, the 1-percent-annual-chance flood has been adopted by FEMA as the base flood for floodplain management purposes. The 0.2-percent-annual-chance flood is employed to indicate additional areas of flood risk in the community. For each stream studied by detailed methods, the 1- and 0.2-percent-annual-chance floodplain boundaries have been delineated using the flood elevations determined at each cross section. Between cross sections, the boundaries were interpolated using points and breaklines at a scale of 1:2400, 1:1200, and 1:600 with a contour interval of 2-10 feet (Reference 18).

The 1- and 0.2-percent-annual-chance floodplain boundaries are shown on the FIRM (Exhibit 2). On this map, the 1-percent-annual-chance floodplain boundary corresponds to the boundary of the areas of special flood hazards (Zones A, AE, V, and VE); and the

0.2-percent-annual-chance floodplain boundary corresponds to the boundary of areas of moderate flood hazards. In cases where the 1- and 0.2-percent-annual-chance floodplain boundaries are close together, only the 1-percent-annual-chance floodplain boundary has been shown. Small areas within the floodplain boundaries may lie above the flood elevations but cannot be shown due to limitations of the map scale and/or lack of detailed topographic data.

For the streams studied by approximate methods, only the 1-percent-annual-chance floodplain boundary is shown on the FIRM (Exhibit 2).

4.2 Floodways

Encroachment on floodplains, such as structures and fill, reduces flood-carrying capacity, increases flood heights and velocities, and increases flood hazards in areas beyond the encroachment itself. One aspect of floodplain management involves balancing the economic gain from floodplain development against the resulting increase in flood hazard. For purposes of the NFIP, a floodway is used as a tool to assist local communities in this aspect of floodplain management. Under this concept, the area of the 1-percent-annual-chance floodplain is divided into a floodway and a floodway fringe. The floodway is the channel of a stream, plus any adjacent floodplain areas, that must be kept free of encroachment so that the 1-percent-annual-chance flood can be carried without substantial increases in flood heights. Minimum Federal standards limit such increases to 1.0 foot, provided that hazardous velocities are not produced. The floodways in this study are presented to local agencies as minimum standards that can be adopted directly or that can be used as a basis for additional floodway studies.

The floodway presented in this FIS report and on the FIRM was computed for certain stream segments on the basis of equal conveyance reduction from each side of the floodplain. Floodway widths were computed at cross sections. Between cross sections, the floodway boundaries were interpolated. The results of the floodway computations have been tabulated for selected cross sections (Table 5). In cases where the floodway and 1-percent-annual-chance floodplain boundaries are either close together or collinear, only the floodway boundary has been shown.

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY (FEET NAVD)	WITHOUT FLOODWAY (FEET NAVD)	WITH FLOODWAY (FEET NAVD)	INCREASE (FEET)
LITTLE RIVER								
A	2,480	967[2]	13,086	3.4	817.0	813.2[3]	814.2[3]	1.0
B	6,210	437[2]	6,914	6.4	817.0	813.9[3]	814.8[3]	0.9
C	11,125	456[2]	7,499	5.9	817.0	816.3[3]	816.8[3]	0.5
D	13,080	365[2]	7,951	5.6	817.3	817.3	817.7	0.4
E	13,240	413[2]	7,854	5.7	817.5	817.5	817.9	0.4
F	14,670	368[2]	7,222	6.2	817.9	817.9	818.2	0.3
G	22,500	591	9,527	4.6	820.2	820.2	820.5	0.3
H	26,860	448	7,738	5.6	821.4	821.4	821.7	0.3
I	29,040	285	5,896	7.3	822.5	822.5	822.8	0.3
J	32,290	188	5,002	8.6	824.7	824.7	825.2	0.5
K	33,520	220	5,204	8.3	825.6	825.6	826.3	0.7
L	40,265	330	5,591	7.7	832.0	832.0	832.8	0.8
M	42,530	685	13,365	3.2	834.2	834.2	834.8	0.6
N	44,820	580	9,275	4.4	835.0	835.0	835.5	0.5
O	46,240	225	4,618	8.9	835.5	835.5	836.2	0.7
P	47,910	510	8,539	4.8	837.8	837.8	838.5	0.7
Q	53,200	330	6,952	5.9	840.2	840.2	841.1	0.9

[1] Stream distance in feet above mouth

[2] This width extends beyond county boundary

[3] Elevations without considering backwater effect from Tennessee River

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

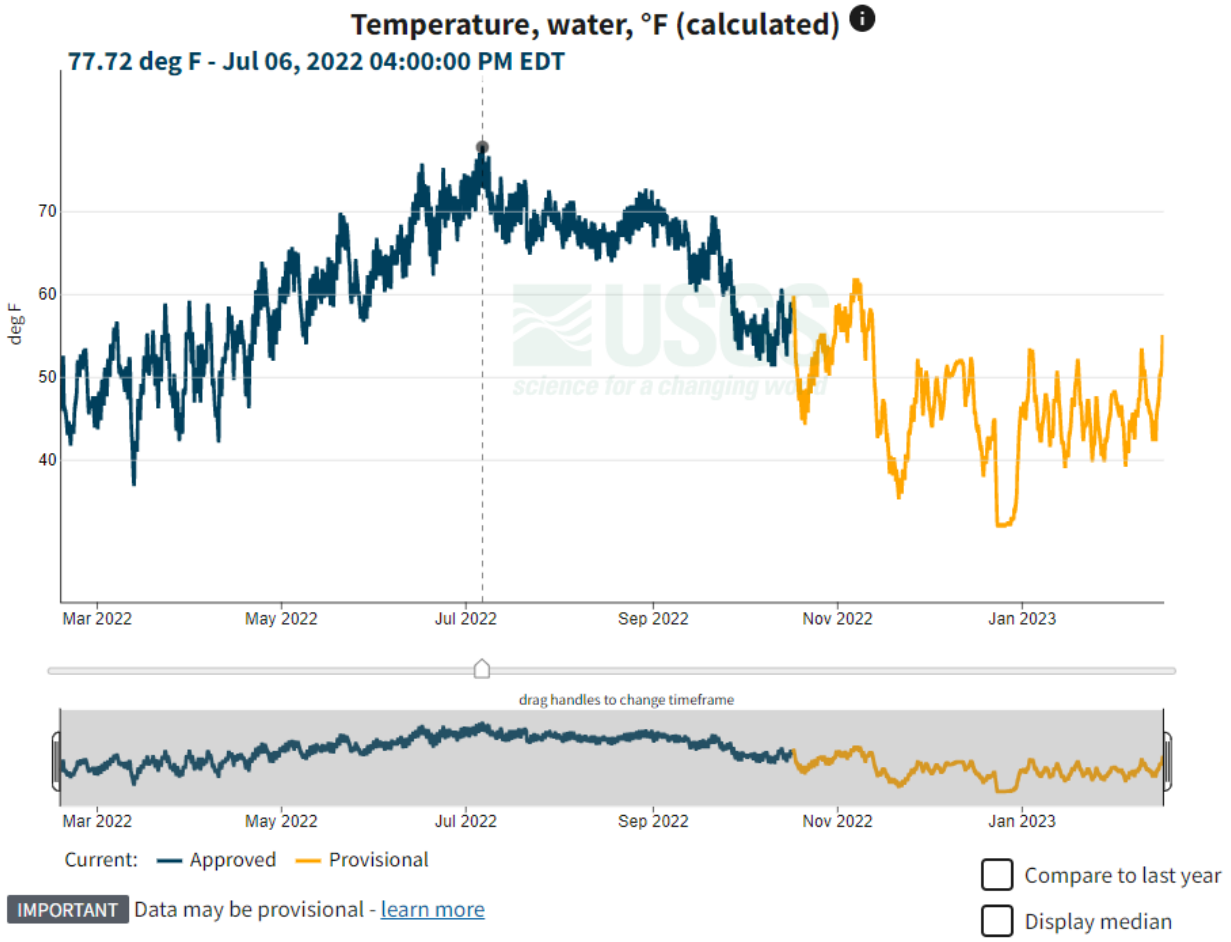
BLOUNT COUNTY, TN

(AND INCORPORATED AREAS)

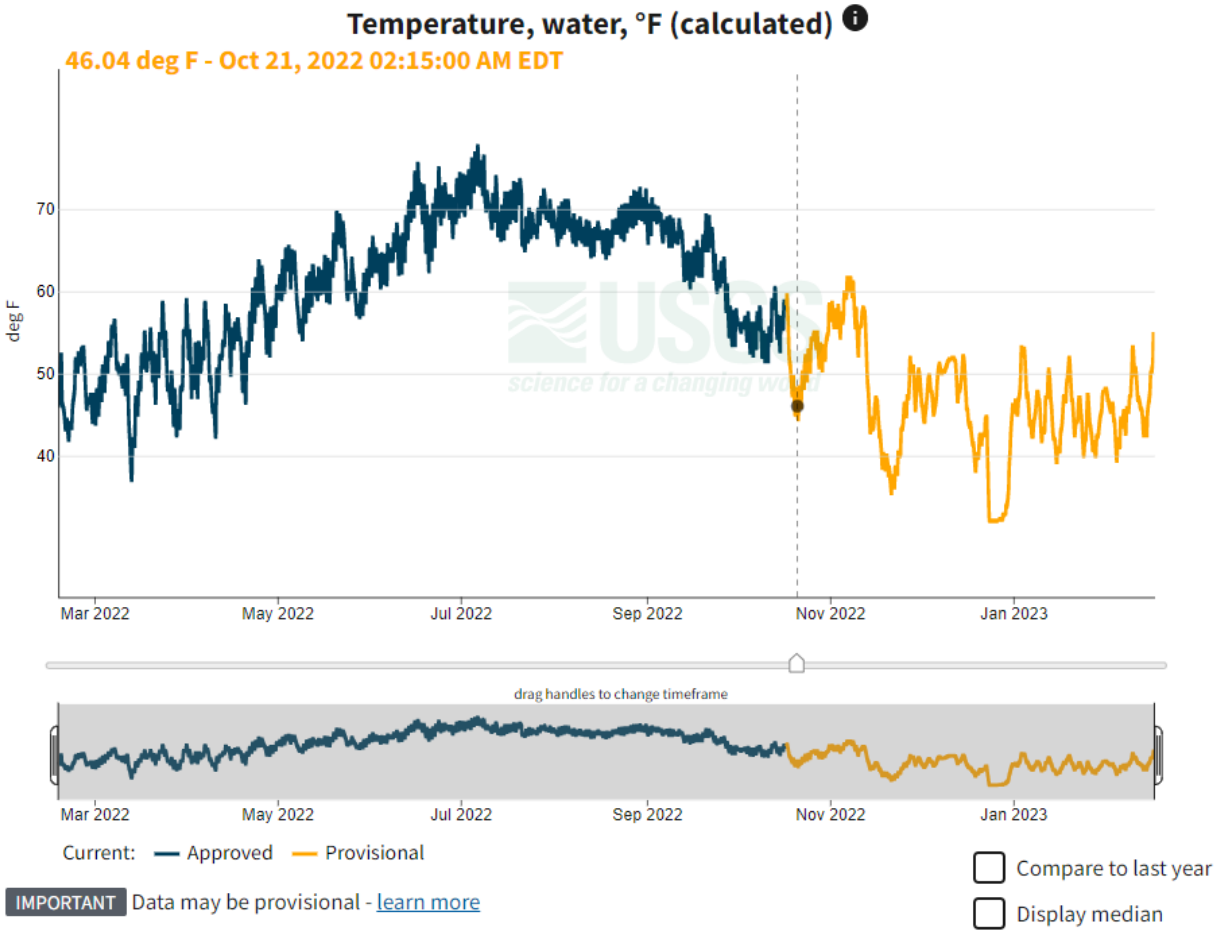
FLOODWAY DATA

LITTLE RIVER

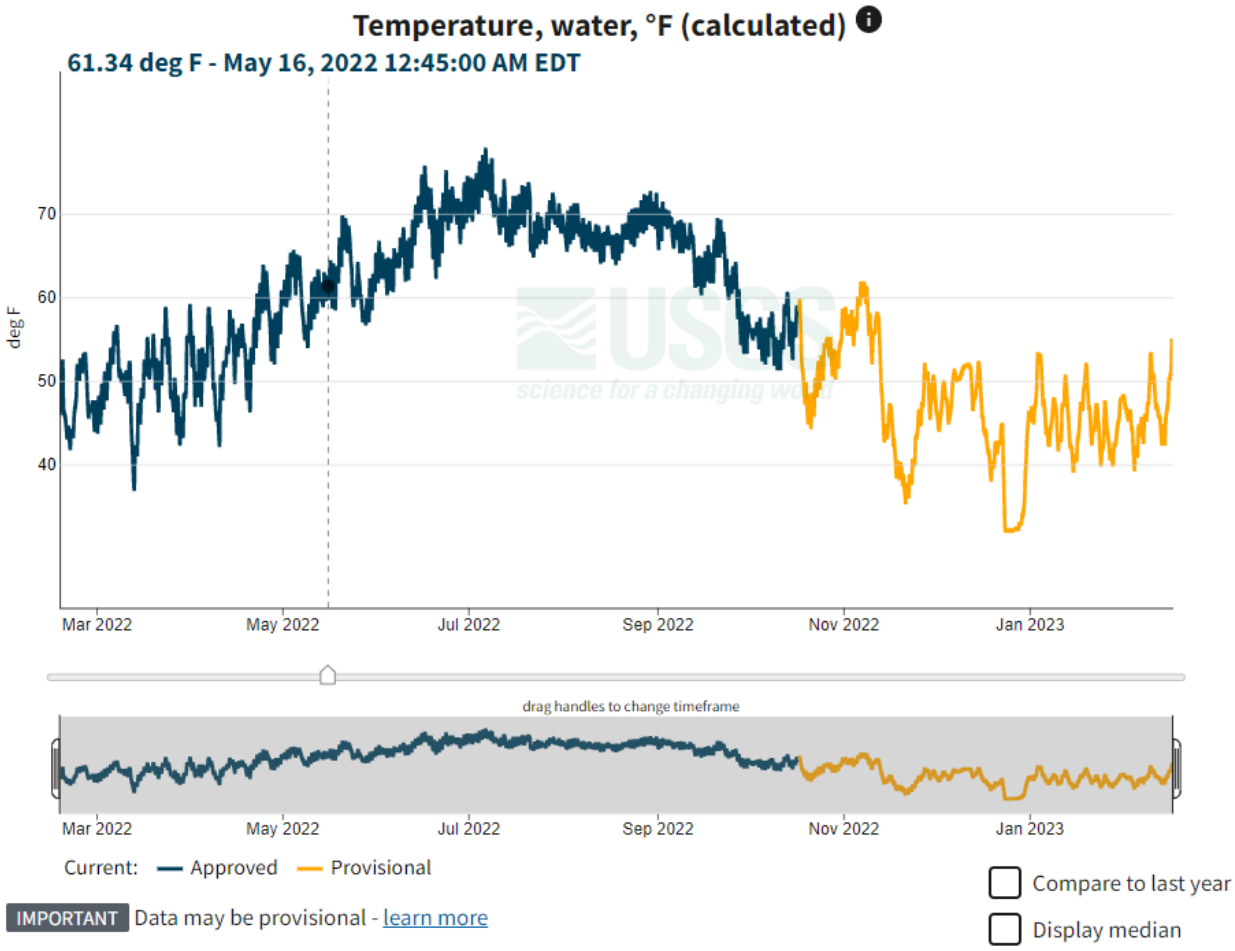
Peak Water Temperature during 2022



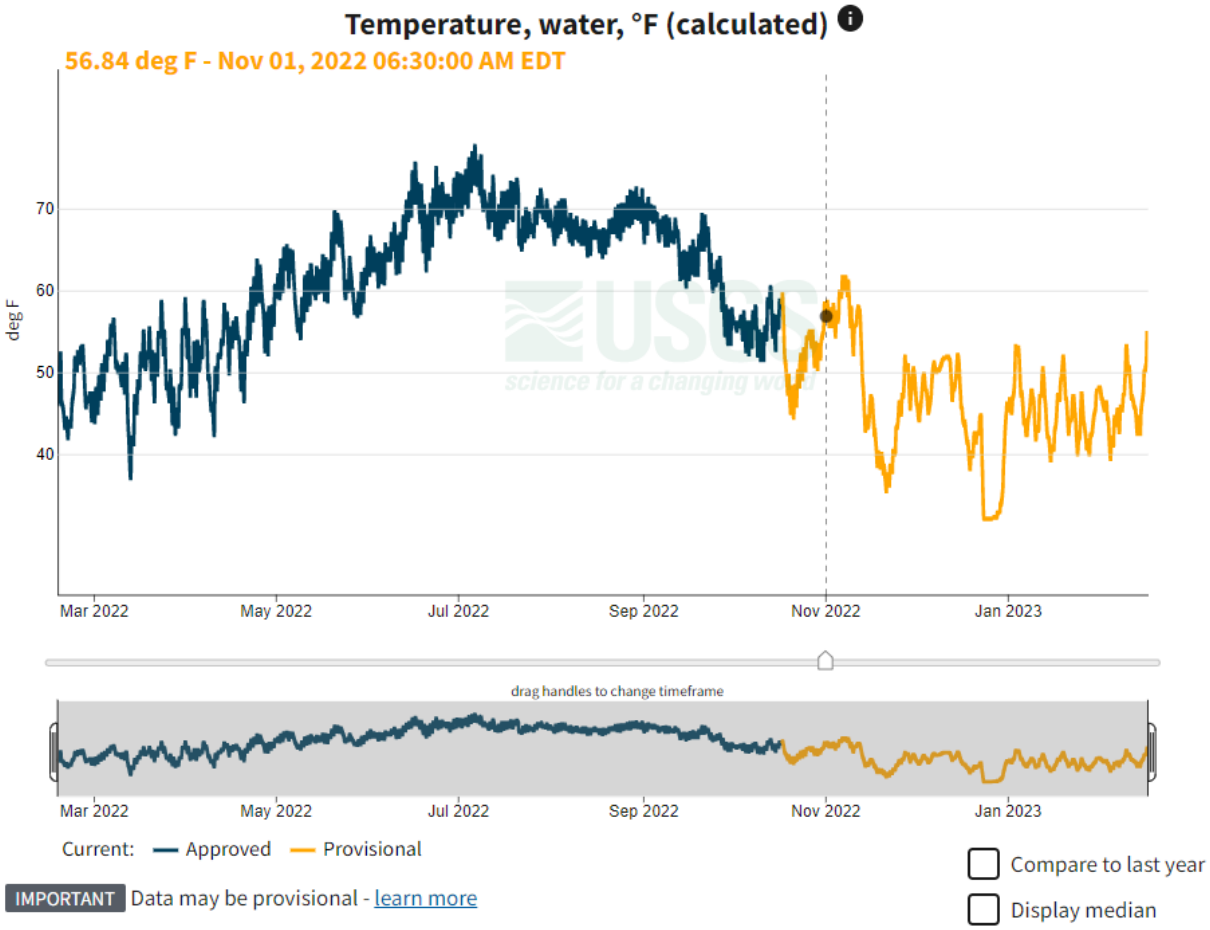
Lowest Water Temperature during 2022 TVA Summer Operating Guide Water Elevation (between may 16 and nov 1st)



End of TVA Water Elevation Rising (May 16th)



Beginning of TVA Water Elevation Drawdown(November 1st)



A.05 Applied Shear Stress Calculations

Step 1: River discharge calculations

	discharges (cubic feet per second)				
Little River Mile Markers	10%	2%	1%	0.20%	
At mouth	27000	39000	44500	58000	anne is at 4.2 miles upstream from mouth
About 1.56 miles upstream of SR33	25000	36000	41000	54000	approx 4 miles upstream from annes
average	25980.76211	37469.98799	42714.17	55964.3	

Step 2: Velocity Gradient Calculations

Cross Section	Distance upstream from mouth in feet	Distance upstream from mouth in miles	velocities for 1% (feet per sec)	Velocity Gradient	
A	2480	0.46969697	3.4		
B	6210	1.176136364	6.4	0.0008	
C	11125	2.107007576	5.9	-0.0001	
D	13080	2.477272727	5.6	-0.00015	
E	13240	2.507575758	5.7	0.00063	
F	14670	2.778409091	6.2	0.00035	
G	22500	4.261363636	4.6	-0.0002	
H	26860	5.087121212	5.6	0.00023	
I	29040	5.5	7.3	0.00078	
J	32290	6.115530303	8.6	0.0004	
K	33520	6.348484848	8.3	-0.00024	
L	40265	7.62594697	7.7	-8.9E-05	
M	42530	8.054924242			
N	44820	8.488636364			
O	46240	8.757575758			
P	47910	9.073863636			
Q	53200	10.07575758			

Step 3: Viscosity Calculations viscosity decreases as temp increases

date	temperatures	dynamic viscosity			
7/6/2022	77.72	0.000018420			
5/16/2022	61.34	0.000022966			
11/1/2022	56.84	0.000024535			
10/21/2022	46.04	0.000029100			

A.05 Applied Shear Stress Calculations

Step 4: Shear Stress Calculations

shear stress = viscosity times velocity gradient

77.72	0.000018420									
61.34	0.000022966									
56.84	0.000024535									
46.04	0.000029100				temp deg F	77.72	61.34	56.84	46.04	
					dynamic viscosity	0.000018420	2.2966E-05	2.4535E-05	0.0000291	
Cross Section	Distance upstream from mouth in feet	Distance upstream from mouth in miles	velocities for 1% (feet per sec)	Velocity Gradient		shear stress	shear stress	shear stress	shear stress	
A	2480	0.469697	3.4							
B	6210	1.176136	6.4	0.000804		1.48E-08	1.85E-08	1.97E-08	2.34E-08	
C	11125	2.107008	5.9	0.000102		1.87E-09	2.34E-09	2.50E-09	2.96E-09	
D	13080	2.477273	5.6	0.000153		2.83E-09	3.52E-09	3.76E-09	4.47E-09	
E	13240	2.507576	5.7	0.000625		1.15E-08	1.44E-08	1.53E-08	1.82E-08	
F	14670	2.778409	6.2	0.00035		6.44E-09	8.03E-09	8.58E-09	1.02E-08	
G	22500	4.261364	4.6	0.000204		3.76E-09	4.69E-09	5.01E-09	5.95E-09	
H	26860	5.087121	5.6	0.000229		4.22E-09	5.27E-09	5.63E-09	6.67E-09	
I	29040	5.5	7.3	0.00078		1.44E-08	1.79E-08	1.91E-08	2.27E-08	
J	32290	6.11553	8.6	0.0004		7.37E-09	9.19E-09	9.81E-09	1.16E-08	
K	33520	6.348485	8.3	0.000244		4.49E-09	5.60E-09	5.98E-09	7.10E-09	
L	40265	7.625947	7.7	8.9E-05		1.64E-09	2.04E-09	2.18E-09	2.59E-09	
					average shear stresses for	5.18E-09	6.46E-09	6.90E-09	8.18E-09	psf

A.05 Applied Shear Stress Calculations

Step 5: compare to NCDOT Channel Linings Permissible shear stresses

Table 2.3. Typical Permissible Shear Stresses for Bare Soil and Stone Linings

Lining Category	Lining Type	Permissible Shear Stress N/m^2	Permissible Shear Stress lb/ft^2
Bare Soil[1] Cohesive (PI = 10)	Clayey sands	1.8-4.5	0.037-0.095
	Inorganic silts	1.1-4.0	0.027-0.11
	Silty sands	1.1-3.4	0.024-0.072
Bare Soil[1] Cohesive (PI ≥ 20)	Clayey sands	4.5	0.094
	Inorganic silts	4.0	0.083
	Silty sands	3.5	0.072
	Inorganic clays	6.6	0.14
Bare Soil[2] Non-cohesive (PI < 10)	Finer than coarse sand D_{75}<1.3 mm (0.05 in)	1.0	0.02
	Fine gravel D_{75}=7.5 mm (0.3 in)	5.6	0.12
	Gravel D_{75}=15 mm (0.6 in)	11	0.24
Gravel Mulch[3]	Coarse gravel D_{50} = 25 mm (1 in)	19	0.4
	Very coarse gravel D_{50} = 50 mm (2 in)	38	0.8
Rock Riprap[3]	D_{50} = 0.15 m (0.5 ft)	113	2.4
	D_{50} = 0.30 m (1.0 ft)	227	4.8

[1]Based on Equation 4.6 assuming a soil void ratio of 0.5 (USDA, 1987).
[2]Based on Equation 4.5 derived from USDA (1987)
[3]Based on Equation 6.7 with Shield's parameter equal to 0.047.

temp deg F	77.72	61.34	56.84	46.04	
dynamic viscosity	0.00001842	0.000022966	0.000024535	0.0000291	
shear stress	5.18023E-09	6.45870E-09	6.89995E-09	8.18376E-09	psf

Critical Shear Stress and Erodibility Coefficient Calculations

- Critical shear stress calculated with Smerdon and Beasley's empirical relationship between the plasticity index and critical shear stress of cohesive soils.
  - conservative plasticity index value taken from USDA soil report for site

$$Iw := 2$$

$$\tau_c := (0.16) \cdot (Iw)^{0.84} \ (Pa)$$

$\tau_c = 0.006 \ psf$ $\tau_c = 0.286 \ Pa$

- Erodibility coefficient calculated with Hanson and Simon's relationship between erodibility coefficient and critical shear stress for cohesive silts, silt-clays, and clays.

$$k := \left(2 \cdot 10^{-7}\right) \cdot \left(0.286^{-0.5}\right) \cdot \frac{m^3}{N \cdot s}$$

$k = 0.102 \ \frac{in^3}{lbf \cdot s}$ $k = 0.374 \ \frac{cm^3}{N \cdot s}$

-Erodibilty coefficient calculated with Arulanadan et al. relationship between erodibility coefficient and critical shear stress for bank toes.

$$k := \left(1 \cdot 10^{-7}\right) \cdot \left(0.286^{-0.5}\right) \cdot \frac{m^3}{N \cdot s}$$

$k = 0.051 \ \frac{in^3}{lbf \cdot s}$ $k = 0.187 \ \frac{cm^3}{N \cdot s}$

Created with PTC Mathcad Express. See www.mathcad.com for more information.

protected. Therefore permissible shear stress is not significantly affected by the erodibility of the underlying soil. However, if the lining moves, the underlying soil will be exposed to the erosive force of the flow.

Table 2.3 provides typical examples of permissible shear stress for selected lining types. Representative values for different soil types are based on the methods found in Chapter 4 while those for gravel mulch and riprap are based on methods found in Chapter 7. Vegetative and RECP lining performance relates to how well they protect the underlying soil from shear stresses so these linings do not have permissible shear stresses independent of soil types. Chapters 4 (vegetation) and 5 (RECPs) describe the methods for analyzing these linings. Permissible shear stress for gabion mattresses depends on rock size and mattress thickness as is described in Section 7.2.

Table 2.3. Typical Permissible Shear Stresses for Bare Soil and Stone Linings

		Permissible Shear Stress	
Lining Category	Lining Type	N/m^2	lb/ft^2
Bare Soil[1] Cohesive (PI = 10)	Clayey sands	1.8-4.5	0.037-0.095
	Inorganic silts	1.1-4.0	0.027-0.11
	Silty sands	1.1-3.4	0.024-0.072
Bare Soil[1] Cohesive (PI $\geq$ 20)	Clayey sands	4.5	0.094
	Inorganic silts	4.0	0.083
	Silty sands	3.5	0.072
	Inorganic clays	6.6	0.14
Bare Soil[2] Non-cohesive (PI < 10)	Finer than coarse sand D_{75}<1.3 mm (0.05 in)	1.0	0.02
	Fine gravel D_{75}=7.5 mm (0.3 in)	5.6	0.12
	Gravel D_{75}=15 mm (0.6 in)	11	0.24
Gravel Mulch[3]	Coarse gravel D_{50} = 25 mm (1 in)	19	0.4
	Very coarse gravel D_{50} = 50 mm (2 in)	38	0.8
Rock Riprap[3]	D_{50} = 0.15 m (0.5 ft)	113	2.4
	D_{50} = 0.30 m (1.0 ft)	227	4.8

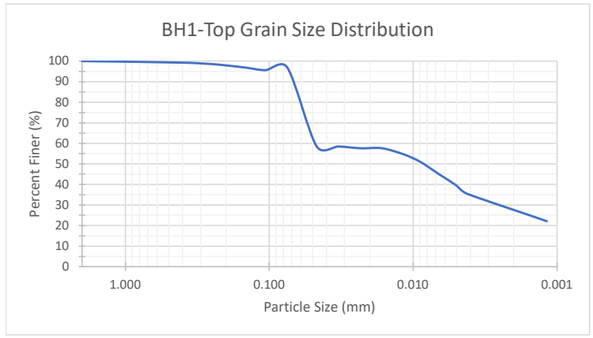
[1]Based on Equation 4.6 assuming a soil void ratio of 0.5 (USDA, 1987).
[2]Based on Equation 4.5 derived from USDA (1987)
[3]Based on Equation 6.7 with Shield's parameter equal to 0.047.

2.3 DESIGN PARAMETERS

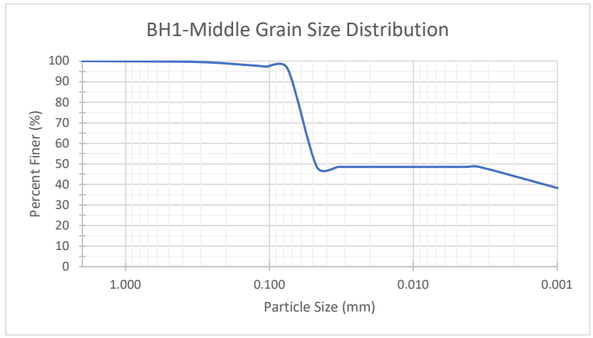
2.3.1 Design Discharge Frequency

Design flow rates for permanent roadside and median drainage channel linings usually have a 5 or 10-year return period. A lower return period flow is allowable if a transitional lining is to be used, typically the mean annual storm (approximately a 2-year return period, i.e., 50 percent probability of occurrence in a year). Transitional channel linings are often used during the establishment of vegetation. The probability of damage during this relatively short time is low,

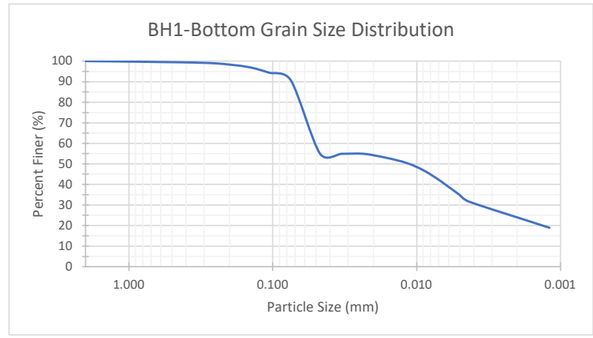
Graphs combined



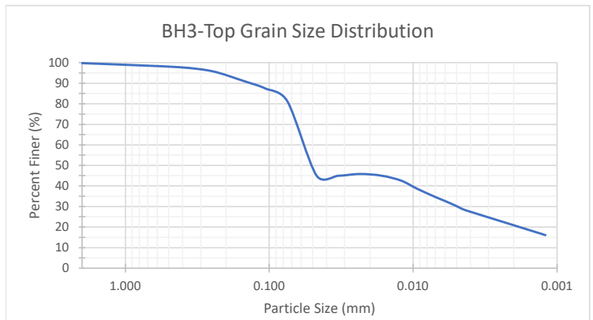
22.16519 % clay
77.16608 % silt silt loam
0.638786 % sand



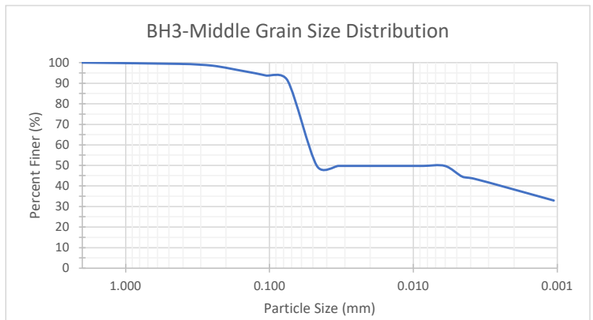
38.1609 % clay
61.61265 % silt silty clay loam
0.226449 % sand



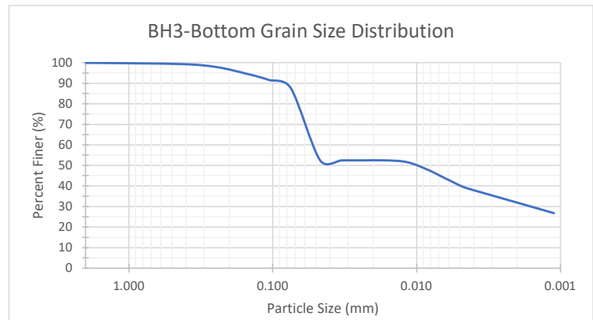
18.98928 % clay
80.46099 % silt silt loam
0.509745 % sand



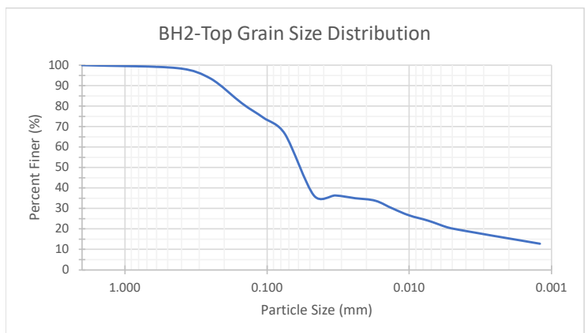
16.15724 % clay
81.59019 % silt silt loam
2.073159 % sand



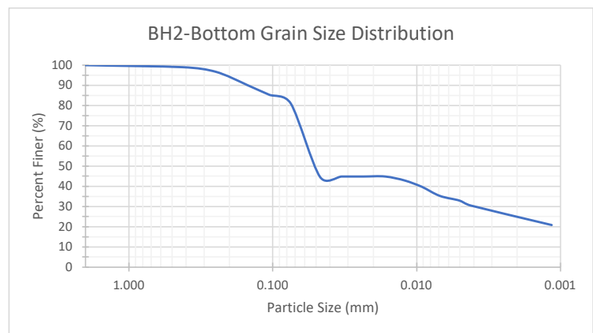
32.92374 % clay
66.51722 % silt silty clay loam
0.559043 % sand



26.73587 % clay
72.57174 % silt silty clay loam
0.642928 % sand



12.72026 % clay
85.85258 % silt silt loam
1.377953 % sand



20.88997 % clay
78.13325 % silt silt loam
0.976777 % sand

THE UNIVERSITY OF TENNESSEE

Department of Civil and Environmental Engineering

Project Name:	CE 432 Borings	Boring No:	2	Sample No:	top
Depth:	<1ft				
Team Members:	Natalie and Steven			Date:	2/21/2023

Mass of Original Sample (W_0): 101.6 g Mass of 200 Wash residue ($W_{residue}$): 34.92 g ass of W_{200} (W_0-$W_{residue}$): 66.68 g

Mechanical Analysis

Sieve #	Opening (mm)	Sieve Mass (g)	Sieve + Soil Mass (g)	Mass Retained (g)	Cumulative Mass Retained (g)	Cumulative Percent Retained (%)	Cumulative Percent Passing (%)
10	2.000				0.05	0.0492126	99.9507874
40	0.425				1.45	1.42716535	98.5728346
60	0.250				6.68	6.57480315	93.4251969
100	0.150				18.89	18.5925197	81.4074803
140	0.106				26.08	25.6692913	74.3307087
200	0.075				34.12	33.5826772	66.4173228

Hydrometer No: 152H Concentration of Dispersing Agent (X_d): 40 g/L Volume of Stock Solution (V_d): 125 mL

Dispersing Agent Correction (Cd = $0.001X_dV_d$) 5 g/L Meniscus Correction (cm) 0.5 g/L

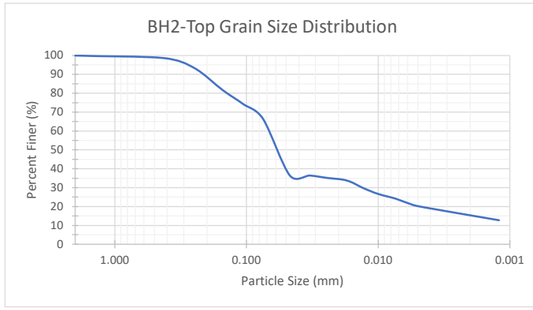
Specific Gravity (G_s): 2.7 % passing No. 4 Sieve= 100 W_{200}/W_0 0.34370079 g

Hydrometer Analysis

Time	Elapsed Time (min)	Temp (°C)	Unit mass, ρ_w (g/cm^3)	Hydrometer Reading, R (g/L)	Temp Correction m	Corrected Reading, R_{corr}	Effective Depth, L (cm)	Constant, K	Particle Diamter, D (mm)	Particle Percent Finer	Total Percent Finer
	0.5	23	0.9975	60	0.655	56.155	6.5	0.01297	0.046764	54.71796	36.3422059
	1	23	0.9975	60	0.655	56.155	6.5	0.01297	0.033067	54.71796	36.3422059
	2	23	0.9975	58	0.655	54.155	6.8	0.01297	0.023915	52.76914	35.0478525
	4	23	0.9975	56	0.655	52.155	7.1	0.01297	0.017280	50.82032	33.7534992
	8	23	0.9975	50	0.655	46.155	8.1	0.01297	0.013051	44.97387	29.8704392
	15	23	0.9975	45	0.655	41.155	8.9	0.01297	0.009991	40.10182	26.6345558
	30	23	0.9975	41	0.655	37.155	9.6	0.01297	0.007337	36.20418	24.0458491
	60	23	0.9975	36	0.655	32.155	10.4	0.01297	0.005400	31.33214	20.8099658
	90	23	0.9975	34	0.655	30.155	10.7	0.01297	0.004472	29.38332	19.5156125
	1440	23	0.9975	23.5	0.655	19.655	12.5	0.01297	0.001208	19.15202	12.7202574

[1] $m = 1000[0.99823 - \rho_w - 0.000025\,(T - 20)]$. where T is water temperature (°C) and ρ_w is water unit mass (g/cm^3) at temperature T.
[2] $R_{corr} = R + m - C_d + C_m$
[3] L obtained from Table 2 of ASTM D422
[4] K obtained from Table 3 of ASTM D422
[5] $D = K\,(L/t)^{1/2}$ where t is elapsed time
[6] $P = (R_{corr}\,a/W_0)$ where a obtained from Table 1 of ASTM D422
[7] Refer to ASTM D422, Section 16 (based on W_{200}/W_0)

combined particle size (mm)	%passing	Classification
2.000	99.95079	Sand
0.425	98.57283	Silt
0.250	93.4252	Silt
0.150	81.40748	Silt
0.106	74.33071	Silt
0.075	66.41732	Silt
0.046764	36.34221	Silt
0.033067142	36.34221	Silt
0.023915498	35.04785	Silt
0.017279818	33.7535	Silt
0.013050811	29.87044	Silt
0.009990549	26.63456	Silt
0.00733694	24.04585	Silt
0.005399842	20.80997	Silt
0.004472091	19.51561	Silt
0.001208408	12.72026	Clay



12.72026 % clay
85.85258 % silt
1.377953 % sand

THE UNIVERSITY OF TENNESSEE

Department of Civil and Environmental Engineering

Project Name:	CE 432 Borings	Boring No:	2	Sample No:	bottom
Depth:	<1ft				
Team Members:	Natalie and Steven			Date:	2/21/2023

Mass of Original Sample (W_0): 100.33 g Mass of 200 Wash residue ($W_{residue}$): 19.48 g ass of W_{200} (W_0-$W_{residue}$): 80.85 g

Mechanical Analysis

Sieve #	Opening (mm)	Sieve Mass (g)	Sieve + Soil Mass (g)	Mass Retained (g)	Cumulative Mass Retained (g)	Cumulative Percent Retained (%)	Cumulative Percent Passing (%)
10	2.000				0	0	100
40	0.425				0.98	0.97677664	99.0232234
60	0.250				3.22	3.20940895	96.790591
100	0.150				9.87	9.83753613	90.1624639
140	0.106				14.72	14.6715838	85.3284162
200	0.075				19.12	19.0571115	80.9428885

Hydrometer No: 152H Concentration of Dispersing Agent (X_d): 40 g/L Volume of Stock Solution (V_d): 125 mL

Dispersing Agent Correction (Cd = $0.001X_dV_d$) 5 g/L Meniscus Correction (cm) 0.5 g/L

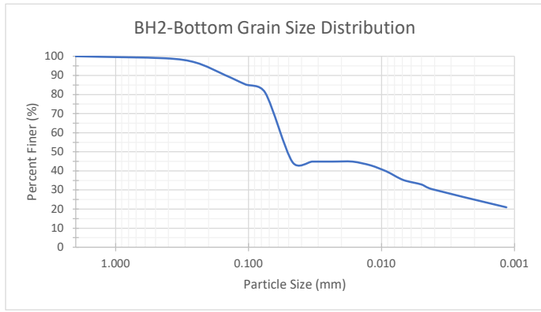
Specific Gravity (G_s): 2.7 % passing No. 4 Sieve= 100 W_{200}/W_0 0.19415927 g

Hydrometer Analysis

Time	Elapsed Time (min)	Temp (°C)	Unit mass, ρ_w (g/cm^3)	Hydrometer Reading, R (g/L)	Temp Correction m	Corrected Reading, R_{corr}	Effective Depth, L (cm)	Constant, K	Particle Diamter, D (mm)	Particle Percent Finer	Total Percent Finer
	0.5	22	0.9978	60	0.38	55.88	6.5	0.01297	0.046764	55.13924	44.6312939
	1	23	0.9975	60	0.655	56.155	6.5	0.01297	0.033067	55.4106	44.8509361
	2	23	0.9975	60	0.655	56.155	6.5	0.01297	0.023382	55.4106	44.8509361
	4	23	0.9975	60	0.655	56.155	6.5	0.01297	0.016534	55.4106	44.8509361
	8	23	0.9975	57.5	0.655	53.655	6.9	0.01297	0.012045	52.94374	42.8541889
	15	23	0.9975	53.5	0.655	49.655	7.5	0.01297	0.009171	48.99676	39.6593934
	30	23	0.9975	48	0.655	44.155	8.4	0.01297	0.006863	43.56967	35.2665495
	60	23	0.9975	45	0.655	41.155	8.9	0.01297	0.004995	40.60944	32.8704528
	90	23	0.9975	42	0.655	38.155	9.4	0.01297	0.004192	37.64921	30.4743561
	1440	23	0.9975	30	0.655	26.155	11.4	0.01297	0.001154	25.80828	20.8899695

[1] $m = 1000[0.99823 - \rho_w - 0.000025\,(T - 20)]$. where T is water temperature (°C) and ρ_w is water unit mass (g/cm^3) at temperature T.
[2] $R_{corr} = R + m - C_d + C_m$
[3] L obtained from Table 2 of ASTM D422
[4] K obtained from Table 3 of ASTM D422
[5] $D = K\,(L/t)^{1/2}$ where t is elapsed time
[6] $P = (R_{corr}\,a/W_0)$ where a obtained from Table 1 of ASTM D422
[7] Refer to ASTM D422, Section 16 (based on W_{200}/W_0)

combined particle siz	% passing	Classification
2.000	100	Sand
0.425	99.02322	Silt
0.250	96.79059	Silt
0.150	90.16246	Silt
0.106	85.32842	Silt
0.075	80.94289	Silt
0.046764	44.63129	Silt
0.033067	44.85094	Silt
0.023382	44.85094	Silt
0.016534	44.85094	Silt
0.012045	42.85419	Silt
0.009171	39.65939	Silt
0.006863	35.26655	Silt
0.004995	32.87045	Silt
0.004192	30.47436	Silt
0.001154	20.88997	Clay



20.88997 % clay
78.13325 % silt
0.976777 % sand

THE UNIVERSITY OF TENNESSEE

Department of Civil and Environmental Engineering

Project Name:	CE 432 Borings	Boring No:	3	Sample No:	bottom	Depth:	<1ft
Team Members:	Natalie and Steven					Date:	2/21/2023
Mass of Original Sample (W_0):	101.1 g	Mass of 200 Wash residue ($W_{residue}$):	12.77 g	ass of W_{200} (W_0-$W_{residue}$):	88.33 g		

Mechanical Analysis

Sieve #	Opening (mm)	Sieve Mass (g)	Sieve + Soil Mass (g)	Mass Retained (g)	Cumulative Mass Retained (g)	Cumulative Percent Retained (%)	Cumulative Percent Passing (%)
10	2.000				0.05	0.049	99.951
40	0.425				0.7	0.692	99.308
60	0.250				2.04	2.018	97.982
100	0.150				5.55	5.490	94.510
140	0.106				8.51	8.417	91.583
200	0.075				12.5	12.364	87.636

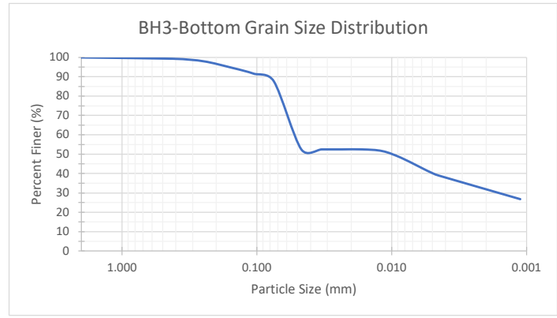
Hydrometer No:	152H	Concentration of Dispersing Agent (X_d):	40 g/L	Volume of Stock Solution (V_d):	125 mL
Dispersing Agent Correction (Cd = $0.001X_dV_d$)	5 g/L	Meniscus Correction (cm)	0.5 g/L		
Specific Gravity (G_s):	2.7	% passing No. 4 Sieve=	100	W_{200}/W_0	0.12631058 g

Hydrometer Analysis

Time	Elapsed Time (min)	Temp (°C)	Unit mass, ρ_w (g/cm^3)	Hydrometer Reading, R (g/L)	Temp Correction m	Corrected Reading, R_{corr}	Effective Depth, L (cm)	Constant, K	Particle Diamter, D (mm)	Particle Percent Finer	Total Percent Finer
	0.5	23	0.9975	65	0.655	61.155	6.5	0.01297	0.046764	59.88472	52.4805739
	1	23	0.9975	65	0.655	61.155	6.5	0.01297	0.033067	59.88472	52.4805739
	2	23	0.9975	65	0.655	61.155	6.5	0.01297	0.023382	59.88472	52.4805739
	4	23	0.9975	65	0.655	61.155	6.5	0.01297	0.016534	59.88472	52.4805739
	8	23	0.9975	64	0.655	60.155	6.5	0.01297	0.011691	58.90549	51.6224172
	15	23	0.9975	60	0.655	56.155	6.5	0.01297	0.008538	54.98858	48.1897903
	30	23	0.9975	55	0.655	51.155	7.3	0.01297	0.006398	50.09243	43.8990068
	60	23	0.9975	50	0.655	46.155	8.1	0.01297	0.004765	45.19629	39.6082232
	90	23	0.9975	48	0.655	44.155	8.4	0.01297	0.003962	43.23783	37.8919098
	1440	23	0.9975	35	0.655	31.155	10.6	0.01297	0.001113	30.50786	26.7358725

[1] $m = 1000[0.99823 - \rho_w - 0.000025(T - 20)]$, where T is water temperature (°C) and ρ_w is water unit mass (g/cm^3) at temperature T.
[2] $R_{corr} = R + m - C_d + C_m$
[3] L obtained from Table 2 of ASTM D422
[4] K obtained from Table 3 of ASTM D422
[5] $D = K(L/t)^{1/2}$ where t is elapsed time
[6] $P = (R_{corr}\, a/W_0)$ where a obtained from Table 1 of ASTM D422
[7] Refer to ASTM D422, Section 16 (based on $W_{\#10}/W_O$)

combined particle siz	% passing	Classification
2.000	99.95054	Sand
0.425	99.30762	Silt
0.250	97.9822	Silt
0.150	94.51039	Silt
0.106	91.58259	Silt
0.075	87.636	Silt
0.046764	52.48057	Silt
0.033067	52.48057	Silt
0.023382	52.48057	Silt
0.016534	52.48057	Silt
0.011691	51.62242	Silt
0.008538	48.18979	Silt
0.006398	43.89901	Silt
0.004765	39.60822	Silt
0.003962	37.89191	Silt
0.001113	26.73587	Clay



26.73587 % clay
72.57174 % silt
0.642928 % sand

THE UNIVERSITY OF TENNESSEE

Department of Civil and Environmental Engineering

Project Name:	CE 432 Borings	Boring No:	3	Sample No:	middle	Depth:	<1ft
Team Members:	Natalie and Steven					Date:	2/20/2023

Mass of Original Sample (W_0): 101.96 g Mass of 200 Wash residue ($W_{residue}$): 8.78 g ass of W_{200} (W_0-$W_{residue}$): 93.18 g

Mechanical Analysis

Sieve #	Opening (mm)	Sieve Mass (g)	Sieve + Soil Mass (g)	Mass Retained (g)	Cumulative Mass Retained (g)	Cumulative Percent Retained (%)	Cumulative Percent Passing (%)
10	2.000				0	0.000	100.000
40	0.425				0.57	0.559	99.441
60	0.250				1.53	1.501	98.499
100	0.150				4.27	4.188	95.812
140	0.106				6.33	6.208	93.792
200	0.075				8.91	8.739	91.261

Hydrometer No: 152H Concentration of Dispersing Agent (X_d): 40 g/L Volume of Stock Solution (V_d): 125 mL

Dispersing Agent Correction (Cd = $0.001X_dV_d$) 5 g/L Meniscus Correction (cm) 0.5 g/L

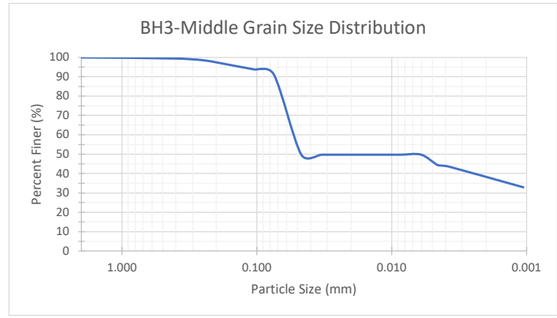
Specific Gravity (G_s): 2.7 % passing No. 4 Sieve= 100 W_{200}/W_0 0.0861122 g

Hydrometer Analysis

Time	Elapsed Time (min)	Temp (°C)	Unit mass, ρ_w (g/cm^3)	Hydrometer Reading, R (g/L)	Temp Correction m	Corrected Reading, R_{corr}	Effective Depth, L (cm)	Constant, K	Particle Diamter, D (mm)	Particle Percent Finer	Total Percent Finer
	0.5	23	0.9975	60	0.655	56.155	6.5	0.01297	0.046764	54.52476	49.7599975
	1	23	0.9975	60	0.655	56.155	6.5	0.01297	0.033067	54.52476	49.7599975
	2	23	0.9975	60	0.655	56.155	6.5	0.01297	0.023382	54.52476	49.7599975
	4	23	0.9975	60	0.655	56.155	6.5	0.01297	0.016534	54.52476	49.7599975
	8	23	0.9975	60	0.655	56.155	6.5	0.01297	0.011691	54.52476	49.7599975
	15	23	0.9975	60	0.655	56.155	6.5	0.01297	0.008538	54.52476	49.7599975
	30	23	0.9975	60	0.655	56.155	6.5	0.01297	0.006037	54.52476	49.7599975
	60	23	0.9975	54	0.655	50.155	7.4	0.01297	0.004555	48.69895	44.4432851
	90	23	0.9975	53	0.655	49.155	7.6	0.01297	0.003769	47.72798	43.5571664
	1440	23	0.9975	41	0.655	37.155	9.6	0.01297	0.001059	36.07635	32.9237416

[1] $m = 1000[0.99823 - \rho_w - 0.000025\,(T - 20)]$. where T is water temperature (°C) and ρ_w is water unit mass (g/cm^3) at temperature T.
[2] $R_{corr} = R + m - C_d + C_m$
[3] L obtained from Table 2 of ASTM D422
[4] K obtained from Table 3 of ASTM D422
[5] $D = K\,(L/t)^{1/2}$ where t is elapsed time
[6] $P = (R_{corr}\ a/W_0)$ where a obtained from Table 1 of ASTM D422
[7] Refer to ASTM D422, Section 16 (based on $W_{\#10}/W_O$)

combined particle siz	% passing	Classification
2.000	100	Sand
0.425	99.44096	Silt
0.250	98.49941	Silt
0.150	95.81208	Silt
0.106	93.79168	Silt
0.075	91.26128	Silt
0.046764	49.76	Silt
0.033067	49.76	Silt
0.023382	49.76	Silt
0.016534	49.76	Silt
0.011691	49.76	Silt
0.008538	49.76	Silt
0.006037	49.76	Silt
0.004555	44.44329	Silt
0.003769	43.55717	Silt
0.001059	32.92374	Clay



32.92374 % clay
66.51722 % silt
0.559043 % sand

THE UNIVERSITY OF TENNESSEE

Department of Civil and Environmental Engineering

Project Name:	CE 432 Borings	Boring No:	3	Sample No:	top	Depth:	<1ft
Team Members:	Natalie and Steven					Date:	2/20/2023

Mass of Original Sample (W_0): 100.33 g Mass of 200 Wash residue ($W_{residue}$): 16.87 g ass of W_{200} (W_0-$W_{residue}$): 83.46 g

Mechanical Analysis

Sieve #	Opening (mm)	Sieve Mass (g)	Sieve + Soil Mass (g)	Mass Retained (g)	Cumulative Mass Retained (g)	Cumulative Percent Retained (%)	Cumulative Percent Passing (%)
10	2.000				0.18	0.179	99.821
40	0.425				2.26	2.253	97.747
60	0.250				4.21	4.196	95.804
100	0.150				9.03	9.000	91.000
140	0.106				12.63	12.588	87.412
200	0.075				18.82	18.758	81.242

Hydrometer No: 152H Concentration of Dispersing Agent (X_d): 40 g/L Volume of Stock Solution (V_d): 125 mL

Dispersing Agent Correction (Cd = 0.001X_dV_d): 5 g/L Meniscus Correction (cm) 0.5 g/L

Specific Gravity (G_s): 2.7 % passing No. 4 Sieve= 100 W_{200}/W_0 0.16814512 g

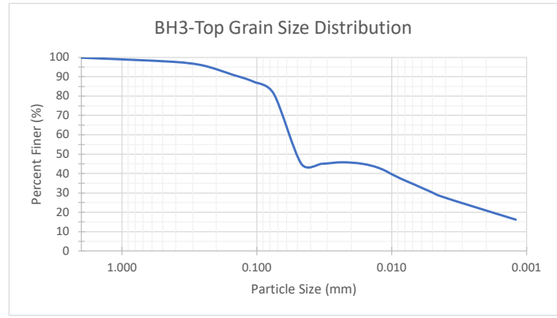
Hydrometer Analysis

Time	Elapsed Time (min)	Temp (°C)	Unit mass, ρ_w (g/cm^3)	Hydrometer Reading, R (g/L)	Temp Correction m	Corrected Reading, R_{corr}	Effective Depth, L (cm)	Constant, K	Particle Diamter, D (mm)	Particle Percent Finer	Total Percent Finer
	0.5	23	0.9975	60	0.655	56.155	6.5	0.01297	0.046764	55.4106	45.0166212
	1	23	0.9975	60	0.655	56.155	6.5	0.01297	0.033067	55.4106	45.0166212
	2	23	0.9975	61	0.655	57.155	6.5	0.01297	0.023382	56.39734	45.8182705
	4	23	0.9975	60	0.655	56.155	6.5	0.01297	0.016534	55.4106	45.0166212
	8	23	0.9975	57	0.655	53.155	7	0.01297	0.012132	52.45036	42.611673
	15	23	0.9975	52	0.655	48.155	7.8	0.01297	0.009353	47.51665	38.6034261
	30	23	0.9975	47	0.655	43.155	8.6	0.01297	0.006944	42.58293	34.5951792
	60	23	0.9975	42	0.655	38.155	9.4	0.01297	0.005134	37.64921	30.5869323
	90	23	0.9975	39	0.655	35.155	9.9	0.01297	0.004302	34.68898	28.1819841
	1440	23	0.9975	24	0.655	20.155	12.4	0.01297	0.001204	19.88782	16.1572433

[1] m = 1000[0.99823 – ρ_w – 0.000025 (T – 20)]. where T is water temperature (°C) and ρ_w is water unit mass (g/cm^3) at temperature T.
[2] $R_{corr} = R + m - C_d + C_m$
[3] L obtained from Table 2 of ASTM D422
[4] K obtained from Table 3 of ASTM D422
[5] $D = K (L/t)^{1/2}$ where t is elapsed time
[6] $P = (R_{corr}\ a/W_0)$ where a obtained from Table 1 of ASTM D422
[7] Refer to ASTM D422, Section 16 (based on $W_{\#10}/W_O$)

combined

particle siz	% passing	Classification
2.000	99.82059	Sand
0.425	97.74743	Silt
0.250	95.80385	Silt
0.150	90.9997	Silt
0.106	87.41154	Silt
0.075	81.2419	Silt
0.046764	45.01662	Silt
0.033067	45.01662	Silt
0.023382	45.81827	Silt
0.016534	45.01662	Silt
0.012132	42.61167	Silt
0.009353	38.60343	Silt
0.006944	34.59518	Silt
0.005134	30.58693	Silt
0.004302	28.18198	Silt
0.001204	16.15724	Clay



16.15724 % clay
81.59019 % silt
2.073159 % sand

THE UNIVERSITY OF TENNESSEE

Department of Civil and Environmental Engineering

Project Name:	CE 432 Borings	Boring No:	1	Sample No:	bottom	Depth:	<1ft
Team Members:	Natalie and Steven					Date:	2/20/2023

Mass of Original Sample (W_0): 100.05 g Mass of 200 Wash residue ($W_{residue}$): 9.22 g ass of W_{200} (W_0-$W_{residue}$): 90.83 g

Mechanical Analysis

Sieve #	Opening (mm)	Sieve Mass (g)	Sieve + Soil Mass (g)	Mass Retained (g)	Cumulative Mass Retained (g)	Cumulative Percent Retained (%)	Cumulative Percent Passing (%)
10	2.000				0.04	0.040	99.960
40	0.425				0.55	0.550	99.450
60	0.250				1.13	1.129	98.871
100	0.150				2.77	2.769	97.231
140	0.106				5.64	5.637	94.363
200	0.075				9.29	9.285	90.715

Hydrometer No: 152H Concentration of Dispersing Agent (X_d): 40 g/L Volume of Stock Solution (V_d): 125 mL

Dispersing Agent Correction ($Cd = 0.001X_dV_d$) 5 g/L Meniscus Correction (cm) 0.5 g/L

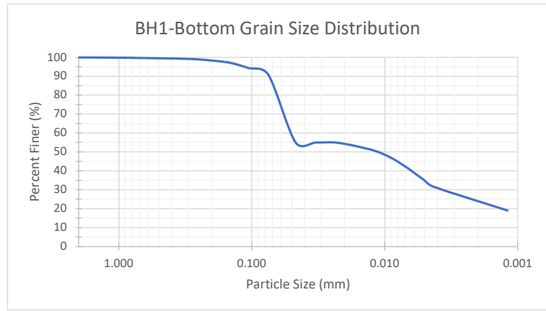
Specific Gravity (G_s): 2.7 % passing No. 4 Sieve= 100 W_{200}/W_0 0.0921539 g

Hydrometer Analysis

Time	Elapsed Time (min)	Temp (°C)	Unit mass, ρ_w (g/cm^3)	Hydrometer Reading, R (g/L)	Temp Correction m	Corrected Reading, R_{corr}	Effective Depth, L (cm)	Constant, K	Particle Diamter, D (mm)	Particle Percent Finer	Total Percent Finer
	0.5	23	0.9975	65	0.655	61.155	6.5	0.01297	0.046764	60.51319	54.894327
	1	23	0.9975	65	0.655	61.155	6.5	0.01297	0.033067	60.51319	54.894327
	2	23	0.9975	65	0.655	61.155	6.5	0.01297	0.023382	60.51319	54.894327
	4	23	0.9975	63	0.655	59.155	6.5	0.01297	0.016534	58.53418	53.099075
	8	23	0.9975	60	0.655	56.155	6.5	0.01297	0.011691	55.56567	50.406196
	15	23	0.9975	56	0.655	52.155	7.1	0.01297	0.008923	51.60765	46.815692
	30	23	0.9975	50	0.655	46.155	8.1	0.01297	0.006739	45.67061	41.429935
	60	23	0.9975	43	0.655	39.155	9.2	0.01297	0.005079	38.74408	35.146552
	90	23	0.9975	39	0.655	35.155	9.9	0.01297	0.004302	34.78606	31.556047
	1440	23	0.9975	25	0.655	21.155	12.2	0.01297	0.001194	20.93298	18.989281

[1] $m = 1000[0.99823 - \rho_w - 0.000025\,(T - 20)]$. where T is water temperature (°C) and ρ_w is water unit mass (g/cm^3) at temperature T.
[2] $R_{corr} = R + m - C_d + C_m$
[3] L obtained from Table 2 of ASTM D422
[4] K obtained from Table 3 of ASTM D422
[5] $D = K\,(L/t)^{1/2}$ where t is elapsed time
[6] $P = (R_{corr}\ a/W_0)$ where a obtained from Table 1 of ASTM D422
[7] Refer to ASTM D422, Section 16 (based on $W_{\#10}/W_O$)

combined particle size (mm)	%passing	Classification
2.000	99.96002	Sand
0.425	99.45027	Silt
0.250	98.87056	Silt
0.150	97.23138	Silt
0.106	94.36282	Silt
0.075	90.71464	Silt
0.046764	54.89433	Silt
0.033067142	54.89433	Silt
0.023382	54.89433	Silt
0.016533571	53.09907	Silt
0.011691	50.4062	Silt
0.008923259	46.81569	Silt
0.00673941	41.42993	Silt
0.005078767	35.14655	Silt
0.004301662	31.55605	Silt
0.001193819	18.98928	Clay



18.98928 % clay
80.46099 % silt
0.509745 % sand

THE UNIVERSITY OF TENNESSEE

Department of Civil and Environmental Engineering

Project Name:	CE 432 Borings	Boring No:	1	Sample No:	middle	Depth:	<1ft
Team Members:	Natalie and Steven					Date:	2/20/2023

Mass of Original Sample (W_0): 110.4 g Mass of 200 Wash residue ($W_{residue}$): 3.96 g ass of W_{200} (W_0-$W_{residue}$): 106.44 g

Mechanical Analysis

Sieve #	Opening (mm)	Sieve Mass (g)	Sieve + Soil Mass (g)	Mass Retained (g)	Cumulative Mass Retained (g)	Cumulative Percent Retained (%)	Cumulative Percent Passing (%)
10	2.000				0	0.000	100.000
40	0.425				0.25	0.226	99.774
60	0.250				0.8	0.725	99.275
100	0.150				1.98	1.793	98.207
140	0.106				2.93	2.654	97.346
200	0.075				4	3.623	96.377

Hydrometer No: 152H Concentration of Dispersing Agent (X_d): 40 g/L Volume of Stock Solution (V_d): 125 mL

Dispersing Agent Correction (Cd = $0.001X_dV_d$) 5 g/L Meniscus Correction (cm) 0.5 g/L

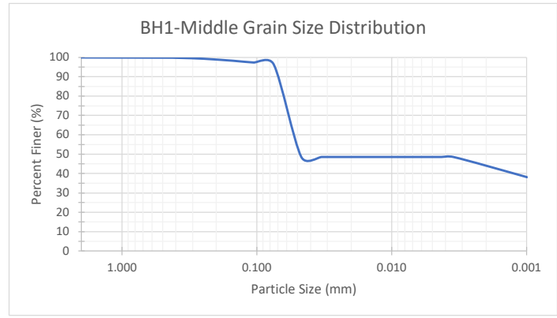
Specific Gravity (G_s): 2.7 % passing No. 4 Sieve= 100 W_{200}/W_0 0.03586957 g

Hydrometer Analysis

Time	Elapsed Time (min)	Temp (°C)	Unit mass, ρ_w (g/cm^3)	Hydrometer Reading, R (g/L)	Temp Correction m	Corrected Reading, R_{corr}	Effective Depth, L (cm)	Constant, K	Particle Diamter, D (mm)	Particle Percent Finer	Total Percent Finer
	0.5	23	0.9975	60	0.655	56.155	6.5	0.01297	0.046764	50.35639	48.5318791
	1	23	0.9975	60	0.655	56.155	6.5	0.01297	0.033067	50.35639	48.5318791
	2	23	0.9975	60	0.655	56.155	6.5	0.01297	0.023382	50.35639	48.5318791
	4	23	0.9975	60	0.655	56.155	6.5	0.01297	0.016534	50.35639	48.5318791
	8	23	0.9975	60	0.655	56.155	6.5	0.01297	0.011691	50.35639	48.5318791
	15	23	0.9975	60	0.655	56.155	6.5	0.01297	0.008538	50.35639	48.5318791
	30	23	0.9975	60	0.655	56.155	6.5	0.01297	0.006037	50.35639	48.5318791
	60	23	0.9975	60	0.655	56.155	6.5	0.01297	0.004269	50.35639	48.5318791
	90	23	0.9975	60	0.655	56.155	6.5	0.01297	0.003486	50.35639	48.5318791
	1440	23	0.9975	48	0.655	44.155	8.4	0.01297	0.000991	39.59552	38.1608961

[1] $m = 1000[0.99823 - \rho_w - 0.000025(T - 20)]$, where T is water temperature (°C) and ρ_w is water unit mass (g/cm^3) at temperature T.
[2] $R_{corr} = R + m - C_d + C_m$
[3] L obtained from Table 2 of ASTM D422
[4] K obtained from Table 3 of ASTM D422
[5] $D = K(L/t)^{1/2}$ where t is elapsed time
[6] $P = (R_{corr}\, a/W_0)$ where a obtained from Table 1 of ASTM D422
[7] Refer to ASTM D422, Section 16 (based on $W_{\#10}/W_O$)

combined particle siz	% passing	Classification
2.000	100	Sand
0.425	99.77355	Silt
0.250	99.27536	Silt
0.150	98.20652	Silt
0.106	97.34601	Silt
0.075	96.37681	Silt
0.046764	48.53188	Silt
0.033067	48.53188	Silt
0.023382	48.53188	Silt
0.016534	48.53188	Silt
0.011691	48.53188	Silt
0.008538	48.53188	Silt
0.006037	48.53188	Silt
0.004269	48.53188	Silt
0.003486	48.53188	Silt
0.000991	38.1609	Clay



38.1609 % clay
61.61265 % silt
0.226449 % sand

THE UNIVERSITY OF TENNESSEE

Department of Civil and Environmental Engineering

Project Name:	CE 432 Borings	Boring No:	1	Sample No:	top	Depth:	<1ft
Team Members:	Natalie and Steven					Date:	2/20/2023

Mass of Original Sample (W_0): 100.19 g Mass of 200 Wash residue ($W_{residue}$): 6.14 g ass of W_{200} (W_0-$W_{residue}$): 94.05 g

Mechanical Analysis

Sieve #	Opening (mm)	Sieve Mass (g)	Sieve + Soil Mass (g)	Mass Retained (g)	Cumulative Mass Retained (g)	Cumulative Percent Retained (%)	Cumulative Percent Passing (%)
10	2.000				0.03	0.030	99.970
40	0.425				0.67	0.669	99.331
60	0.250				1.49	1.487	98.513
100	0.150				3.05	3.044	96.956
140	0.106				4.44	4.432	95.568
200	0.075				3.13	3.124	96.876

Hydrometer No: 152H Concentration of Dispersing Agent (X_d): 40 g/L Volume of Stock Solution (V_d): 125 mL

Dispersing Agent Correction (Cd = $0.001X_dV_d$) 5 g/L Meniscus Correction (cm) 0.5 g/L

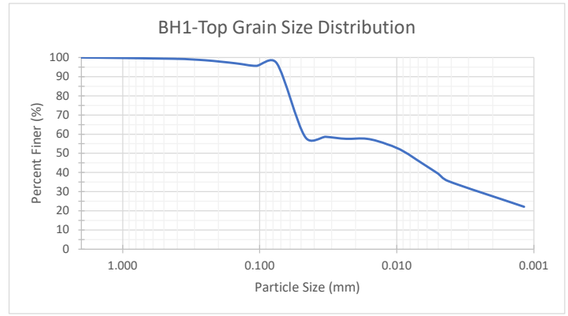
Specific Gravity (G_s): 2.7 % passing No. 4 Sieve= 100 W_{200}/W_0 0.06128356 g

Hydrometer Analysis

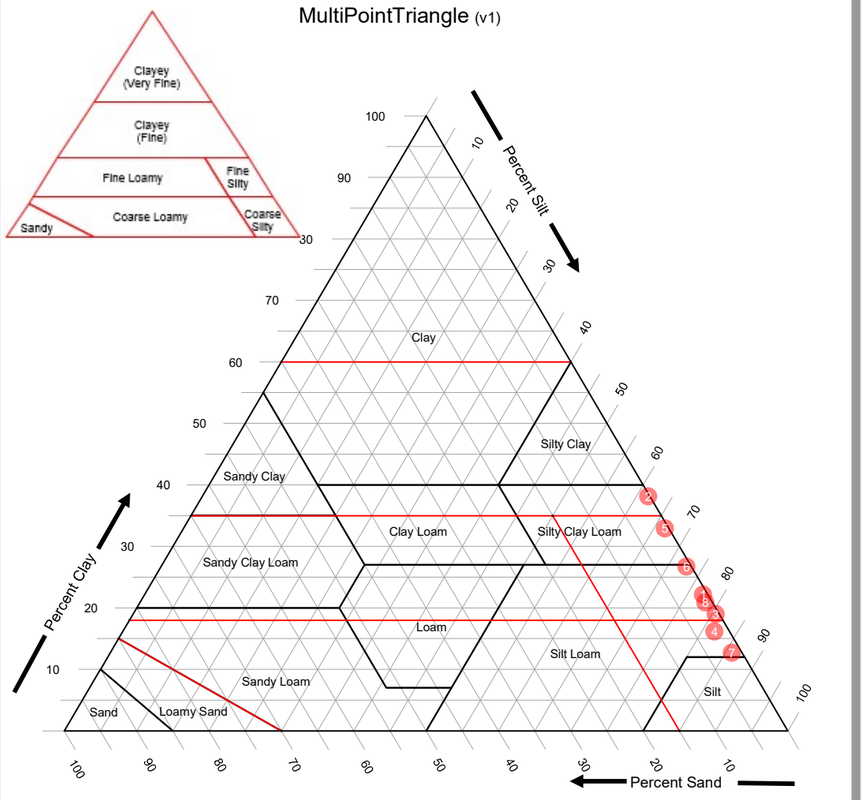
Time	Elapsed Time (min)	Temp (°C)	Unit mass, ρ_w (g/cm^3)	Hydrometer Reading, R (g/L)	Temp Correction m	Corrected Reading, R_{corr}	Effective Depth, L (cm)	Constant, K	Particle Diamter, D (mm)	Particle Percent Finer	Total Percent Finer
	0.5	23	0.9975	65	0.655	61.155	6.5	0.01297	0.046764	60.42864	58.5408062
	1	23	0.9975	65	0.655	61.155	6.5	0.01297	0.033067	60.42864	58.5408062
	2	23	0.9975	64	0.655	60.155	6.5	0.01297	0.023382	59.44051	57.5835532
	4	23	0.9975	64	0.655	60.155	6.5	0.01297	0.016534	59.44051	57.5835532
	8	23	0.9975	61	0.655	57.155	6.5	0.01297	0.011691	56.47615	54.7117942
	15	23	0.9975	57	0.655	53.155	7	0.01297	0.008860	52.52366	50.8827823
	30	23	0.9975	51	0.655	47.155	7.9	0.01297	0.006656	46.59492	45.1392644
	60	23	0.9975	45	0.655	41.155	8.9	0.01297	0.004995	40.66618	39.3957465
	90	23	0.9975	41	0.655	37.155	9.6	0.01297	0.004236	36.71369	35.5667346
	1440	23	0.9975	27	0.655	23.155	11.9	0.01297	0.001179	22.87998	22.1651928

[1] $m = 1000[0.99823 - \rho_w - 0.000025(T-20)]$, where T is water temperature (°C) and ρ_w is water unit mass (g/cm^3) at temperature T.
[2] $R_{corr} = R + m - C_d + C_m$
[3] L obtained from Table 2 of ASTM D422
[4] K obtained from Table 3 of ASTM D422
[5] $D = K(L/t)^{1/2}$ where t is elapsed time
[6] $P = (R_{corr}\, a/W_0)$ where a obtained from Table 1 of ASTM D422
[7] Refer to ASTM D422, Section 16 (based on $W_{\#10}/W_O$)

combined particle siz	% passing	Classification
2.000	99.97006	Sand
0.425	99.33127	Silt
0.250	98.51283	Silt
0.150	96.95578	Silt
0.106	95.56842	Silt
0.075	96.87594	Silt
0.046764	58.54081	Silt
0.033067	58.54081	Silt
0.023382	57.58355	Silt
0.016534	57.58355	Silt
0.011691	54.71179	Silt
0.00886	50.88278	Silt
0.006656	45.13926	Silt
0.004995	39.39575	Silt
0.004236	35.56673	Silt
0.001179	22.16519	Clay



22.16519 % clay
77.16608 % silt
0.638786 % sand



Send comments or suggestions to mark.vanlear@usda.gov

Instructions: Populate yellow cells. Total Sand, Silt, and Clay must equal 100%. Sand fractions are optional (only used with sands, loamy sands, and sandy loams if known), but if used must equal Total Sand.

Total	Sand (%)	
	Clay (%)	
	Silt (%)	100.00%

Sand Fractions	Very Coarse Sand (%)	
	Coarse Sand (%)	
	Medium Sand (%)	
	Fine Sand (%)	
	Very Fine Sand (%)	
	Sand Fractions Sum	0.00%

USDA Texture: SILT

Save/Plot | Clear | Clear All

Point	Sand	Clay	Silt	VCS	CS	MS	FS	VFS	X	Y	Texture
1	0.64%	22.17%	77.19%						0.88275	0.192	SILT LOAM
2	0.23%	38.16%	61.61%						0.8069	0.33048	SILTY CLAY LOAM
3	0.51%	18.99%	80.50%						0.89995	0.16446	SILT LOAM
4	2.07%	16.16%	81.77%						0.8985	0.13995	SILT LOAM
5	0.56%	32.92%	66.52%						0.8298	0.2851	SILTY CLAY LOAM
6	0.64%	26.74%	72.62%						0.8599	0.23158	SILT LOAM
7	1.38%	12.72%	85.90%						0.9226	0.11016	SILT LOAM
8	0.98%	20.89%	78.13%						0.88575	0.18091	SILT LOAM

Beaufort Scale

Portland, OR
Weather Forecast Office

Estimating Wind Speed and Sea State

[Also, see estimating wind while on land] [Printable Version .pdf]

Estimating Wind Speed and Sea State with Visual Clues

Beaufort number	Wind Description	Wind Speed	Wave Height	Visual Clues
0	Calm	0 knots	0 feet	Sea is like a mirror. Smoke rises vertically.
1	Light Air	1-3 kts	< 1/2	Ripples with the appearance of scales are formed, but without foam crests. Smoke drifts from funnel.
2	Light breeze	4-6 kts	1/2 ft (max 1)	Small wavelets, still short but more pronounced, crests have glassy appearance and do not break. Wind felt on face. Smoke rises at about 80 degrees.
3	Gentle Breeze	7-10 kts	2 ft (max 3)	Large wavelets, crests begin to break. Foam of glassy appearance. Perhaps scattered white horses (white caps). Wind extends light flag and pennants. Smoke rises at about 70 deg.
4	Moderate Breeze	11-16 kts	3 ft (max 5)	Small waves, becoming longer. Fairly frequent white horses (white caps). Wind raises dust and loose paper on deck. Smoke rises at about 50 deg. No noticeable sound in the rigging. Slack halyards curve and sway. Heavy flag flaps limply.
5	Fresh Breeze	17-21kts	6 ft (max 8)	Moderate waves, taking more pronounced long form. Many white horses (white caps) are formed (chance of some spray). Wind felt strongly on face. Smoke rises at about 30 deg. Slack halyards whip while bending continuously to leeward. Taut halyards maintain slightly bent position. Low whistle in the rigging. Heavy flag doesn't extended but flaps over entire length.
6	Strong Breeze	22-27 kts	9 ft (max 12)	Large waves begin to form. White foam crests are more extensive everywhere (probably some spray). Wind stings face in temperatures below 35 deg F (2C). Slight effort in maintaining balance against wind. Smoke rises at about 15 deg. Both slack and taut halyards whip slightly in bent position. Low moaning, rather than whistle, in the rigging. Heavy flag extends and flaps more vigorously.
7	Near Gale	28-33 kts	13 ft (max 19)	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of wind. Necessary to lean slightly into the wind to maintain balance. Smoke rises at about 5 to 10 deg. Higher pitched moaning and whistling heard from rigging. Halyards still whip slightly. Heavy flag extends fully and flaps only at the end. Oilskins and loose clothing inflate and pull against the body.
8	Gale	34-40 kts	18 ft (max 25)	Moderately high waves of greater length. Edges of crests begin to break into the spindrift. The foam is blown in well-marked streaks along the direction of the wind. Head pushed back by the force of the wind if allowed to relax. Oilskins and loose clothing inflate and pull strongly. Halyards rigidly bent. Loud whistle from rigging. Heavy flag straight out and whipping.
9	Strong Gale	41-47 kts	23 ft (max 32)	High waves. Dense streaks of foam along direction of wind. Crests of waves begin to topple, tumble and roll over. Spray may affect visibility.
10	Storm	48-55 kts	29 ft (max 41)	Very high waves with long overhanging crests. The resulting foam, in great patches is blown in dense streaks along the direction of the wind. On the whole, the sea takes on a whitish appearance. Tumbling of the sea becomes heavy and shock-like. Visibility affected.
11	Violent Storm	56-63 kts	37 ft (max 52)	Exceptionally high waves (small and medium-sized ships might be for time lost to view behind the waves). The sea is completely covered with long white patches of foam lying along the direction of the wind. Everywhere, the edges of the wave crests are blown into froth. Visibility greatly affected.
12	Hurricane	64+ kts	45+ ft	The air is filled with foam and spray. The sea is completely white with driving spray. Visibility is seriously affected.

Weight and Size

The weight and size of individual riprap pieces are essential factors in resisting erosive water forces. The weight of the rock fragment is one design element for riprap but is difficult to obtain in the field for the larger sizes. The relationship between weight and size is approximately:

$$W_n = 0.75\ \gamma D_n^3$$

where: W_n - Percentage of total weight of rock where n percent is smaller
γ - Unit weight of rock
D_n - Representative diameter of rock where n percent is smaller

This formula assumes the shape of the rock fragment is between a sphere and a cube. The weight and size may be determined in the laboratory or in the field. The unit weight of riprap generally varies from 150 to 175 pounds per cubic foot (2.4 to 2.8 g/cm^3) and correlates with surface saturated dry specific gravity (SSSG). Rock having an SSSG above 2.6 is typically suitable for riprap.

Determination of the relationship between weight and size is difficult. Rock is either graded by size or counted and weighed, but rarely are weight and size correlated. Rarely does rock break into perfect cubical shapes; and because of the various shapes and sizes, weighing and sorting the individual pieces is difficult. The American Society for Testing and Materials Procedure D-5519 provides three methods for obtaining size and weight data.

Typically, for sizes up to 36 inches (1 meter) minimum diameter, rock pieces are sorted by size with a sieve or template, and the number of individual pieces is counted

A.12 Armor Weight Calculations

2-16. Armor Unit Stability

a. The most widely used measure of armor unit stability is that developed by Hudson (1961) which is given in Equation 2-15:

$$W = \frac{\gamma_r H^3}{K_D \left(\frac{\gamma_r}{\gamma_w} - 1\right)^3 \cot \theta} \qquad (2\text{-}15)$$

where

W = required individual armor unit weight, lb (or W_{50} for graded riprap)

γ_r = specific weight of the armor unit, lb/ft^3

H = monochromatic wave height

K_D = stability coefficient given in Table 2-3

γ_w = specific weight of water at the site (salt or fresh)

θ = is structure slope (from the horizontal)

gamma r	150	175
H	2	
KD	1.2	
gamma w	62.4	
cot theta	1.5	3

W (150, 1.5)	240.9629056	Design Weight of armor
W (150, 3.0)	120.4814528	
W (175, 1.5)	132.3713896	
W (175, 3.0)	66.18569481	

Table 2-3
Suggested Values for Use In Determining Armor Weight (Breaking Wave Conditions)

Armor Unit	n[1]	Placement	Slope (cot θ)	K_D
Quarrystone				
Smooth rounded	2	Random	1.5 to 3.0	1.2
Smooth rounded	>3	Random	1.5 to 3.0	1.6
Rough angular	1	Random	1.5 to 3.0	Do Not Use
Rough angular	2	Random	1.5 to 3.0	2.0
Rough angular	>3	Random	1.5 to 3.0	2.2
Rough angular	2	Special[6]	1.5 to 3.0	7.0 to 20.0
Graded riprap[3]	2[4]	Random	2.0 to 6.0	2.2
Concrete Armor Units				
Tetrapod	2	Random	1.5 to 3.0	7.0
Tripod	2	Random	1.5 to 3.0	9.0
Tripod	1	Uniform	1.5 to 3.0	12.0
Dolos	2	Random	2.0 to 3.0[5]	15.0[6]

A.12 Armor Weight Calculations - Dimensions

dimenstions are per linear foot around shoreline — need 2:1 for rock stability

	height	distance from bank toe	round up	2:1 slope	weight from 2:1 slope
profile 1	1	1.6067	1.6	2	300
profile 2	2	0.8033	1	4	1200
profile 3	4	0.4017	0.5	8	4800
profile 4	1	1.6067	1.6	2	300

exceeds minimum required weight of rock armor

unit weight of rip rap	150	pcf
required weight of rock armor	241	p

equation 241 pounds * (1ft cubed / 150p) * (1/ linear foot times height)

LDA ENGINEERING

Transmittal

110 Tyson Boulevard, Alcoa, TN 37701

PROJECT:	STEM STEM	DATE:	3/7/2023
SUBJECT:	UTK Senior Design_Wheeler Rd UAV	TRANSMITTAL ID:	00003
PURPOSE:	For your use and distribution	VIA:	Info Exchange

FROM

NAME	COMPANY	EMAIL	PHONE
James Albert Jr 110 Tyson Boulevard Alcoa TN 37701 United States	LDA Engineering	jcalbert@ldaengineering.com	865-573-7672

TO

NAME	COMPANY	EMAIL	PHONE
stremayn@vols.utk.edu		stremayn@vols.utk.edu	

REMARKS:

Steven,

Please see the attached folder containing the point cloud data for the Wheeler Rd UAV flight.

Thanks,

Jimmy Albert, E.I.

LDA Engineering | STRONGER. HAPPIER. COMMUNITIES.

Direct: (865) 306-5069 | Mobile: (865) 548-0474

www.ldaengineering.com | jcalbert@ldaengineering.com

DESCRIPTION OF CONTENTS

QTY	DATED	TITLE	NOTES
1	3/7/2023	WHEELER RD SENIOR DESIGN PROJ (2)	

COPIES:

James Albert Jr (LDA Engineering)

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

1) Select **EITHER** Option A or Option B for Bank Profile and enter the data in the relevant box- cells in the alternative option are ignored in the simulation and may be left blank if desired.
2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).
3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.

To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below

◉ Option A

Point	Station (m)	Elevation (m)	Top of toe?
A	0.00	1.00	
B	1.00	1.00	
C	1.11	0.99	☐
D	1.23	0.98	☐
E	1.34	0.97	☐
F	1.46	0.96	☐
G	1.57	0.95	☐
H	1.68	0.94	☐
I	1.80	0.93	☐
J	1.91	0.92	☐
K	2.03	0.91	☐
L	2.14	0.90	☐
M	2.25	0.89	☐
N	2.37	0.88	☐
O	2.48	0.87	☐
P	2.60	0.85	☐
Q	2.60	0.55	☑
R	3.03	0.49	
S	3.46	0.43	
T	3.88	0.37	
U	4.31	0.30	
V	4.74	0.24	
W	6.16	0.19	

Shear emergence elev: 0.55

Shear surface angle: 35.00

Option B - Enter a bank height and angle, the model will generate a bank profile

○ Option B

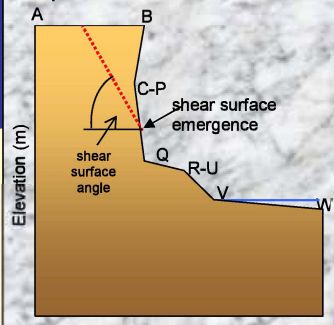
- a) Input bank height (m)
- b) Input bank angle (°)
- c) Input bank toe length (m)
- d) Input bank toe angle (°)
- Input shear surface angle

Bank layer thickness (m)

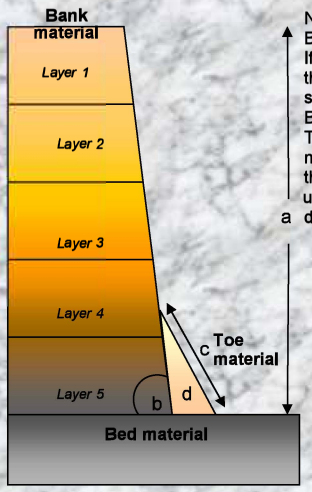
		Elevation of layer base (m)
	Top Layer	
Layer 1	0.00	1.00
Layer 2	0.00	1.00
Layer 3	0.00	1.00
Layer 4	0.00	1.00
Layer 5	1.00	0.00
	Bottom Layer	

Parallel layers, starting from point B

Definition of points used in bank profile



A - bank top: place beyond start of shear surface
B - bank edge
C-P - breaks of slope on bank (if no breaks of slope place as intermediary points)
Q - top of bank toe
R-U - breaks of slope on bank toe (if no breaks of slope then insert as intermediary points)
V - base of bank toe
W - end point (typically mid point of channel)



Notes:
Bank profile may overhang.
If the bank profile is fully populated, the shear surface emergence point should be anywhere between points B and Q.
The shear surface emergence point must not be on a horizontal section - the elevation of this point must be unique or an error message will display.

Channel and flow parameters

18.3	Input reach length (m)
0.0005	Input reach slope (m/m)
0.55	Input elevation of flow (m)
4380	Input duration of flow (hrs)

View Bank Geometry

Run Bank Geometry Macro

Select material types (or select "own data" and add values below)

Bank Material					Bank Toe Material
Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
Own data	Own data	Own data	Own data	Own data	Own data

Bank and bank-toe material data tables.

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white boxes.

Material Descriptors			Bank Model Input Data					Groundwater Model Input Data						Toe Model Input Data	
Bank material type	*Description*	*Mean grain size, D_{50} (m)*	*Friction angle ϕ' (degrees)*	*Cohesion c' (kPa)*	*Saturated unit weight (kN/m^3)*	*ϕ^b (degrees)*	*Chemical concentration (kg/kg)*	*Hydraulic Conductivity k_{sat} (m/s)*	*Bulk Modulus (Pa)*	*Porosity*	*Residual water content*	*van Genuchten α (1/m)*	*van Genuchten n*	τ_c (Pa)	*k* (cm^3/Ns)
1	Boulders	0.512	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	498	0.004
2	Cobbles	0.128	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	124	0.009
3	Gravel	0.0113	36.0	0.0	20.0	15.0	-	3.160E-03	1.354E+08	0.320	0.070	3.5237	2.3286	11.0	0.030
4a and 4b	Angular sand	0.00035	32.3	0.4	18.5	15.0	-	7.439E-05	1.354E+07	0.375	0.053	3.5237	3.1769	Coarse (0.71 mm) or	
5a and 5b	Rounded sand	0.00035	28.3	0.4	18.5	15.0	-	1.130E-06	6.056E+07	0.380	0.133	2.0563	2.3286	Fine (0.18 mm)	
6a, 6b and 6c	Silt	-	26.6	4.3	18.0	15.0	-	5.064E-06	1.049E+07	0.489	0.050	0.6577	1.6788	Erodible (0.100 Pa),	
7a, 7b and 7c	Soft clay	-	26.4	8.2	17.7	15.0	-	9.473E-07	1.354E+06	0.472	0.079	1.5812	1.4158	Moderate (5.00 Pa), or	
8a, 8b and 8c	Stiff clay	-	21.1	12.6	17.7	15.0	-	1.708E-06	5.417E+06	0.459	0.093	1.4962	1.2531	Resistant (50.0 Pa)	
	Own data layer 1		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 2		25.0	10.0	18.0	15.0	0.0							0.72	0.236
9	Own data layer 3		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 4		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 5			10.0	18.0	15.0	0.0							0.72	0.236
	Own data Bank Toe													0.72	0.118

COMING SOON!

Need to know the critical shear stress (τ_c) ?		Need to know the erodibility coefficient (*k*) ?	
Input non-cohesive particle diameter (mm)	0.075	Input critical shear stress τ_c (Pa)	0.721
Critical Shear Stress τ_c (Pa)	0.05	Erodibility Coefficient (cm^3/Ns)	0.118

Simulate the mechanical effects of *bank top* vegetation on bank stability using a root-reinforcement model

RipRoot (Pollen and Simon, 2005) is a global load-sharing fiber-bundle model. It explicitly simulates both the snapping of roots and the slipping of roots through the soil matrix, by determining the minimum applied load required to either break each root or pull each root out of the soil matrix. As the strength of each root is removed from the fiber bundle, the load is redistributed to the remaining roots according to the ratio of the diameter of each root to the sum of the diameters of all the intact roots. RipRoot builds on earlier work by Waldron (1977), Wu *et al*. (1979) and Waldron and Dakessian (1981).

Run Root-Reinforcement Model

Root-Reinforcement Model Output

List of Species
Percent of Assemblage

Added cohesion due to roots, c_r [ ] **kPa**

Protect the bank and/or bank-toe against *hydraulic erosion* by adding treatments (or select "own data" and add values below)

Protection

Bank Protection	Bank Toe Protection
No protection	No protection

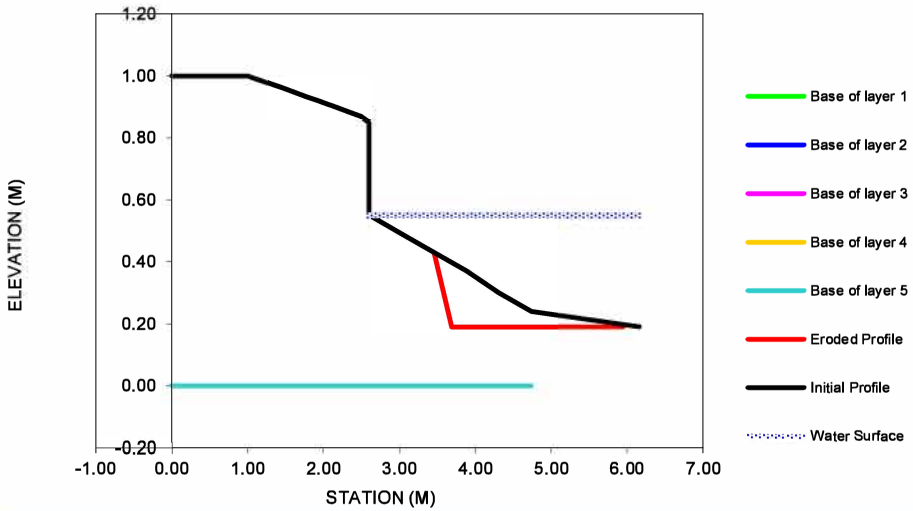
Bank and bank-toe protection data table

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white box.

Bank and Bank-Toe Protection Descriptors

Protection type	*Description*	*Permissible shear stress (Pa)*
1	No protection	-
2	Coir fiber	108
3	Geotextile (synthetic)	144
4	Jute net	22
5	Large Woody Debris	192
6	Live fascine	100
7	Plant cuttings	17
8	Rip Rap (D_{50} 0.256 m)	204
9	-	
10	-	
11	-	
12	-	
13	Own Data	

Bank Material					Bank Toe Material	
Layer 1	Layer 2	Layer 3	Layer 4	Layer 5		
Own data	Own data	Own data	Own data	Own data	Own data	**Material**
0.72	0.72	0.72	0.72	0.72	0.72	**Critical shear stress (Pa)**
0.236	0.236	0.236	0.236	0.236	0.118	**Erodibility Coefficient (cm^3/Ns)**



Run Toe-Erosion Model

Account for:

Stream Curvature ☐

Effective stress acting on each grain ☐

Average applied boundary shear stress	0.730	Pa
Maximum Lateral Retreat	38.211	cm
Eroded Area - Bank	0.000	m^2
Eroded Area - Bank Toe	0.153	m^2
Eroded Area - Bed	0.041	m^2
Eroded Area - Total	0.194	m^2

Export New (Eroded) Profile into Model

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

1) Select **EITHER** Option A or Option B for Bank Profile and enter the data in the relevant box- cells in the alternative option are ignored in the simulation and may be left blank if desired.
2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).
3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.

To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below

◉ Option A

Point	Station (m)	Elevation (m)	Top of toe?
A	0.00	1.00	
B	1.00	1.00	
C	1.11	0.99	☐
D	1.23	0.98	☐
E	1.34	0.97	☐
F	1.46	0.96	☐
G	1.57	0.95	☐
H	1.68	0.94	☐
I	1.80	0.93	☐
J	1.91	0.92	☐
K	2.03	0.91	☐
L	2.14	0.90	☐
M	2.25	0.89	☐
N	2.37	0.88	☐
O	2.48	0.87	☐
P	2.60	0.85	☐
Q	2.60	0.55	☑
R	3.03	0.49	
S	3.46	0.43	
T	3.88	0.37	
U	4.31	0.30	
V	4.74	0.24	
W	6.16	0.19	

Shear emergence elev: 0.55

Shear surface angle: 35.00

Option B - Enter a bank height and angle, the model will generate a bank profile

○ Option B

- a) Input bank height (m)
- b) Input bank angle (°)
- c) Input bank toe length (m)
- d) Input bank toe angle (°)
- Input shear surface angle

Bank layer thickness (m)

	Elevation of layer base (m)	
	Top Layer	
Layer 1	0.00	1.00
Layer 2	0.00	1.00
Layer 3	0.00	1.00
Layer 4	0.00	1.00
Layer 5	1.00	0.00
	Bottom Layer	

Parallel layers, starting from point B

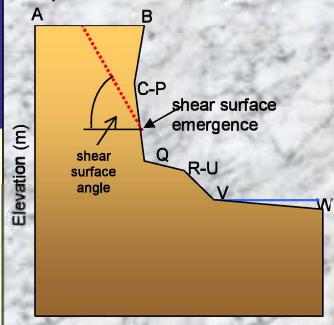
Channel and flow parameters

18.3	Input reach length (m)
0.0005	Input reach slope (m/m)
0.24	Input elevation of flow (m)
4380	Input duration of flow (hrs)

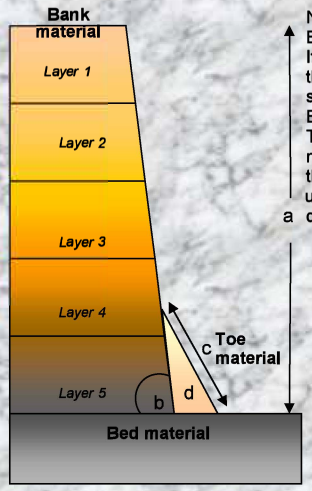
View Bank Geometry

Run Bank Geometry Macro

Definition of points used in bank profile



A - bank top: place beyond start of shear surface
B - bank edge
C-P - breaks of slope on bank (if no breaks of slope place as intermediary points)
Q - top of bank toe
R-U - breaks of slope on bank toe (if no breaks of slope then insert as intermediary points)
V - base of bank toe
W - end point (typically mid point of channel)



Notes:
Bank profile may overhang.
If the bank profile is fully populated, the shear surface emergence point should be anywhere between points B and Q.
The shear surface emergence point must not be on a horizontal section - the elevation of this point must be unique or an error message will display.

Select material types (or select "own data" and add values below)

Bank Material

Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	**Bank Toe Material**
Own data	Own data	Own data	Own data	Own data	Own data

Bank and bank-toe material data tables.

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white boxes.

Material Descriptors			**Bank Model Input Data**					**Groundwater Model Input Data**						**Toe Model Input Data**	
Bank material type	*Description*	*Mean grain size, D_{50} (m)*	*Friction angle ϕ' (degrees)*	*Cohesion c' (kPa)*	*Saturated unit weight (kN/m^3)*	*ϕ^b (degrees)*	*Chemical concentration (kg/kg)*	*Hydraulic Conductivity k_{sat} (m/s)*	*Bulk Modulus (Pa)*	*Porosity*	*Residual water content*	*van Genuchten α (1/m)*	*van Genuchten n*	τ_c (Pa)	*k* (cm^3/Ns)
1	Boulders	0.512	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	498	0.004
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3	Gravel	0.0113	36.0	0.0	20.0	15.0	-	3.160E-03	1.354E+08	0.320	0.070	3.5237	2.3286	11.0	0.030
4a and 4b	Angular sand	0.00035	32.3	0.4	18.5	15.0	-	7.439E-05	1.354E+07	0.375	0.053	3.5237	3.1769	Coarse (0.71 mm) or	
5a and 5b	Rounded sand	0.00035	28.3	0.4	18.5	15.0	-	1.130E-06	6.056E+07	0.380	0.033	2.0563	2.3286	Fine (0.18 mm)	
6a, 6b and 6c	Silt	-	26.6	4.3	18.0	15.0	-	5.064E-06	1.049E+07	0.489	0.050	0.6577	1.6788	Erodible (0.100 Pa),	
7a, 7b and 7c	Soft clay	-	26.4	8.2	17.7	15.0	-	9.473E-07	1.354E+06	0.542	0.079	1.5812	1.4158	Moderate (5.00 Pa), or	
8a, 8b and 8c	Stiff clay	-	21.1	12.6	17.7	15.0	-	1.708E-06	5.417E+06	0.459	0.093	1.4962	1.2531	Resistant (50.0 Pa)	
	Own data layer 1		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 2		25.0	10.0	18.0	15.0	0.0							0.72	0.236
9	Own data layer 3		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 4		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 5			10.0	18.0	15.0	0.0							0.72	0.236
	Own data Bank Toe													0.72	0.118

COMING SOON!

Need to know the critical shear stress (τ_c) ?		**Need to know the erodibility coefficient (k) ?**	
Input non-cohesive particle diameter (mm)	0.075	Input critical shear stress τ_c (Pa)	0.721
Critical Shear Stress τ_c (Pa)	0.05	Erodibility Coefficient (cm^3/Ns)	0.118

Simulate the mechanical effects of *bank top* vegetation on bank stability using a root-reinforcement model

RipRoot (Pollen and Simon, 2005) is a global load-sharing fiber-bundle model. It explicitly simulates both the snapping of roots and the slipping of roots through the soil matrix, by determining the minimum applied load required to either break each root or pull each root out of the soil matrix. As the strength of each root is removed from the fiber bundle, the load is redistributed to the remaining roots according to the ratio of the diameter of each root to the sum of the diameters of all the intact roots. RipRoot builds on earlier work by Waldron (1977), Wu *et al*. (1979) and Waldron and Dakessian (1981).

Run Root-Reinforcement Model

Root-Reinforcement Model Output

List of Species Bare Soil/ No vegetation;
Percent of Assemblage 100;

Added cohesion due to roots, c_r 0.0 kPa

Protect the bank and/or bank-toe against *hydraulic erosion* by adding treatments (or select "own data" and add values below)

Protection

Bank Protection	Bank Toe Protection
No protection	No protection

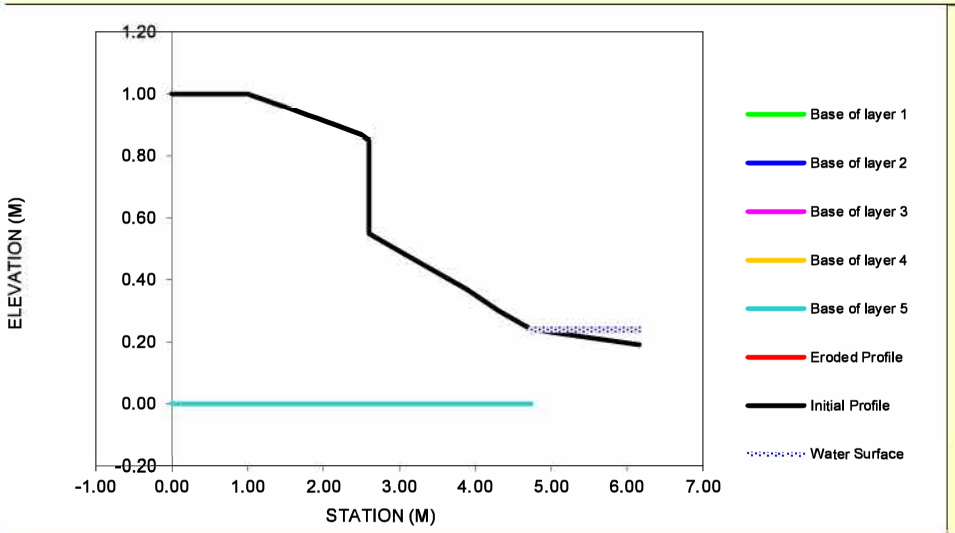
Bank and bank-toe protection data table

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white box.

Bank and Bank-Toe Protection Descriptors

Protection type	*Description*	*Permissible shear stress (Pa)*
1	No protection	-
2	Coir fiber	108
3	Geotextile (synthetic)	144
4	Jute net	22
5	Large Woody Debris	192
6	Live fascine	100
7	Plant cuttings	17
8	Rip Rap (D_{50} 0.256 m)	204
9	-	
10	-	
11	-	
12	-	
13	Own Data	

	Bank Material					Bank Toe Material	
	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5		
Material	Own data	Own data	Own data	Own data	Own data	Own data	
Critical shear stress (Pa)	0.72	0.72	0.72	0.72	0.72	0.72	
Erodibility Coefficient (cm^3/Ns)	0.236	0.236	0.236	0.236	0.236	0.118	



Run Toe-Erosion Model

Account for:

Stream Curvature ☐

Effective stress acting on each grain ☐

Average applied boundary shear stress	0.060	Pa
Maximum Lateral Retreat	0.000	cm
Eroded Area - Bank	0.000	m^2
Eroded Area - Bank Toe	0.000	m^2
Eroded Area - Bed	0.000	m^2
Eroded Area - Total	0.000	m^2

Export New (Eroded) Profile into Model

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

1) Select **EITHER** Option A or Option B for Bank Profile and enter the data in the relevant box- cells in the alternative option are ignored in the simulation and may be left blank if desired.
2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).
3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.

To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below

◉ Option A

Point	Station (m)	Elevation (m)	Top of toe?
A	0.00	1.03	
B	0.92	1.03	
C	0.92	0.99	☐
D	0.92	0.95	☐
E	0.92	0.91	☐
F	0.92	0.87	☐
G	0.92	0.83	☐
H	0.92	0.79	☐
I	0.92	0.75	☐
J	0.92	0.71	☐
K	0.92	0.66	☐
L	0.92	0.62	☐
M	0.92	0.58	☐
N	0.92	0.54	☐
O	0.92	0.50	☐
P	0.92	0.46	☐
Q	0.92	0.42	☑
R	1.29	0.36	
S	1.65	0.30	
T	2.02	0.24	
U	2.38	0.18	
V	2.75	0.12	
W	5.16	0.00	

Shear emergence elev: 0.42

Shear surface angle: 35.00

Option B - Enter a bank height and angle, the model will generate a bank profile

○ Option B

- a) Input bank height (m)
- b) Input bank angle (°)
- c) Input bank toe length (m)
- d) Input bank toe angle (°)

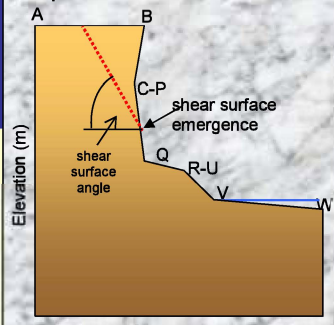
Input shear surface angle

Bank layer thickness (m)

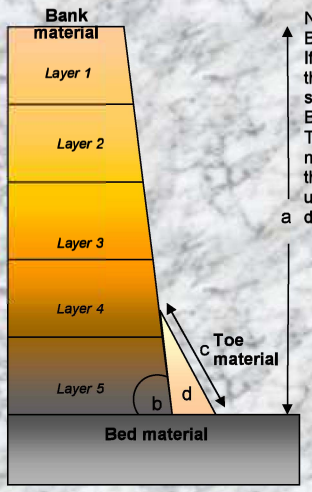
		Elevation of layer base (m)
	Top Layer	
Layer 1	0.00	1.03
Layer 2	0.00	1.03
Layer 3	0.00	1.03
Layer 4	0.00	1.03
Layer 5	1.03	0.00
	Bottom Layer	

Parallel layers, starting from point B

Definition of points used in bank profile



A - bank top: place beyond start of shear surface
B - bank edge
C-P - breaks of slope on bank (if no breaks of slope place as intermediary points)
Q - top of bank toe
R-U - breaks of slope on bank toe (if no breaks of slope then insert as intermediary points)
V - base of bank toe
W - end point (typically mid point of channel)



Notes:
Bank profile may overhang.
If the bank profile is fully populated, the shear surface emergence point should be anywhere between points B and Q.
The shear surface emergence point must not be on a horizontal section - the elevation of this point must be unique or an error message will display.

Channel and flow parameters

14.178	Input reach length (m)
0.0005	Input reach slope (m/m)
0.42	Input elevation of flow (m)
4380	Input duration of flow (hrs)

View Bank Geometry

Run Bank Geometry Macro

Select material types (or select "own data" and add values below)

Bank Material					Bank Toe Material
Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
Own data	Own data	Own data	Own data	Own data	Own data

Bank and bank-toe material data tables.

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white boxes.

Material Descriptors			Bank Model Input Data					Groundwater Model Input Data						Toe Model Input Data	
Bank material type	*Description*	*Mean grain size, D_{50} (m)*	*Friction angle ϕ' (degrees)*	*Cohesion c' (kPa)*	*Saturated unit weight (kN/m^3)*	*ϕ^b (degrees)*	*Chemical concentration (kg/kg)*	*Hydraulic Conductivity k_{sat} (m/s)*	*Bulk Modulus (Pa)*	*Porosity*	*Residual water content*	*van Genuchten α (1/m)*	*van Genuchten n*	τ_c (Pa)	*k* (cm^3/Ns)
1	Boulders	0.512	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	498	0.004
2	Cobbles	0.128	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	124	0.009
3	Gravel	0.0113	36.0	0.0	20.0	15.0	-	3.160E-03	1.354E+08	0.320	0.070	3.5237	2.3286	11.0	0.030
4a and 4b	Angular sand	0.00035	32.3	0.4	18.5	15.0	-	7.439E-05	1.354E+07	0.375	0.053	3.5237	3.1769	Coarse (0.71 mm) or	
5a and 5b	Rounded sand	0.00035	28.3	0.4	18.5	15.0	-	1.130E-06	6.056E+07	0.380	0.033	2.0563	2.3286	Fine (0.18 mm)	
6a, 6b and 6c	Silt	-	26.6	4.3	18.0	15.0	-	5.064E-06	1.049E+07	0.489	0.050	0.6577	1.6788	Erodible (0.100 Pa),	
7a, 7b and 7c	Soft clay	-	26.4	8.2	17.7	15.0	-	9.473E-07	1.354E+06	0.472	0.079	1.5812	1.4158	Moderate (5.00 Pa), or	
8a, 8b and 8c	Stiff clay	-	21.1	12.6	17.7	15.0	-	1.708E-06	5.417E+06	0.459	0.093	1.4962	1.2531	Resistant (50.0 Pa)	
	Own data layer 1		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 2		25.0	10.0	18.0	15.0	0.0							0.72	0.236
9	Own data layer 3		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 4		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 5			10.0	18.0	15.0	0.0							0.72	0.236
	Own data Bank Toe													0.72	0.118

COMING SOON!

Need to know the critical shear stress (τ_c) ?		Need to know the erodibility coefficient (*k*) ?	
Input non-cohesive particle diameter (mm)	0.075	Input critical shear stress τ_c (Pa)	0.721
Critical Shear Stress τ_c (Pa)	0.05	Erodibility Coefficient (cm^3/Ns)	0.118

Simulate the mechanical effects of *bank top* vegetation on bank stability using a root-reinforcement model

RipRoot (Pollen and Simon, 2005) is a global load-sharing fiber-bundle model. It explicitly simulates both the snapping of roots and the slipping of roots through the soil matrix, by determining the minimum applied load required to either break each root or pull each root out of the soil matrix. As the strength of each root is removed from the fiber bundle, the load is redistributed to the remaining roots according to the ratio of the diameter of each root to the sum of the diameters of all the intact roots. RipRoot builds on earlier work by Waldron (1977), Wu *et al*. (1979) and Waldron and Dakessian (1981).

Run Root-Reinforcement Model

Root-Reinforcement Model Output

List of Species Bare Soil/ No vegetation;
Percent of Assemblage 100;

Added cohesion due to roots, c_r 0.0 kPa

Protect the bank and/or bank-toe against *hydraulic erosion* by adding treatments (or select "own data" and add values below)

Protection

Bank Protection	Bank Toe Protection
No protection	No protection

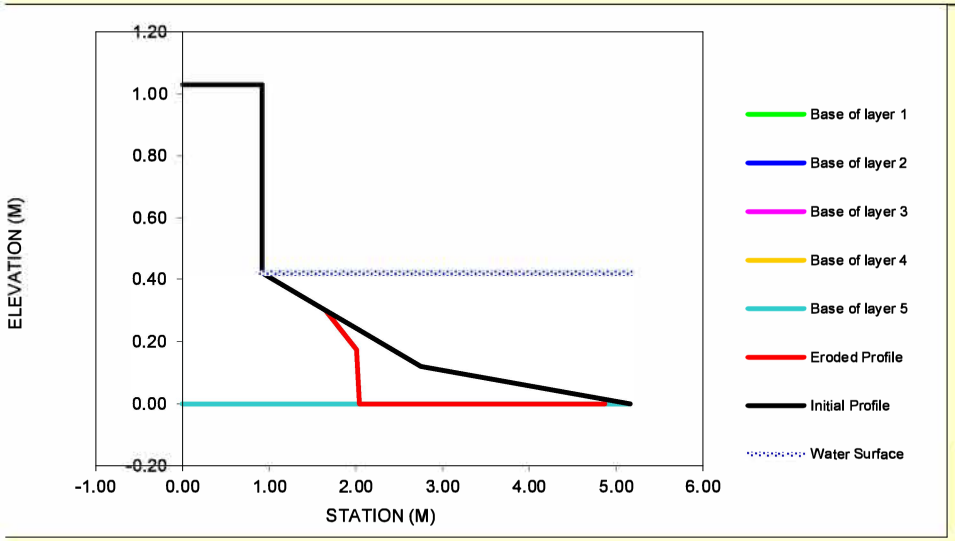
Bank and bank-toe protection data table

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white box.

Bank and Bank-Toe Protection Descriptors

Protection type	*Description*	*Permissible shear stress (Pa)*
1	No protection	-
2	Coir fiber	108
3	Geotextile (synthetic)	144
4	Jute net	22
5	Large Woody Debris	192
6	Live fascine	100
7	Plant cuttings	17
8	Rip Rap (D_{50} 0.256 m)	204
9	-	
10	-	
11	-	
12	-	
13	Own Data	

	Bank Material					Bank Toe Material	
	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5		
Material	Own data	Own data	Own data	Own data	Own data	Own data	
Critical shear stress (Pa)	0.72	0.72	0.72	0.72	0.72	0.72	
Erodibility Coefficient (cm^3/Ns)	0.236	0.236	0.236	0.236	0.236	0.118	



Run Toe-Erosion Model

Account for:

Stream Curvature ☐

Effective stress acting on each grain ☐

Average applied boundary shear stress	0.700	Pa
Maximum Lateral Retreat	34.082	cm
Eroded Area - Bank	0.000	m^2
Eroded Area - Bank Toe	0.129	m^2
Eroded Area - Bed	0.159	m^2
Eroded Area - Total	0.288	m^2

Export New (Eroded) Profile into Model

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

1) Select **EITHER** Option A or Option B for Bank Profile and enter the data in the relevant box- cells in the alternative option are ignored in the simulation and may be left blank if desired.
2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).
3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.

To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below

◉ Option A

Point	Station (m)	Elevation (m)	Top of toe?
A	0.00	1.03	
B	0.92	1.03	
C	0.92	0.99	☐
D	0.92	0.95	☐
E	0.92	0.91	☐
F	0.92	0.87	☐
G	0.92	0.83	☐
H	0.92	0.79	☐
I	0.92	0.75	☐
J	0.92	0.71	☐
K	0.92	0.66	☐
L	0.92	0.62	☐
M	0.92	0.58	☐
N	0.92	0.54	☐
O	0.92	0.50	☐
P	0.92	0.46	☐
Q	0.92	0.42	☑
R	1.29	0.36	
S	1.65	0.30	
T	2.02	0.24	
U	2.38	0.18	
V	2.75	0.12	
W	5.16	0.00	

Shear emergence elev: 0.42

Shear surface angle: 35.00

Option B - Enter a bank height and angle, the model will generate a bank profile

○ Option B

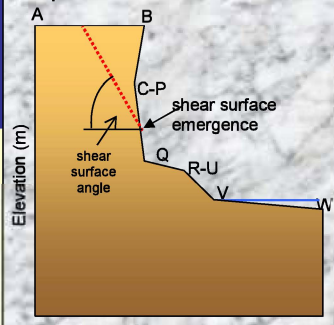
- a) Input bank height (m)
- b) Input bank angle (°)
- c) Input bank toe length (m)
- d) Input bank toe angle (°)
- Input shear surface angle

Bank layer thickness (m)

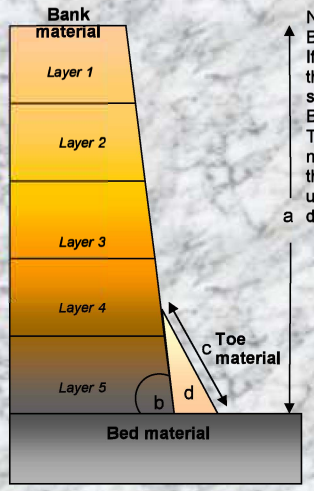
		Elevation of layer base (m)
	Top Layer	
Layer 1	0.00	1.03
Layer 2	0.00	1.03
Layer 3	0.00	1.03
Layer 4	0.00	1.03
Layer 5	1.03	0.00
	Bottom Layer	

Parallel layers, starting from point B

Definition of points used in bank profile



A - bank top: place beyond start of shear surface
B - bank edge
C-P - breaks of slope on bank (if no breaks of slope place as intermediary points)
Q - top of bank toe
R-U - breaks of slope on bank toe (if no breaks of slope then insert as intermediary points)
V - base of bank toe
W - end point (typically mid point of channel)



Notes:
Bank profile may overhang.
If the bank profile is fully populated, the shear surface emergence point should be anywhere between points B and Q.
The shear surface emergence point must not be on a horizontal section - the elevation of this point must be unique or an error message will display.

Channel and flow parameters

14.178	Input reach length (m)
0.0005	Input reach slope (m/m)
0.12	Input elevation of flow (m)
4380	Input duration of flow (hrs)

View Bank Geometry

Run Bank Geometry Macro

Select material types (or select "own data" and add values below)

Bank Material					Bank Toe Material
Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
Own data	Own data	Own data	Own data	Own data	Own data

Bank and bank-toe material data tables.

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white boxes.

Material Descriptors			Bank Model Input Data					Groundwater Model Input Data						Toe Model Input Data	
Bank material type	*Description*	*Mean grain size, D_{50} (m)*	*Friction angle ϕ' (degrees)*	*Cohesion c' (kPa)*	*Saturated unit weight (kN/m^3)*	*ϕ^b (degrees)*	*Chemical concentration (kg/kg)*	*Hydraulic Conductivity k_{sat} (m/s)*	*Bulk Modulus (Pa)*	*Porosity*	*Residual water content*	*van Genuchten α (1/m)*	*van Genuchten n*	τ_c (Pa)	*k* (cm^3/Ns)
1	Boulders	0.512	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	498	0.004
2	Cobbles	0.128	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	124	0.009
3	Gravel	0.0113	36.0	0.0	20.0	15.0	-	3.160E-03	1.354E+08	0.320	0.070	3.5237	2.3286	11.0	0.030
4a and 4b	Angular sand	0.00035	32.3	0.4	18.5	15.0	-	7.439E-05	1.354E+07	0.375	0.053	3.5237	3.1769	Coarse (0.71 mm) or	
5a and 5b	Rounded sand	0.00035	28.3	0.4	18.5	15.0	-	1.130E-06	6.056E+07	0.380	0.033	2.0563	2.3286	Fine (0.18 mm)	
6a, 6b and 6c	Silt	-	26.6	4.3	18.0	15.0	-	5.064E-06	1.049E+07	0.489	0.050	0.6577	1.6788	Erodible (0.100 Pa),	
7a, 7b and 7c	Soft clay	-	26.4	8.2	17.7	15.0	-	9.473E-07	1.354E+06	0.472	0.079	1.5812	1.4158	Moderate (5.00 Pa), or	
8a, 8b and 8c	Stiff clay	-	21.1	12.6	17.7	15.0	-	1.708E-06	5.417E+06	0.459	0.093	1.4962	1.2531	Resistant (50.0 Pa)	
	Own data layer 1		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 2		25.0	10.0	18.0	15.0	0.0							0.72	0.236
9	Own data layer 3		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 4		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 5			10.0	18.0	15.0	0.0							0.72	0.236
	Own data Bank Toe													0.72	0.118

COMING SOON!

Need to know the critical shear stress (τ_c) ?		Need to know the erodibility coefficient (*k*) ?	
Input non-cohesive particle diameter (mm)	0.075	Input critical shear stress τ_c (Pa)	0.721
Critical Shear Stress τ_c (Pa)	0.05	Erodibility Coefficient (cm^3/Ns)	0.118

Simulate the mechanical effects of *bank top* vegetation on bank stability using a root-reinforcement model

RipRoot (Pollen and Simon, 2005) is a global load-sharing fiber-bundle model. It explicitly simulates both the snapping of roots and the slipping of roots through the soil matrix, by determining the minimum applied load required to either break each root or pull each root out of the soil matrix. As the strength of each root is removed from the fiber bundle, the load is redistributed to the remaining roots according to the ratio of the diameter of each root to the sum of the diameters of all the intact roots. RipRoot builds on earlier work by Waldron (1977), Wu *et al*. (1979) and Waldron and Dakessian (1981).

Run Root-Reinforcement Model

Root-Reinforcement Model Output

List of Species Bare Soil/ No vegetation;
Percent of Assemblage 100;

Added cohesion due to roots, c_r 0.0 kPa

Protect the bank and/or bank-toe against *hydraulic erosion* by adding treatments (or select "own data" and add values below)

Protection

Bank Protection	Bank Toe Protection
No protection	No protection

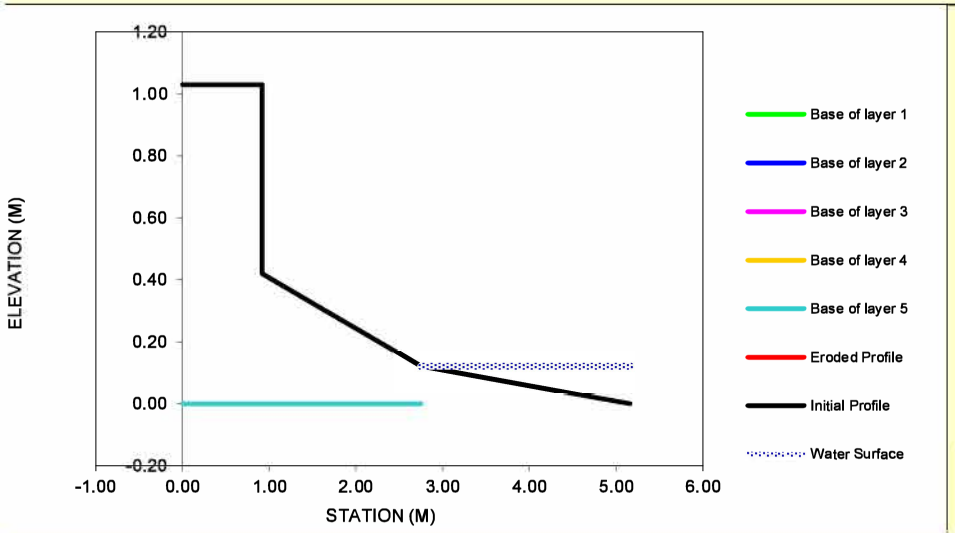
Bank and bank-toe protection data table

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white box.

Bank and Bank-Toe Protection Descriptors

Protection type	*Description*	*Permissible shear stress (Pa)*
1	No protection	-
2	Coir fiber	108
3	Geotextile (synthetic)	144
4	Jute net	22
5	Large Woody Debris	192
6	Live fascine	100
7	Plant cuttings	17
8	Rip Rap (D_{50} 0.256 m)	204
9	-	
10	-	
11	-	
12	-	
13	Own Data	

	Bank Material					Bank Toe Material	
	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5		
Material	Own data	Own data	Own data	Own data	Own data	Own data	
Critical shear stress (Pa)	0.72	0.72	0.72	0.72	0.72	0.72	
Erodibility Coefficient (cm^3/Ns)	0.236	0.236	0.236	0.236	0.236	0.118	



Run Toe-Erosion Model

Account for:

Stream Curvature ☐

Effective stress acting on each grain ☐

Average applied boundary shear stress	0.150	Pa
Maximum Lateral Retreat	0.000	cm
Eroded Area - Bank	0.000	m^2
Eroded Area - Bank Toe	0.000	m^2
Eroded Area - Bed	0.000	m^2
Eroded Area - Total	0.000	m^2

Export New (Eroded) Profile into Model

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

1) Select **EITHER** Option A or Option B for Bank Profile and enter the data in the relevant box- cells in the alternative option are ignored in the simulation and may be left blank if desired.
2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).
3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.

To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below

◉ Option A

Point	Station (m)	Elevation (m)	Top of toe?
A	-0.82	1.61	
B	0.92	1.61	
C	0.92	1.53	☐
D	0.92	1.45	☐
E	0.92	1.37	☐
F	0.92	1.29	☐
G	0.92	1.20	☐
H	0.92	1.12	☐
I	0.92	1.04	☐
J	0.92	0.96	☐
K	0.92	0.88	☐
L	0.92	0.80	☐
M	0.92	0.72	☐
N	0.92	0.63	☐
O	0.92	0.55	☐
P	0.92	0.47	☐
Q	0.92	0.39	☑
R	1.29	0.32	
S	1.65	0.26	
T	2.02	0.20	
U	2.38	0.14	
V	2.75	0.08	
W	5.16	0.00	

Shear emergence elev: 0.39

Shear surface angle: 35.00

Option B - Enter a bank height and angle, the model will generate a bank profile

○ Option B

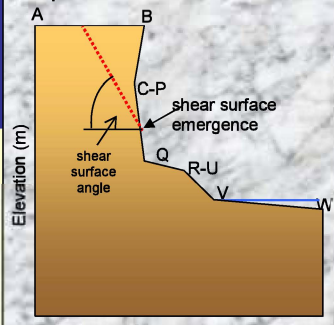
- a) Input bank height (m)
- b) Input bank angle (°)
- c) Input bank toe length (m)
- d) Input bank toe angle (°)
- Input shear surface angle

Bank layer thickness (m)

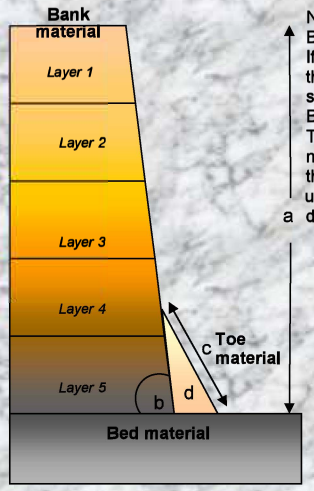
		Elevation of layer base (m)
	Top Layer	
Layer 1	0.00	1.61
Layer 2	0.00	1.61
Layer 3	0.00	1.61
Layer 4	0.00	1.61
Layer 5	1.61	0.00
	Bottom Layer	

Parallel layers, starting from point B

Definition of points used in bank profile



A - bank top: place beyond start of shear surface
B - bank edge
C-P - breaks of slope on bank (if no breaks of slope place as intermediary points)
Q - top of bank toe
R-U - breaks of slope on bank toe (if no breaks of slope then insert as intermediary points)
V - base of bank toe
W - end point (typically mid point of channel)



Notes:
Bank profile may overhang.
If the bank profile is fully populated, the shear surface emergence point should be anywhere between points B and Q.
The shear surface emergence point must not be on a horizontal section - the elevation of this point must be unique or an error message will display.

Channel and flow parameters

7.457	Input reach length (m)
0.0005	Input reach slope (m/m)
0.39	Input elevation of flow (m)
4380	Input duration of flow (hrs)

View Bank Geometry

Run Bank Geometry Macro

Select material types (or select "own data" and add values below)

Bank Material

Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	**Bank Toe Material**
Own data	Own data	Own data	Own data	Own data	Own data

Bank and bank-toe material data tables.

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white boxes.

Material Descriptors			**Bank Model Input Data**					**Groundwater Model Input Data**						**Toe Model Input Data**	
Bank material type	*Description*	*Mean grain size, D_{50} (m)*	*Friction angle ϕ' (degrees)*	*Cohesion c' (kPa)*	*Saturated unit weight (kN/m^3)*	*ϕ^b (degrees)*	*Chemical concentration (kg/kg)*	*Hydraulic Conductivity k_{sat} (m/s)*	*Bulk Modulus (Pa)*	*Porosity*	*Residual water content*	*van Genuchten α (1/m)*	*van Genuchten n*	τ_c (Pa)	*k* (cm^3/Ns)
1	Boulders	0.512	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	498	0.004
2	Cobbles	0.128	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	124	0.009
3	Gravel	0.0113	36.0	0.0	20.0	15.0	-	3.160E-03	1.354E+08	0.320	0.070	3.5237	2.3286	11.0	0.030
4a and 4b	Angular sand	0.00035	32.3	0.4	18.5	15.0	-	7.439E-05	1.354E+07	0.375	0.053	3.5237	3.1769	Coarse (0.71 mm) or	
5a and 5b	Rounded sand	0.00035	28.3	0.4	18.5	15.0	-	1.130E-06	6.056E+07	0.380	0.033	3.0563	2.3286	Fine (0.18 mm)	
6a, 6b and 6c	Silt	-	26.6	4.3	18.0	15.0	-	5.064E-06	1.049E+07	0.489	0.050	0.6577	1.6788	Erodible (0.100 Pa),	
7a, 7b and 7c	Soft clay	-	26.4	8.2	17.7	15.0	-	9.473E-07	1.354E+06	0.542	0.079	1.5812	1.4158	Moderate (5.00 Pa), or	
8a, 8b and 8c	Stiff clay	-	21.1	12.6	17.7	15.0	-	1.708E-06	5.417E+06	0.459	0.093	1.4962	1.2531	Resistant (50.0 Pa)	
	Own data layer 1		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 2		25.0	10.0	18.0	15.0	0.0							0.72	0.236
9	Own data layer 3		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 4		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 5			10.0	18.0	15.0	0.0							0.72	0.236
	Own data Bank Toe													0.72	0.118

COMING SOON!

Need to know the critical shear stress (τ_c) ?		**Need to know the erodibility coefficient (k) ?**	
Input non-cohesive particle diameter (mm)	0.075	Input critical shear stress τ_c (Pa)	0.721
Critical Shear Stress τ_c (Pa)	0.05	Erodibility Coefficient (cm^3/Ns)	0.118

Simulate the mechanical effects of *bank top* vegetation on bank stability using a root-reinforcement model

RipRoot (Pollen and Simon, 2005) is a global load-sharing fiber-bundle model. It explicitly simulates both the snapping of roots and the slipping of roots through the soil matrix, by determining the minimum applied load required to either break each root or pull each root out of the soil matrix. As the strength of each root is removed from the fiber bundle, the load is redistributed to the remaining roots according to the ratio of the diameter of each root to the sum of the diameters of all the intact roots. RipRoot builds on earlier work by Waldron (1977), Wu *et al*. (1979) and Waldron and Dakessian (1981).

Run Root-Reinforcement Model

Root-Reinforcement Model Output

List of Species Bare Soil/ No vegetation;
Percent of Assemblage 100;

Added cohesion due to roots, c_r 0.0 kPa

Protect the bank and/or bank-toe against *hydraulic erosion* by adding treatments (or select "own data" and add values below)

Protection

Bank Protection	Bank Toe Protection
No protection	No protection

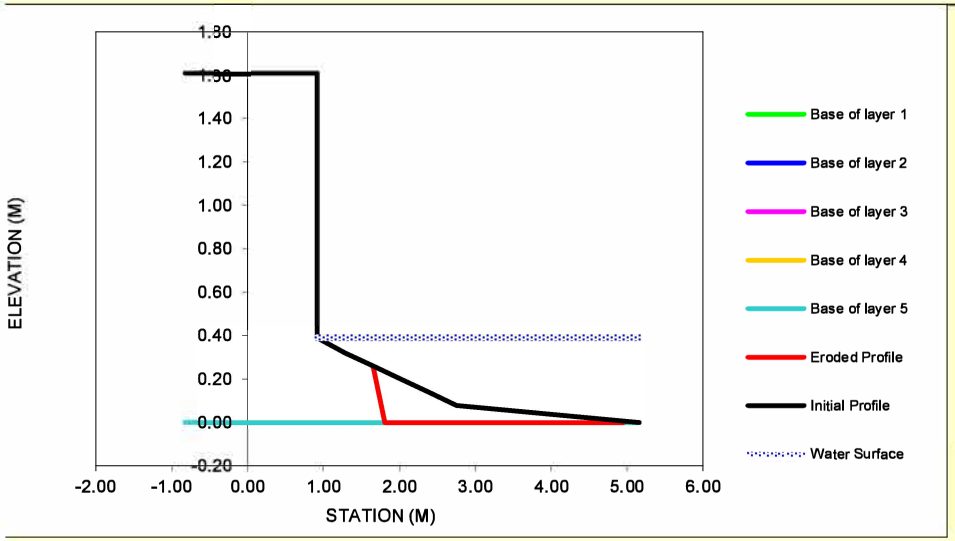
Bank and bank-toe protection data table

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white box.

Bank and Bank-Toe Protection Descriptors

Protection type	*Description*	*Permissible shear stress (Pa)*
1	No protection	-
2	Coir fiber	108
3	Geotextile (synthetic)	144
4	Jute net	22
5	Large Woody Debris	192
6	Live fascine	100
7	Plant cuttings	17
8	Rip Rap (D_{50} 0.256 m)	204
9	-	
10	-	
11	-	
12	-	
13	Own Data	

	Bank Material					Bank Toe Material	
	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5		
Material	Own data	Own data	Own data	Own data	Own data	Own data	
Critical shear stress (Pa)	0.72	0.72	0.72	0.72	0.72	0.72	
Erodibility Coefficient (cm^3/Ns)	0.236	0.236	0.236	0.236	0.236	0.118	



Run Toe-Erosion Model

Account for:

Stream Curvature ☐

Effective stress acting on each grain ☐

Average applied boundary shear stress	0.750	Pa
Maximum Lateral Retreat	37.559	cm
Eroded Area - Bank	0.000	m^2
Eroded Area - Bank Toe	0.159	m^2
Eroded Area - Bed	0.104	m^2
Eroded Area - Total	0.263	m^2

Export New (Eroded) Profile into Model

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

1) Select **EITHER** Option A or Option B for Bank Profile and enter the data in the relevant box- cells in the alternative option are ignored in the simulation and may be left blank if desired.
2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).
3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.

To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below

◉ Option A

Point	Station (m)	Elevation (m)	Top of toe?
A	-0.82	1.61	
B	0.92	1.61	
C	0.92	1.53	☐
D	0.92	1.45	☐
E	0.92	1.37	☐
F	0.92	1.29	☐
G	0.92	1.20	☐
H	0.92	1.12	☐
I	0.92	1.04	☐
J	0.92	0.96	☐
K	0.92	0.88	☐
L	0.92	0.80	☐
M	0.92	0.72	☐
N	0.92	0.63	☐
O	0.92	0.55	☐
P	0.92	0.47	☐
Q	0.92	0.39	☑
R	1.29	0.32	
S	1.65	0.26	
T	2.02	0.20	
U	2.38	0.14	
V	2.75	0.08	
W	5.16	0.00	

Shear emergence elev: 0.39

Shear surface angle: 35.00

Option B - Enter a bank height and angle, the model will generate a bank profile

○ Option B

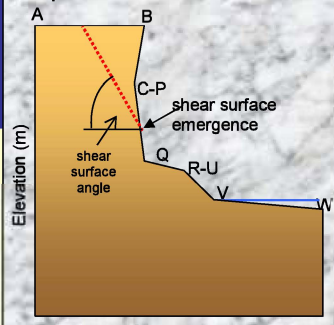
- a) Input bank height (m)
- b) Input bank angle (°)
- c) Input bank toe length (m)
- d) Input bank toe angle (°)
- Input shear surface angle

Bank layer thickness (m)

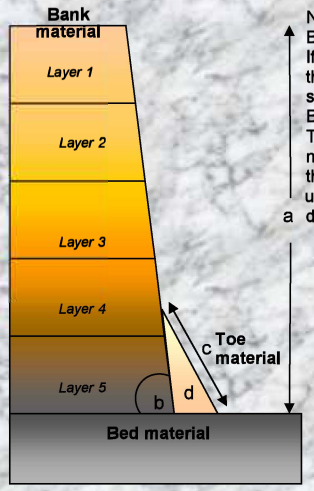
		Elevation of layer base (m)
	Top Layer	
Layer 1	0.00	1.61
Layer 2	0.00	1.61
Layer 3	0.00	1.61
Layer 4	0.00	1.61
Layer 5	1.61	0.00
	Bottom Layer	

Parallel layers, starting from point B

Definition of points used in bank profile



A - bank top: place beyond start of shear surface
B - bank edge
C-P - breaks of slope on bank (if no breaks of slope place as intermediary points)
Q - top of bank toe
R-U - breaks of slope on bank toe (if no breaks of slope then insert as intermediary points)
V - base of bank toe
W - end point (typically mid point of channel)



Notes:
Bank profile may overhang.
If the bank profile is fully populated, the shear surface emergence point should be anywhere between points B and Q.
The shear surface emergence point must not be on a horizontal section - the elevation of this point must be unique or an error message will display.

Channel and flow parameters

7.457	Input reach length (m)
0.0005	Input reach slope (m/m)
0.08	Input elevation of flow (m)
4380	Input duration of flow (hrs)

View Bank Geometry

Run Bank Geometry Macro

Select material types (or select "own data" and add values below)

Bank Material

Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	**Bank Toe Material**
Own data	Own data	Own data	Own data	Own data	Own data

Bank and bank-toe material data tables.

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white boxes.

Material Descriptors			**Bank Model Input Data**					**Groundwater Model Input Data**						**Toe Model Input Data**	
Bank material type	*Description*	*Mean grain size, D_{50} (m)*	*Friction angle ϕ' (degrees)*	*Cohesion c' (kPa)*	*Saturated unit weight (kN/m^3)*	*ϕ^b (degrees)*	*Chemical concentration (kg/kg)*	*Hydraulic Conductivity k_{sat} (m/s)*	*Bulk Modulus (Pa)*	*Porosity*	*Residual water content*	*van Genuchten α (1/m)*	*van Genuchten n*	τ_c (Pa)	*k* (cm^3/Ns)
1	Boulders	0.512	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	498	0.004
2	Cobbles	0.128	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	124	0.009
3	Gravel	0.0113	36.0	0.0	20.0	15.0	-	3.160E-03	1.354E+08	0.320	0.070	3.5237	2.3286	11.0	0.030
4a and 4b	Angular sand	0.00035	32.3	0.4	18.5	15.0	-	7.439E-05	1.354E+07	0.375	0.053	3.5237	3.1769	Coarse (0.71 mm) or	
5a and 5b	Rounded sand	0.00035	28.3	0.4	18.5	15.0	-	1.130E-06	6.056E+07	0.380	0.033	3.0563	2.3286	Fine (0.18 mm)	
6a, 6b and 6c	Silt	-	26.6	4.3	18.0	15.0	-	5.064E-06	1.049E+07	0.489	0.050	0.6577	1.6788	Erodible (0.100 Pa),	
7a, 7b and 7c	Soft clay	-	26.4	8.2	17.7	15.0	-	9.473E-07	1.354E+06	0.542	0.079	1.5812	1.4158	Moderate (5.00 Pa), or	
8a, 8b and 8c	Stiff clay	-	21.1	12.6	17.7	15.0	-	1.708E-06	5.417E+06	0.459	0.093	1.4962	1.2531	Resistant (50.0 Pa)	
	Own data layer 1		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 2		25.0	10.0	18.0	15.0	0.0							0.72	0.236
9	Own data layer 3		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 4		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 5			10.0	18.0	15.0	0.0							0.72	0.236
	Own data Bank Toe													0.72	0.118

COMING SOON!

Need to know the critical shear stress (τ_c) ?		**Need to know the erodibility coefficient (k) ?**	
Input non-cohesive particle diameter (mm)	0.075	Input critical shear stress τ_c (Pa)	0.721
Critical Shear Stress τ_c (Pa)	0.05	Erodibility Coefficient (cm^3/Ns)	0.118

Simulate the mechanical effects of *bank top* vegetation on bank stability using a root-reinforcement model

RipRoot (Pollen and Simon, 2005) is a global load-sharing fiber-bundle model. It explicitly simulates both the snapping of roots and the slipping of roots through the soil matrix, by determining the minimum applied load required to either break each root or pull each root out of the soil matrix. As the strength of each root is removed from the fiber bundle, the load is redistributed to the remaining roots according to the ratio of the diameter of each root to the sum of the diameters of all the intact roots. RipRoot builds on earlier work by Waldron (1977), Wu *et al*. (1979) and Waldron and Dakessian (1981).

Run Root-Reinforcement Model

Root-Reinforcement Model Output

List of Species Bare Soil/ No vegetation;
Percent of Assemblage 100;

Added cohesion due to roots, c_r 0.0 kPa

Protect the bank and/or bank-toe against *hydraulic erosion* by adding treatments (or select "own data" and add values below)

Protection

Bank Protection	Bank Toe Protection
No protection	No protection

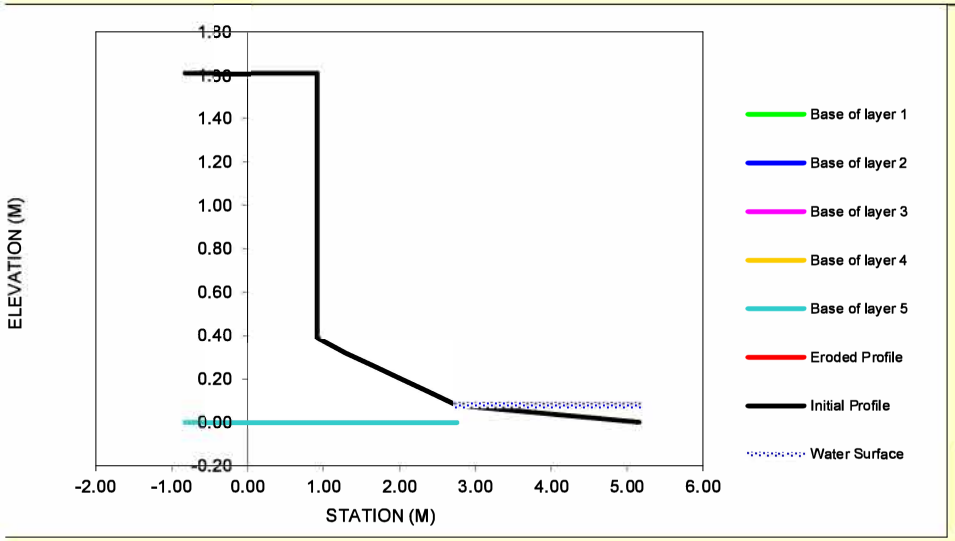
Bank and bank-toe protection data table

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white box.

Bank and Bank-Toe Protection Descriptors

Protection type	*Description*	*Permissible shear stress (Pa)*
1	No protection	-
2	Coir fiber	108
3	Geotextile (synthetic)	144
4	Jute net	22
5	Large Woody Debris	192
6	Live fascine	100
7	Plant cuttings	17
8	Rip Rap (D_{50} 0.256 m)	204
9	-	
10	-	
11	-	
12	-	
13	Own Data	

	Bank Material					Bank Toe Material	
	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5		
Material	Own data	Own data	Own data	Own data	Own data	Own data	
Critical shear stress (Pa)	0.72	0.72	0.72	0.72	0.72	0.72	
Erodibility Coefficient (cm^3/Ns)	0.236	0.236	0.236	0.236	0.236	0.118	



Run Toe-Erosion Model

Account for:

Stream Curvature ☐

Effective stress acting on each grain ☐

Average applied boundary shear stress	0.100	Pa
Maximum Lateral Retreat	0.000	cm
Eroded Area - Bank	0.000	m^2
Eroded Area - Bank Toe	0.000	m^2
Eroded Area - Bed	0.000	m^2
Eroded Area - Total	0.000	m^2

Export New (Eroded) Profile into Model

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

1) Select **EITHER** Option A or Option B for Bank Profile and enter the data in the relevant box- cells in the alternative option are ignored in the simulation and may be left blank if desired.
2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).
3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.

To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below

◉ Option A

Point	Station (m)	Elevation (m)	Top of toe?
A	0.00	0.75	
B	0.92	0.75	
C	0.92	0.73	☐
D	0.92	0.71	☐
E	0.92	0.69	☐
F	0.92	0.67	☐
G	0.92	0.65	☐
H	0.92	0.63	☐
I	0.92	0.61	☐
J	0.92	0.59	☐
K	0.92	0.56	☐
L	0.92	0.54	☐
M	0.92	0.52	☐
N	0.92	0.50	☐
O	0.92	0.48	☐
P	0.92	0.46	☐
Q	0.92	0.44	☑
R	1.23	0.38	
S	1.53	0.32	
T	1.84	0.26	
U	2.14	0.20	
V	2.44	0.14	
W	5.16	0.00	

Shear emergence elev: 0.44

Shear surface angle: 35.00

Option B - Enter a bank height and angle, the model will generate a bank profile

○ Option B

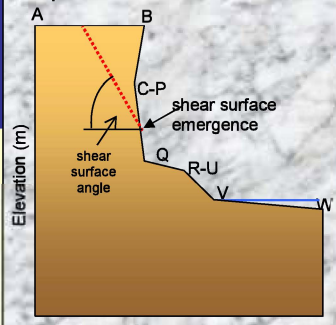
- a) Input bank height (m)
- b) Input bank angle (°)
- c) Input bank toe length (m)
- d) Input bank toe angle (°)
- Input shear surface angle

Bank layer thickness (m)

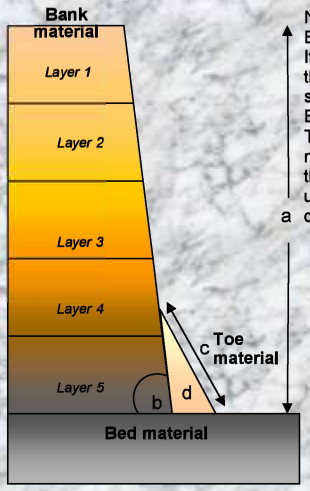
		Elevation of layer base (m)
	Top Layer	
Layer 1	0.00	0.75
Layer 2	0.00	0.75
Layer 3	0.00	0.75
Layer 4	0.00	0.75
Layer 5	0.75	0.00
	Bottom Layer	

Parallel layers, starting from point B

Definition of points used in bank profile



A - bank top: place beyond start of shear surface
B - bank edge
C-P - breaks of slope on bank (if no breaks of slope place as intermediary points)
Q - top of bank toe
R-U - breaks of slope on bank toe (if no breaks of slope then insert as intermediary points)
V - base of bank toe
W - end point (typically mid point of channel)



Notes:
Bank profile may overhang.
If the bank profile is fully populated, the shear surface emergence point should be anywhere between points B and Q.
The shear surface emergence point must not be on a horizontal section - the elevation of this point must be unique or an error message will display.

Channel and flow parameters

23.589	Input reach length (m)
0.0005	Input reach slope (m/m)
0.44	Input elevation of flow (m)
4380	Input duration of flow (hrs)

View Bank Geometry

Run Bank Geometry Macro

Select material types (or select "own data" and add values below)

Bank Material					Bank Toe Material
Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
Own data	Own data	Own data	Own data	Own data	Own data

Bank and bank-toe material data tables.

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white boxes.

Material Descriptors			Bank Model Input Data					Groundwater Model Input Data						Toe Model Input Data	
Bank material type	*Description*	*Mean grain size, D_{50} (m)*	*Friction angle ϕ' (degrees)*	*Cohesion c' (kPa)*	*Saturated unit weight (kN/m^3)*	*ϕ^b (degrees)*	*Chemical concentration (kg/kg)*	*Hydraulic Conductivity k_{sat} (m/s)*	*Bulk Modulus (Pa)*	*Porosity*	*Residual water content*	*van Genuchten α (1/m)*	*van Genuchten n*	τ_c (Pa)	*k* (cm^3/Ns)
1	Boulders	0.512	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	498	0.004
2	Cobbles	0.128	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	124	0.009
3	Gravel	0.0113	36.0	0.0	20.0	15.0	-	3.160E-03	1.354E+08	0.320	0.070	3.5237	2.3286	11.0	0.030
4a and 4b	Angular sand	0.00035	32.3	0.4	18.5	15.0	-	7.439E-05	1.354E+07	0.375	0.053	3.5237	3.1769	Coarse (0.71 mm) or	
5a and 5b	Rounded sand	0.00035	28.3	0.4	18.5	15.0	-	1.130E-06	6.056E+07	0.380	0.033	2.0563	2.3286	Fine (0.18 mm)	
6a, 6b and 6c	Silt	-	26.6	4.3	18.0	15.0	-	5.064E-06	1.049E+07	0.489	0.050	0.6577	1.6788	Erodible (0.100 Pa),	
7a, 7b and 7c	Soft clay	-	26.4	8.2	17.7	15.0	-	9.473E-07	1.354E+06	0.472	0.079	1.5812	1.4158	Moderate (5.00 Pa), or	
8a, 8b and 8c	Stiff clay	-	21.1	12.6	17.7	15.0	-	1.708E-06	5.417E+06	0.459	0.093	1.4962	1.2531	Resistant (50.0 Pa)	
	Own data layer 1		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 2		25.0	10.0	18.0	15.0	0.0							0.72	0.236
9	Own data layer 3		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 4		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 5			10.0	18.0	15.0	0.0							0.72	0.236
	Own data Bank Toe													0.72	0.118

COMING SOON!

Need to know the critical shear stress (τ_c) ?		Need to know the erodibility coefficient (*k*) ?	
Input non-cohesive particle diameter (mm)	0.075	Input critical shear stress τ_c (Pa)	0.721
Critical Shear Stress τ_c (Pa)	0.05	Erodibility Coefficient (cm^3/Ns)	0.118

Simulate the mechanical effects of *bank top* vegetation on bank stability using a root-reinforcement model

RipRoot (Pollen and Simon, 2005) is a global load-sharing fiber-bundle model. It explicitly simulates both the snapping of roots and the slipping of roots through the soil matrix, by determining the minimum applied load required to either break each root or pull each root out of the soil matrix. As the strength of each root is removed from the fiber bundle, the load is redistributed to the remaining roots according to the ratio of the diameter of each root to the sum of the diameters of all the intact roots. RipRoot builds on earlier work by Waldron (1977), Wu *et al*. (1979) and Waldron and Dakessian (1981).

Run Root-Reinforcement Model

Root-Reinforcement Model Output

List of Species Bare Soil/ No vegetation;
Percent of Assemblage 100;

Added cohesion due to roots, c_r 0.0 kPa

Protect the bank and/or bank-toe against *hydraulic erosion* by adding treatments (or select "own data" and add values below)

Protection

Bank Protection	Bank Toe Protection
No protection	No protection

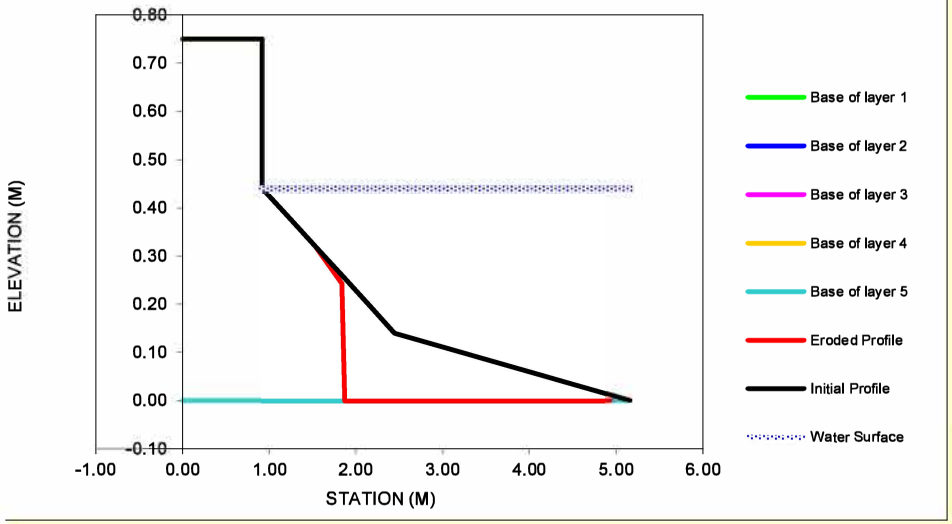
Bank and bank-toe protection data table

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white box.

Bank and Bank-Toe Protection Descriptors

Protection type	*Description*	*Permissible shear stress (Pa)*
1	No protection	-
2	Coir fiber	108
3	Geotextile (synthetic)	144
4	Jute net	22
5	Large Woody Debris	192
6	Live fascine	100
7	Plant cuttings	17
8	Rip Rap (D_{50} 0.256 m)	204
9	-	
10	-	
11	-	
12	-	
13	Own Data	

Bank Material					Bank Toe Material	
Layer 1	Layer 2	Layer 3	Layer 4	Layer 5		
Own data	Own data	Own data	Own data	Own data	Own data	**Material**
0.72	0.72	0.72	0.72	0.72	0.72	**Critical shear stress (Pa)**
0.236	0.236	0.236	0.236	0.236	0.118	**Erodibility Coefficient (cm^3/Ns)**



Run Toe-Erosion Model

Account for:

Stream Curvature ☐

Effective stress acting on each grain ☐

Average applied boundary shear stress	0.690	Pa
Maximum Lateral Retreat	27.241	cm
Eroded Area - Bank	0.000	m^2
Eroded Area - Bank Toe	0.110	m^2
Eroded Area - Bed	0.201	m^2
Eroded Area - Total	0.310	m^2

Export New (Eroded) Profile into Model

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

1) Select **EITHER** Option A or Option B for Bank Profile and enter the data in the relevant box- cells in the alternative option are ignored in the simulation and may be left blank if desired.
2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).
3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.

To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below

◉ Option A

Point	Station (m)	Elevation (m)	Top of toe?
A	0.00	0.75	
B	0.92	0.75	
C	0.92	0.73	☐
D	0.92	0.71	☐
E	0.92	0.69	☐
F	0.92	0.67	☐
G	0.92	0.65	☐
H	0.92	0.63	☐
I	0.92	0.61	☐
J	0.92	0.59	☐
K	0.92	0.56	☐
L	0.92	0.54	☐
M	0.92	0.52	☐
N	0.92	0.50	☐
O	0.92	0.48	☐
P	0.92	0.46	☐
Q	0.92	0.44	☑
R	1.23	0.38	
S	1.53	0.32	
T	1.84	0.26	
U	2.14	0.20	
V	2.44	0.14	
W	5.16	0.00	

Shear emergence elev: 0.44

Shear surface angle: 35.00

Option B - Enter a bank height and angle, the model will generate a bank profile

○ Option B

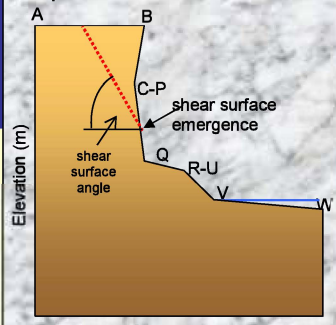
- a) Input bank height (m)
- b) Input bank angle (°)
- c) Input bank toe length (m)
- d) Input bank toe angle (°)
- Input shear surface angle

Bank layer thickness (m)

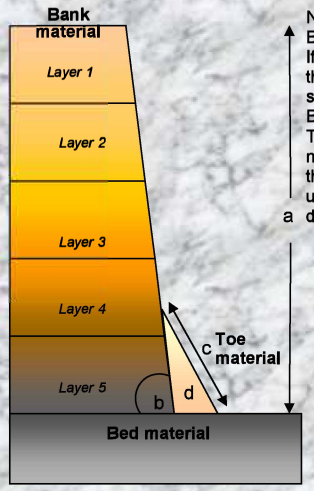
		Elevation of layer base (m)
	Top Layer	
Layer 1	0.00	0.75
Layer 2	0.00	0.75
Layer 3	0.00	0.75
Layer 4	0.00	0.75
Layer 5	0.75	0.00
	Bottom Layer	

Parallel layers, starting from point B

Definition of points used in bank profile



A - bank top: place beyond start of shear surface
B - bank edge
C-P - breaks of slope on bank (if no breaks of slope place as intermediary points)
Q - top of bank toe
R-U - breaks of slope on bank toe (if no breaks of slope then insert as intermediary points)
V - base of bank toe
W - end point (typically mid point of channel)



Notes:
Bank profile may overhang.
If the bank profile is fully populated, the shear surface emergence point should be anywhere between points B and Q.
The shear surface emergence point must not be on a horizontal section - the elevation of this point must be unique or an error message will display.

Channel and flow parameters

23.589	Input reach length (m)
0.0005	Input reach slope (m/m)
0.14	Input elevation of flow (m)
4380	Input duration of flow (hrs)

View Bank Geometry

Run Bank Geometry Macro

Select material types (or select "own data" and add values below)

Bank Material					Bank Toe Material
Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
Own data	Own data	Own data	Own data	Own data	Own data

Bank and bank-toe material data tables.

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white boxes.

Material Descriptors			Bank Model Input Data					Groundwater Model Input Data						Toe Model Input Data	
Bank material type	*Description*	*Mean grain size, D_{50} (m)*	*Friction angle ϕ' (degrees)*	*Cohesion c' (kPa)*	*Saturated unit weight (kN/m^3)*	*ϕ^b (degrees)*	*Chemical concentration (kg/kg)*	*Hydraulic Conductivity k_{sat} (m/s)*	*Bulk Modulus (Pa)*	*Porosity*	*Residual water content*	*van Genuchten α (1/m)*	*van Genuchten n*	τ_c (Pa)	*k* (cm^3/Ns)
1	Boulders	0.512	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	498	0.004
2	Cobbles	0.128	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	124	0.009
3	Gravel	0.0113	36.0	0.0	20.0	15.0	-	3.160E-03	1.354E+08	0.320	0.070	3.5237	2.3286	11.0	0.030
4a and 4b	Angular sand	0.00035	32.3	0.4	18.5	15.0	-	7.439E-05	1.354E+07	0.375	0.053	3.5237	3.1769	Coarse (0.71 mm) or	
5a and 5b	Rounded sand	0.00035	28.3	0.4	18.5	15.0	-	1.130E-06	6.056E+07	0.380	0.033	2.0563	2.3286	Fine (0.18 mm)	
6a, 6b and 6c	Silt	-	26.6	4.3	18.0	15.0	-	5.064E-06	1.049E+07	0.489	0.050	0.6577	1.6788	Erodible (0.100 Pa),	
7a, 7b and 7c	Soft clay	-	26.4	8.2	17.7	15.0	-	9.473E-07	1.354E+06	0.472	0.079	1.5812	1.4158	Moderate (5.00 Pa), or	
8a, 8b and 8c	Stiff clay	-	21.1	12.6	17.7	15.0	-	1.708E-06	5.417E+06	0.459	0.093	1.4962	1.2531	Resistant (50.0 Pa)	
	Own data layer 1		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 2		25.0	10.0	18.0	15.0	0.0							0.72	0.236
9	Own data layer 3		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 4		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 5			10.0	18.0	15.0	0.0							0.72	0.236
	Own data Bank Toe													0.72	0.118

COMING SOON!

Need to know the critical shear stress (τ_c) ?		Need to know the erodibility coefficient (*k*) ?	
Input non-cohesive particle diameter (mm)	0.075	Input critical shear stress τ_c (Pa)	0.721
Critical Shear Stress τ_c (Pa)	0.05	Erodibility Coefficient (cm^3/Ns)	0.118

Simulate the mechanical effects of *bank top* vegetation on bank stability using a root-reinforcement model

RipRoot (Pollen and Simon, 2005) is a global load-sharing fiber-bundle model. It explicitly simulates both the snapping of roots and the slipping of roots through the soil matrix, by determining the minimum applied load required to either break each root or pull each root out of the soil matrix. As the strength of each root is removed from the fiber bundle, the load is redistributed to the remaining roots according to the ratio of the diameter of each root to the sum of the diameters of all the intact roots. RipRoot builds on earlier work by Waldron (1977), Wu *et al*. (1979) and Waldron and Dakessian (1981).

Run Root-Reinforcement Model

Root-Reinforcement Model Output

List of Species Bare Soil/ No vegetation;
Percent of Assemblage 100;

Added cohesion due to roots, c_r 0.0 kPa

Protect the bank and/or bank-toe against *hydraulic erosion* by adding treatments (or select "own data" and add values below)

Protection

Bank Protection	Bank Toe Protection
No protection	No protection

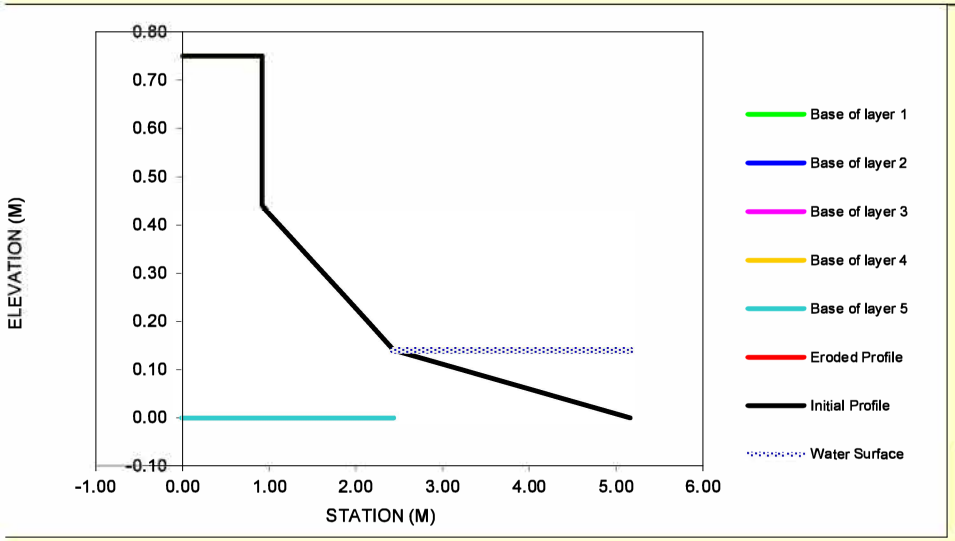
Bank and bank-toe protection data table

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white box.

Bank and Bank-Toe Protection Descriptors

Protection type	*Description*	*Permissible shear stress (Pa)*
1	No protection	-
2	Coir fiber	108
3	Geotextile (synthetic)	144
4	Jute net	22
5	Large Woody Debris	192
6	Live fascine	100
7	Plant cuttings	17
8	Rip Rap (D_{50} 0.256 m)	204
9	-	
10	-	
11	-	
12	-	
13	Own Data	

	Bank Material					Bank Toe Material	
	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5		
Material	Own data	Own data	Own data	Own data	Own data	Own data	
Critical shear stress (Pa)	0.72	0.72	0.72	0.72	0.72	0.72	
Erodibility Coefficient (cm^3/Ns)	0.236	0.236	0.236	0.236	0.236	0.118	



Run Toe-Erosion Model

Account for:

Stream Curvature ☐

Effective stress acting on each grain ☐

Average applied boundary shear stress	0.170	Pa
Maximum Lateral Retreat	0.000	cm
Eroded Area - Bank	0.000	m^2
Eroded Area - Bank Toe	0.000	m^2
Eroded Area - Bed	0.000	m^2
Eroded Area - Total	0.000	m^2

Export New (Eroded) Profile into Model

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

1) Select **EITHER** Option A or Option B for Bank Profile and enter the data in the relevant box- cells in the alternative option are ignored in the simulation and may be left blank if desired.
2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).
3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.

To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below

◉ Option A

Point	Station (m)	Elevation (m)	Top of toe?
A	0.00	1.00	
B	1.00	1.00	
C	1.11	0.99	☐
D	1.23	0.98	☐
E	1.34	0.97	☐
F	1.46	0.96	☐
G	1.57	0.95	☐
H	1.68	0.94	☐
I	1.80	0.93	☐
J	1.91	0.92	☐
K	2.03	0.91	☐
L	2.14	0.90	☐
M	2.25	0.89	☐
N	2.37	0.88	☐
O	2.48	0.87	☐
P	2.60	0.85	☐
Q	2.60	0.55	☑
R	3.03	0.49	
S	3.46	0.43	
T	3.88	0.37	
U	4.31	0.30	
V	4.74	0.24	
W	6.16	0.19	

Shear emergence elev: 0.55

Shear surface angle: 35.00

Option B - Enter a bank height and angle, the model will generate a bank profile

○ Option B

- a) Input bank height (m)
- b) Input bank angle (°)
- c) Input bank toe length (m)
- d) Input bank toe angle (°)

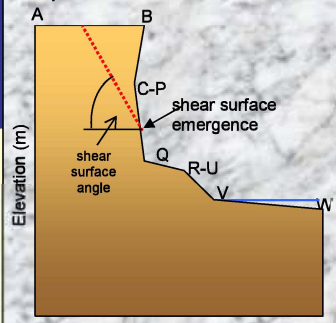
Input shear surface angle

Bank layer thickness (m)

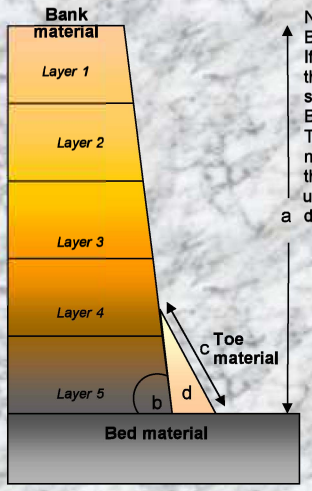
		Elevation of layer base (m)
	Top Layer	
Layer 1	1.00	0.00
Layer 2	0.00	0.00
Layer 3	0.00	0.00
Layer 4	0.00	0.00
Layer 5	0.00	0.00
	Bottom Layer	

Parallel layers, starting from point B

Definition of points used in bank profile



A - bank top: place beyond start of shear surface
B - bank edge
C-P - breaks of slope on bank (if no breaks of slope place as intermediary points)
Q - top of bank toe
R-U - breaks of slope on bank toe (if no breaks of slope then insert as intermediary points)
V - base of bank toe
W - end point (typically mid point of channel)



Notes:
Bank profile may overhang.
If the bank profile is fully populated, the shear surface emergence point should be anywhere between points B and Q.
The shear surface emergence point must not be on a horizontal section - the elevation of this point must be unique or an error message will display.

Channel and flow parameters

18.3	Input reach length (m)
0.0005	Input reach slope (m/m)
0.55	Input elevation of flow (m)
4380	Input duration of flow (hrs)

View Bank Geometry

Run Bank Geometry Macro

Select material types (or select "own data" and add values below)

Bank Material					Bank Toe Material
Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
Own data	Own data	Own data	Own data	Own data	Own data

Bank and bank-toe material data tables.

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white boxes.

Material Descriptors			Bank Model Input Data					Groundwater Model Input Data						Toe Model Input Data	
Bank material type	*Description*	*Mean grain size, D_{50} (m)*	*Friction angle ϕ' (degrees)*	*Cohesion c' (kPa)*	*Saturated unit weight (kN/m^3)*	*ϕ^b (degrees)*	*Chemical concentration (kg/kg)*	*Hydraulic Conductivity k_{sat} (m/s)*	*Bulk Modulus (Pa)*	*Porosity*	*Residual water content*	*van Genuchten α (1/m)*	*van Genuchten n*	τ_c (Pa)	*k* (cm^3/Ns)
1	Boulders	0.512	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	498	0.004
2	Cobbles	0.128	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	124	0.009
3	Gravel	0.0113	36.0	0.0	20.0	15.0	-	3.160E-03	1.354E+08	0.320	0.070	3.5237	2.3286	11.0	0.030
4a and 4b	Angular sand	0.00035	32.3	0.4	18.5	15.0	-	7.439E-05	1.354E+07	0.375	0.053	3.5237	3.1769	Coarse (0.71 mm) or	
5a and 5b	Rounded sand	0.00035	28.3	0.4	18.5	15.0	-	1.130E-06	6.056E+07	0.380	0.033	2.0563	2.3286	Fine (0.18 mm)	
6a, 6b and 6c	Silt	-	26.6	4.3	18.0	15.0	-	5.064E-06	1.049E+07	0.489	0.050	0.6577	1.6788	Erodible (0.100 Pa),	
7a, 7b and 7c	Soft clay	-	26.4	8.2	17.7	15.0	-	9.473E-07	1.354E+06	0.472	0.079	1.5812	1.4158	Moderate (5.00 Pa), or	
8a, 8b and 8c	Stiff clay	-	21.1	12.6	17.7	15.0	-	1.708E-06	5.417E+06	0.459	0.093	1.4962	1.2531	Resistant (50.0 Pa)	
	Own data layer 1		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 2		25.0	10.0	18.0	15.0	0.0							0.72	0.236
9	Own data layer 3		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 4		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 5			10.0	18.0	15.0	0.0							0.72	0.236
	Own data Bank Toe													0.72	0.118

COMING SOON!

Need to know the critical shear stress (τ_c) ?		Need to know the erodibility coefficient (*k*) ?	
Input non-cohesive particle diameter (mm)	0.075	Input critical shear stress τ_c (Pa)	0.721
Critical Shear Stress τ_c (Pa)	0.05	Erodibility Coefficient (cm^3/Ns)	0.118

Simulate the mechanical effects of *bank top* vegetation on bank stability using a root-reinforcement model

RipRoot (Pollen and Simon, 2005) is a global load-sharing fiber-bundle model. It explicitly simulates both the snapping of roots and the slipping of roots through the soil matrix, by determining the minimum applied load required to either break each root or pull each root out of the soil matrix. As the strength of each root is removed from the fiber bundle, the load is redistributed to the remaining roots according to the ratio of the diameter of each root to the sum of the diameters of all the intact roots. RipRoot builds on earlier work by Waldron (1977), Wu *et al*. (1979) and Waldron and Dakessian (1981).

Run Root-Reinforcement Model

Root-Reinforcement Model Output

List of Species River Birch; Eastern Sycamore; Black Willow;
Percent of Assemblage 33.3; 33.3; 33.4;

Added cohesion due to roots, c_r 0.1 kPa

Protect the bank and/or bank-toe against *hydraulic erosion* by adding treatments (or select "own data" and add values below)

Protection

Bank Protection	Bank Toe Protection
Rip Rap (D50 0.256 m)	Own Data

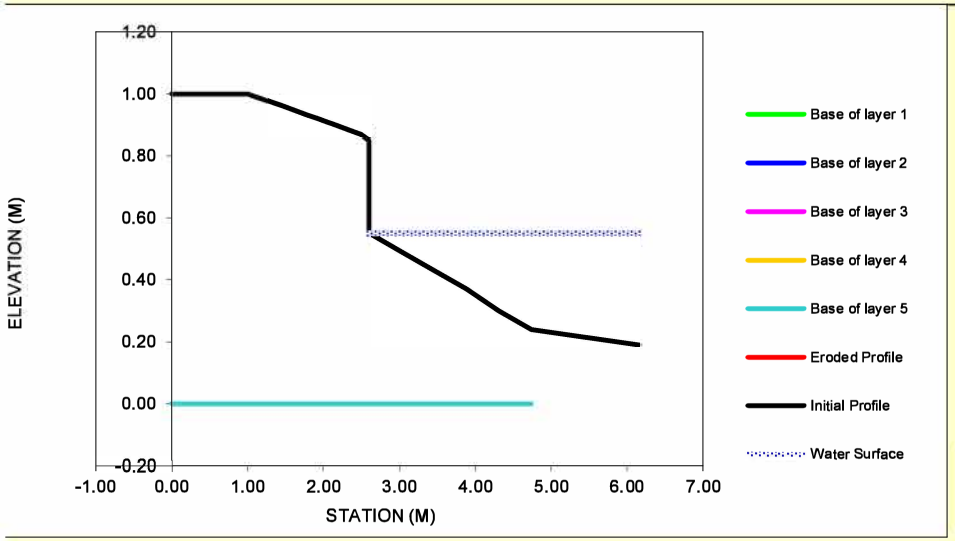
Bank and bank-toe protection data table

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white box.

Bank and Bank-Toe Protection Descriptors

Protection type	*Description*	*Permissible shear stress (Pa)*
1	No protection	-
2	Coir fiber	108
3	Geotextile (synthetic)	144
4	Jute net	22
5	Large Woody Debris	192
6	Live fascine	100
7	Plant cuttings	17
8	Rip Rap (D_{50} 0.256 m)	204
9	-	
10	-	
11	-	
12	-	
13	Own Data	100.0

	Bank Material					Bank Toe Material	
	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5		
Material	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Own Data	Material
Critical shear stress (Pa)	204.00	204.00	204.00	204.00	204.00	1000.00	Critical shear stress (Pa)
Erodibility Coefficient (cm^3/Ns)	0.00 7	0.00 7	0.00 7	0.00 7	0.00 7	0.010	Erodibility Coefficient (cm^3/Ns)



Run Toe-Erosion Model

Account for:

Stream Curvature ☐

Effective stress acting on each grain ☐

Average applied boundary shear stress	0.730	Pa
Maximum Lateral Retreat	0.000	cm
Eroded Area - Bank	0.000	m^2
Eroded Area - Bank Toe	0.000	m^2
Eroded Area - Bed	0.000	m^2
Eroded Area - Total	0.000	m^2

Export New (Eroded) Profile into Model

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

1) Select **EITHER** Option A or Option B for Bank Profile and enter the data in the relevant box- cells in the alternative option are ignored in the simulation and may be left blank if desired.
2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).
3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.

To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below

◉ Option A

Point	Station (m)	Elevation (m)	Top of toe?
A	0.00	1.00	
B	1.00	1.00	
C	1.11	0.99	☐
D	1.23	0.98	☐
E	1.34	0.97	☐
F	1.46	0.96	☐
G	1.57	0.95	☐
H	1.68	0.94	☐
I	1.80	0.93	☐
J	1.91	0.92	☐
K	2.03	0.91	☐
L	2.14	0.90	☐
M	2.25	0.89	☐
N	2.37	0.88	☐
O	2.48	0.87	☐
P	2.60	0.85	☐
Q	2.60	0.55	☑
R	3.03	0.49	
S	3.46	0.43	
T	3.88	0.37	
U	4.31	0.30	
V	4.74	0.24	
W	6.16	0.19	

Shear emergence elev: 0.55

Shear surface angle: 35.00

Option B - Enter a bank height and angle, the model will generate a bank profile

○ Option B

- a) Input bank height (m)
- b) Input bank angle (°)
- c) Input bank toe length (m)
- d) Input bank toe angle (°)
- Input shear surface angle

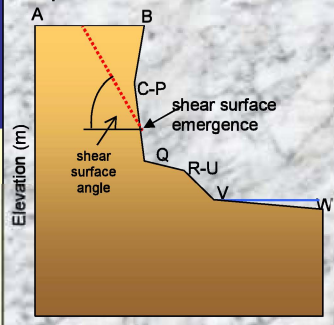
Bank layer thickness (m)

	Top Layer	Elevation of layer base (m)
Layer 1	1.00	0.00
Layer 2	0.00	0.00
Layer 3	0.00	0.00
Layer 4	0.00	0.00
Layer 5	0.00	0.00

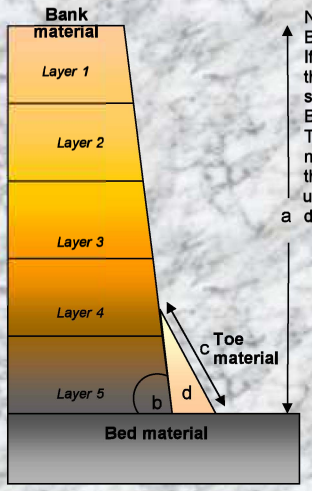
Bottom Layer

Parallel layers, starting from point B

Definition of points used in bank profile



A - bank top: place beyond start of shear surface
B - bank edge
C-P - breaks of slope on bank (if no breaks of slope place as intermediary points)
Q - top of bank toe
R-U - breaks of slope on bank toe (if no breaks of slope then insert as intermediary points)
V - base of bank toe
W - end point (typically mid point of channel)



Notes:
Bank profile may overhang.
If the bank profile is fully populated, the shear surface emergence point should be anywhere between points B and Q.
The shear surface emergence point must not be on a horizontal section - the elevation of this point must be unique or an error message will display.

Channel and flow parameters

18.3	Input reach length (m)
0.0005	Input reach slope (m/m)
0.24	Input elevation of flow (m)
4380	Input duration of flow (hrs)

View Bank Geometry

Run Bank Geometry Macro

Select material types (or select "own data" and add values below)

Bank Material					Bank Toe Material
Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
Own data	Own data	Own data	Own data	Own data	Own data

Bank and bank-toe material data tables.

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white boxes.

Material Descriptors			Bank Model Input Data					Groundwater Model Input Data						Toe Model Input Data	
Bank material type	*Description*	*Mean grain size, D_{50} (m)*	*Friction angle ϕ' (degrees)*	*Cohesion c' (kPa)*	*Saturated unit weight (kN/m^3)*	*ϕ^b (degrees)*	*Chemical concentration (kg/kg)*	*Hydraulic Conductivity k_{sat} (m/s)*	*Bulk Modulus (Pa)*	*Porosity*	*Residual water content*	*van Genuchten α (1/m)*	*van Genuchten n*	τ_c (Pa)	*k* (cm^3/Ns)
1	Boulders	0.512	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	498	0.004
2	Cobbles	0.128	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	124	0.009
3	Gravel	0.0113	36.0	0.0	20.0	15.0	-	3.160E-03	1.354E+08	0.320	0.070	3.5237	2.3286	11.0	0.030
4a and 4b	Angular sand	0.00035	32.3	0.4	18.5	15.0	-	7.439E-05	1.354E+07	0.375	0.053	3.5237	3.1769	Coarse (0.71 mm) or	
5a and 5b	Rounded sand	0.00035	28.3	0.4	18.5	15.0	-	1.130E-06	6.056E+07	0.380	0.033	2.0563	2.3286	Fine (0.18 mm)	
6a, 6b and 6c	Silt	-	26.6	4.3	18.0	15.0	-	5.064E-06	1.049E+07	0.489	0.050	0.6577	1.6788	Erodible (0.100 Pa),	
7a, 7b and 7c	Soft clay	-	26.4	8.2	17.7	15.0	-	9.473E-07	1.354E+06	0.472	0.079	1.5812	1.4158	Moderate (5.00 Pa), or	
8a, 8b and 8c	Stiff clay	-	21.1	12.6	17.7	15.0	-	1.708E-06	5.417E+06	0.459	0.093	1.4962	1.2531	Resistant (50.0 Pa)	
	Own data layer 1		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 2		25.0	10.0	18.0	15.0	0.0							0.72	0.236
9	Own data layer 3		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 4		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 5			10.0	18.0	15.0	0.0							0.72	0.236
	Own data Bank Toe													0.72	0.118

COMING SOON!

Need to know the critical shear stress (τ_c) ?		Need to know the erodibility coefficient (*k*) ?	
Input non-cohesive particle diameter (mm)	0.075	Input critical shear stress τ_c (Pa)	0.721
Critical Shear Stress τ_c (Pa)	0.05	Erodibility Coefficient (cm^3/Ns)	0.118

Simulate the mechanical effects of *bank top* vegetation on bank stability using a root-reinforcement model

RipRoot (Pollen and Simon, 2005) is a global load-sharing fiber-bundle model. It explicitly simulates both the snapping of roots and the slipping of roots through the soil matrix, by determining the minimum applied load required to either break each root or pull each root out of the soil matrix. As the strength of each root is removed from the fiber bundle, the load is redistributed to the remaining roots according to the ratio of the diameter of each root to the sum of the diameters of all the intact roots. RipRoot builds on earlier work by Waldron (1977), Wu *et al*. (1979) and Waldron and Dakessian (1981).

Run Root-Reinforcement Model

Root-Reinforcement Model Output

List of Species River Birch; Eastern Sycamore; Black Willow;
Percent of Assemblage 33.3; 33.3; 33.4;

Added cohesion due to roots, c_r 0.1 kPa

Protect the bank and/or bank-toe against *hydraulic erosion* by adding treatments (or select "own data" and add values below)

Protection

Bank Protection	Bank Toe Protection
Rip Rap (D50 0.256 m)	Own Data

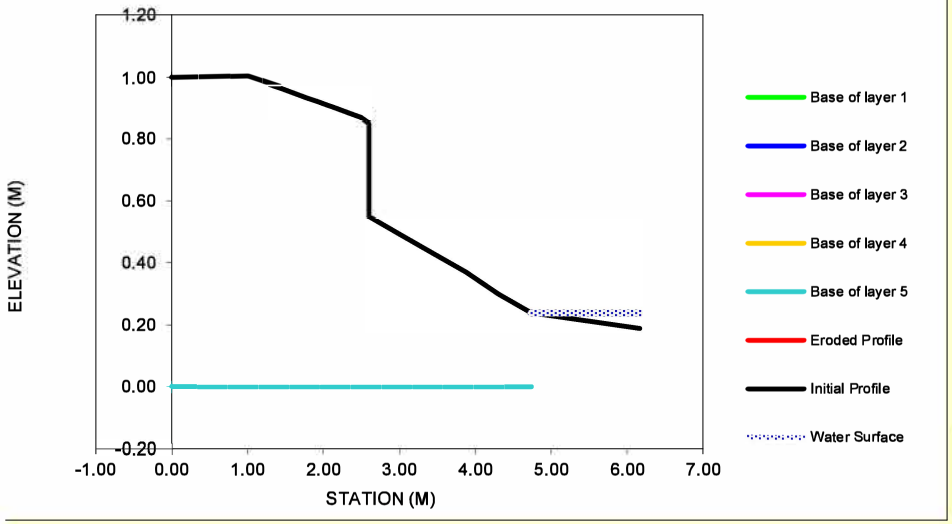
Bank and bank-toe protection data table

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white box.

Bank and Bank-Toe Protection Descriptors

Protection type	*Description*	*Permissible shear stress (Pa)*
1	No protection	-
2	Coir fiber	108
3	Geotextile (synthetic)	144
4	Jute net	22
5	Large Woody Debris	192
6	Live fascine	100
7	Plant cuttings	17
8	Rip Rap (D_{50} 0.256 m)	204
9	-	
10	-	
11	-	
12	-	
13	Own Data	100.0

	Bank Material					Bank Toe Material	
	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5		
Material	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Own Data	**Material**
Critical shear stress (Pa)	204.00	204.00	204.00	204.00	204.00	100.00	**Critical shear stress (Pa)**
Erodibility Coefficient (cm^3/Ns)	0.00 7	0.00 7	0.00 7	0.00 7	0.00 7	0.010	**Erodibility Coefficient (cm^3/Ns)**



Run Toe-Erosion Model

Account for:

Stream Curvature ☐

Effective stress acting on each grain ☐

Average applied boundary shear stress	0.060	Pa
Maximum Lateral Retreat	0.000	cm
Eroded Area - Bank	0.000	m^2
Eroded Area - Bank Toe	0.000	m^2
Eroded Area - Bed	0.000	m^2
Eroded Area - Total	0.000	m^2

Export New (Eroded) Profile into Model

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

1) Select **EITHER** Option A or Option B for Bank Profile and enter the data in the relevant box- cells in the alternative option are ignored in the simulation and may be left blank if desired.
2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).
3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.

To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below

◉ Option A

Point	Station (m)	Elevation (m)	Top of toe?
A	0.00	1.03	
B	0.92	1.03	
C	0.92	0.99	☐
D	0.92	0.95	☐
E	0.92	0.91	☐
F	0.92	0.87	☐
G	0.92	0.83	☐
H	0.92	0.79	☐
I	0.92	0.75	☐
J	0.92	0.71	☐
K	0.92	0.66	☐
L	0.92	0.62	☐
M	0.92	0.58	☐
N	0.92	0.54	☐
O	0.92	0.50	☐
P	0.92	0.46	☐
Q	0.92	0.42	☑
R	1.29	0.36	
S	1.65	0.30	
T	2.02	0.24	
U	2.38	0.18	
V	2.75	0.12	
W	5.16	0.00	

Shear emergence elev: 0.42

Shear surface angle: 35.00

Option B - Enter a bank height and angle, the model will generate a bank profile

○ Option B

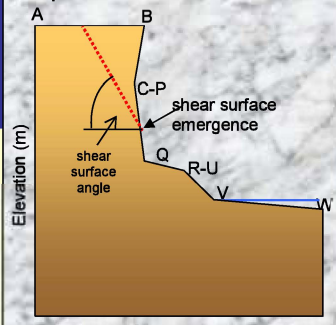
- a) Input bank height (m)
- b) Input bank angle (°)
- c) Input bank toe length (m)
- d) Input bank toe angle (°)
- Input shear surface angle

Bank layer thickness (m)

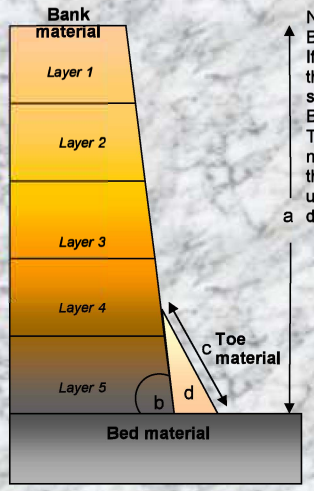
		Elevation of layer base (m)
	Top Layer	
Layer 1	1.03	0.00
Layer 2	0.00	0.00
Layer 3	0.00	0.00
Layer 4	0.00	0.00
Layer 5	0.00	0.00
	Bottom Layer	

Parallel layers, starting from point B

Definition of points used in bank profile



A - bank top: place beyond start of shear surface
B - bank edge
C-P - breaks of slope on bank (if no breaks of slope place as intermediary points)
Q - top of bank toe
R-U - breaks of slope on bank toe (if no breaks of slope then insert as intermediary points)
V - base of bank toe
W - end point (typically mid point of channel)



Notes:
Bank profile may overhang.
If the bank profile is fully populated, the shear surface emergence point should be anywhere between points B and Q.
The shear surface emergence point must not be on a horizontal section - the elevation of this point must be unique or an error message will display.

Channel and flow parameters

14.178	Input reach length (m)
0.0005	Input reach slope (m/m)
0.42	Input elevation of flow (m)
4380	Input duration of flow (hrs)

View Bank Geometry

Run Bank Geometry Macro

Select material types (or select "own data" and add values below)

Bank Material					Bank Toe Material
Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
Own data	Own data	Own data	Own data	Own data	Own data

Bank and bank-toe material data tables.

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white boxes.

Material Descriptors			Bank Model Input Data					Groundwater Model Input Data						Toe Model Input Data	
Bank material type	*Description*	*Mean grain size, D_{50} (m)*	*Friction angle ϕ' (degrees)*	*Cohesion c' (kPa)*	*Saturated unit weight (kN/m^3)*	*ϕ^b (degrees)*	*Chemical concentration (kg/kg)*	*Hydraulic Conductivity k_{sat} (m/s)*	*Bulk Modulus (Pa)*	*Porosity*	*Residual water content*	*van Genuchten α (1/m)*	*van Genuchten n*	τ_c (Pa)	*k* (cm^3/Ns)
1	Boulders	0.512	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	498	0.004
2	Cobbles	0.128	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	124	0.009
3	Gravel	0.0113	36.0	0.0	20.0	15.0	-	3.160E-03	1.354E+08	0.320	0.070	3.5237	2.3286	11.0	0.030
4a and 4b	Angular sand	0.00035	32.3	0.4	18.5	15.0	-	7.439E-05	1.354E+07	0.375	0.053	3.5237	3.1769	Coarse (0.71 mm) or	
5a and 5b	Rounded sand	0.00035	28.3	0.4	18.5	15.0	-	1.130E-06	6.056E+07	0.380	0.033	2.0563	2.3286	Fine (0.18 mm)	
6a, 6b and 6c	Silt	-	26.6	4.3	18.0	15.0	-	5.064E-06	1.049E+07	0.489	0.050	0.6577	1.6788	Erodible (0.100 Pa),	
7a, 7b and 7c	Soft clay	-	26.4	8.2	17.7	15.0	-	9.473E-07	1.354E+06	0.472	0.079	1.5812	1.4158	Moderate (5.00 Pa), or	
8a, 8b and 8c	Stiff clay	-	21.1	12.6	17.7	15.0	-	1.708E-06	5.417E+06	0.459	0.093	1.4962	1.2531	Resistant (50.0 Pa)	
	Own data layer 1		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 2		25.0	10.0	18.0	15.0	0.0							0.72	0.236
9	Own data layer 3		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 4		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 5			10.0	18.0	15.0	0.0							0.72	0.236
	Own data Bank Toe													0.72	0.118

COMING SOON!

Need to know the critical shear stress (τ_c) ?		Need to know the erodibility coefficient (*k*) ?	
Input non-cohesive particle diameter (mm)	0.075	Input critical shear stress τ_c (Pa)	0.721
Critical Shear Stress τ_c (Pa)	0.05	Erodibility Coefficient (cm^3/Ns)	0.118

Simulate the mechanical effects of *bank top* vegetation on bank stability using a root-reinforcement model

RipRoot (Pollen and Simon, 2005) is a global load-sharing fiber-bundle model. It explicitly simulates both the snapping of roots and the slipping of roots through the soil matrix, by determining the minimum applied load required to either break each root or pull each root out of the soil matrix. As the strength of each root is removed from the fiber bundle, the load is redistributed to the remaining roots according to the ratio of the diameter of each root to the sum of the diameters of all the intact roots. RipRoot builds on earlier work by Waldron (1977), Wu *et al*. (1979) and Waldron and Dakessian (1981).

Run Root-Reinforcement Model

Root-Reinforcement Model Output

List of Species River Birch; Eastern Sycamore; Black Willow;
Percent of Assemblage 33.3; 33.3; 33.4;

Added cohesion due to roots, c_r 0.0 kPa

Protect the bank and/or bank-toe against *hydraulic erosion* by adding treatments (or select "own data" and add values below)

Protection

Bank Protection	Bank Toe Protection
Rip Rap (D50 0.256 m)	Own Data

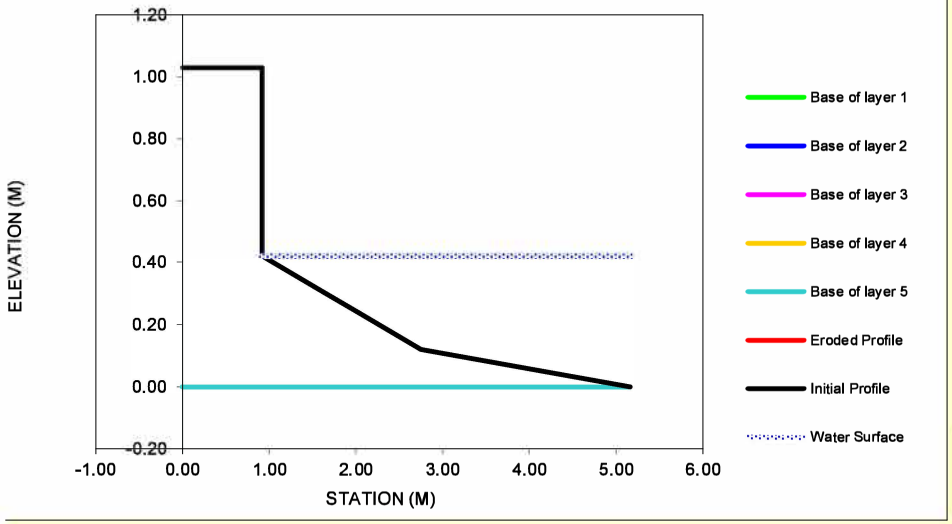
Bank and bank-toe protection data table

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white box.

Bank and Bank-Toe Protection Descriptors

Protection type	*Description*	*Permissible shear stress (Pa)*
1	No protection	-
2	Coir fiber	108
3	Geotextile (synthetic)	144
4	Jute net	22
5	Large Woody Debris	192
6	Live fascine	100
7	Plant cuttings	17
8	Rip Rap (D_{50} 0.256 m)	204
9	-	
10	-	
11	-	
12	-	
13	Own Data	40.0

	Bank Material					Bank Toe Material	
	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5		
Material	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Own Data	**Material**
Critical shear stress (Pa)	204.00	204.00	204.00	204.00	204.00	40.00	**Critical shear stress (Pa)**
Erodibility Coefficient (cm^3/Ns)	0.00 7	0.00 7	0.00 7	0.00 7	0.00 7	0.016	**Erodibility Coefficient (cm^3/Ns)**



Run Toe-Erosion Model

Account for:

Stream Curvature ☐

Effective stress acting on each grain ☐

Average applied boundary shear stress	0.700	Pa
Maximum Lateral Retreat	0.000	cm
Eroded Area - Bank	0.000	m^2
Eroded Area - Bank Toe	0.000	m^2
Eroded Area - Bed	0.000	m^2
Eroded Area - Total	0.000	m^2

Export New (Eroded) Profile into Model

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

1) Select **EITHER** Option A or Option B for Bank Profile and enter the data in the relevant box- cells in the alternative option are ignored in the simulation and may be left blank if desired.
2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).
3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.

To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below

◉ Option A

Point	Station (m)	Elevation (m)	Top of toe?
A	0.00	1.03	
B	0.92	1.03	
C	0.92	0.99	☐
D	0.92	0.95	☐
E	0.92	0.91	☐
F	0.92	0.87	☐
G	0.92	0.83	☐
H	0.92	0.79	☐
I	0.92	0.75	☐
J	0.92	0.71	☐
K	0.92	0.66	☐
L	0.92	0.62	☐
M	0.92	0.58	☐
N	0.92	0.54	☐
O	0.92	0.50	☐
P	0.92	0.46	☐
Q	0.92	0.42	☑
R	1.29	0.36	
S	1.65	0.30	
T	2.02	0.24	
U	2.38	0.18	
V	2.75	0.12	
W	5.16	0.00	

Shear emergence elev: 0.42

Shear surface angle: 35.00

Option B - Enter a bank height and angle, the model will generate a bank profile

○ Option B

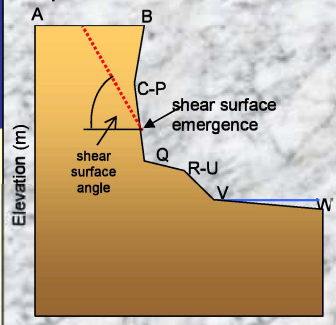
- a) Input bank height (m)
- b) Input bank angle (°)
- c) Input bank toe length (m)
- d) Input bank toe angle (°)
- Input shear surface angle

Bank layer thickness (m)

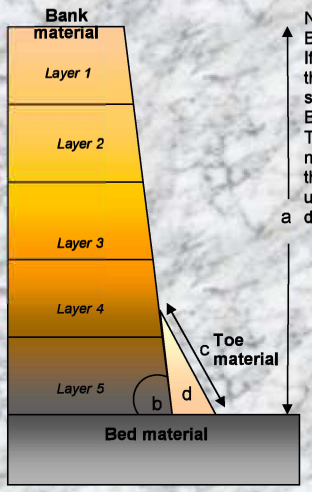
		Elevation of layer base (m)
	Top Layer	
Layer 1	1.03	0.00
Layer 2	0.00	0.00
Layer 3	0.00	0.00
Layer 4	0.00	0.00
Layer 5	0.00	0.00
	Bottom Layer	

Parallel layers, starting from point B

Definition of points used in bank profile



A - bank top: place beyond start of shear surface
B - bank edge
C-P - breaks of slope on bank (if no breaks of slope place as intermediary points)
Q - top of bank toe
R-U - breaks of slope on bank toe (if no breaks of slope then insert as intermediary points)
V - base of bank toe
W - end point (typically mid point of channel)



Notes:
Bank profile may overhang.
If the bank profile is fully populated, the shear surface emergence point should be anywhere between points B and Q.
The shear surface emergence point must not be on a horizontal section - the elevation of this point must be unique or an error message will display.

Channel and flow parameters

14.178	Input reach length (m)
0.0005	Input reach slope (m/m)
0.12	Input elevation of flow (m)
4380	Input duration of flow (hrs)

View Bank Geometry

Run Bank Geometry Macro

Select material types (or select "own data" and add values below)

Bank Material					Bank Toe Material
Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
Own data	Own data	Own data	Own data	Own data	Own data

Bank and bank-toe material data tables.

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white boxes.

Material Descriptors			Bank Model Input Data					Groundwater Model Input Data						Toe Model Input Data	
Bank material type	*Description*	*Mean grain size, D_{50} (m)*	*Friction angle ϕ' (degrees)*	*Cohesion c' (kPa)*	*Saturated unit weight (kN/m^3)*	*ϕ^b (degrees)*	*Chemical concentration (kg/kg)*	*Hydraulic Conductivity k_{sat} (m/s)*	*Bulk Modulus (Pa)*	*Porosity*	*Residual water content*	*van Genuchten α (1/m)*	*van Genuchten n*	τ_c (Pa)	*k* (cm^3/Ns)
1	Boulders	0.512	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	498	0.004
2	Cobbles	0.128	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	124	0.009
3	Gravel	0.0113	36.0	0.0	20.0	15.0	-	3.160E-03	1.354E+08	0.320	0.070	3.5237	2.3286	11.0	0.030
4a and 4b	Angular sand	0.00035	32.3	0.4	18.5	15.0	-	7.439E-05	1.354E+07	0.375	0.053	3.5237	3.1769	Coarse (0.71 mm) or	
5a and 5b	Rounded sand	0.00035	28.3	0.4	18.5	15.0	-	1.130E-06	6.056E+07	0.380	0.033	2.0563	2.3286	Fine (0.18 mm)	
6a, 6b and 6c	Silt	-	26.6	4.3	18.0	15.0	-	5.064E-06	1.049E+07	0.489	0.050	0.6577	1.6788	Erodible (0.100 Pa),	
7a, 7b and 7c	Soft clay	-	26.4	8.2	17.7	15.0	-	9.473E-07	1.354E+06	0.472	0.079	1.5812	1.4158	Moderate (5.00 Pa), or	
8a, 8b and 8c	Stiff clay	-	21.1	12.6	17.7	15.0	-	1.708E-06	5.417E+06	0.459	0.093	1.4962	1.2531	Resistant (50.0 Pa)	
	Own data layer 1		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 2		25.0	10.0	18.0	15.0	0.0							0.72	0.236
9	Own data layer 3		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 4		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 5			10.0	18.0	15.0	0.0							0.72	0.236
	Own data Bank Toe													0.72	0.118

COMING SOON!

Need to know the critical shear stress (τ_c) ?		Need to know the erodibility coefficient (*k*) ?	
Input non-cohesive particle diameter (mm)	0.075	Input critical shear stress τ_c (Pa)	0.721
Critical Shear Stress τ_c (Pa)	0.05	Erodibility Coefficient (cm^3/Ns)	0.118

Simulate the mechanical effects of *bank top* vegetation on bank stability using a root-reinforcement model

RipRoot (Pollen and Simon, 2005) is a global load-sharing fiber-bundle model. It explicitly simulates both the snapping of roots and the slipping of roots through the soil matrix, by determining the minimum applied load required to either break each root or pull each root out of the soil matrix. As the strength of each root is removed from the fiber bundle, the load is redistributed to the remaining roots according to the ratio of the diameter of each root to the sum of the diameters of all the intact roots. RipRoot builds on earlier work by Waldron (1977), Wu *et al*. (1979) and Waldron and Dakessian (1981).

Run Root-Reinforcement Model

Root-Reinforcement Model Output

List of Species River Birch; Eastern Sycamore; Black Willow;
Percent of Assemblage 33.3; 33.3; 33.4;

Added cohesion due to roots, c_r 0.0 kPa

Protect the bank and/or bank-toe against *hydraulic erosion* by adding treatments (or select "own data" and add values below)

Protection

Bank Protection	Bank Toe Protection
Rip Rap (D50 0.256 m)	Own Data

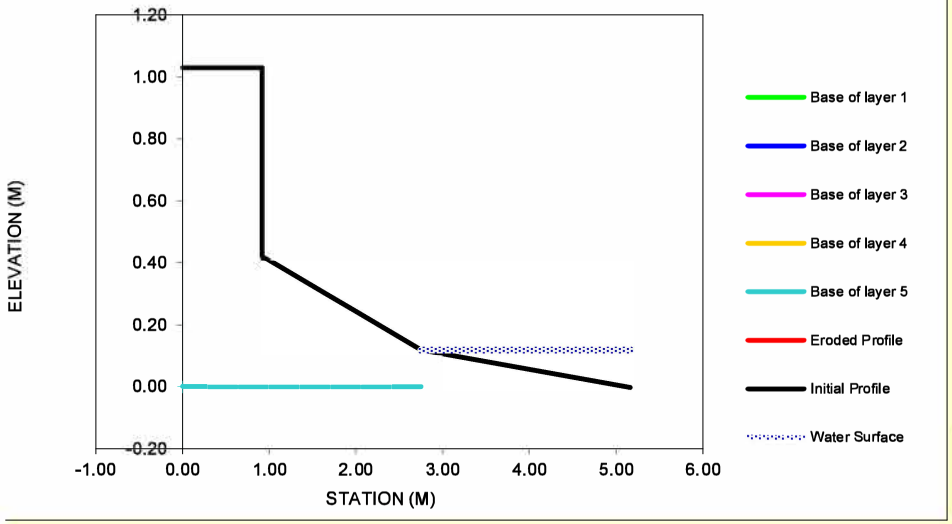
Bank and bank-toe protection data table

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white box.

Bank and Bank-Toe Protection Descriptors

Protection type	*Description*	*Permissible shear stress (Pa)*
1	No protection	-
2	Coir fiber	108
3	Geotextile (synthetic)	144
4	Jute net	22
5	Large Woody Debris	192
6	Live fascine	100
7	Plant cuttings	17
8	Rip Rap (D_{50} 0.256 m)	204
9	-	
10	-	
11	-	
12	-	
13	Own Data	40.0

	Bank Material					Bank Toe Material	
	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5		
Material	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Own Data	**Material**
Critical shear stress (Pa)	204.00	204.00	204.00	204.00	204.00	40.00	**Critical shear stress (Pa)**
Erodibility Coefficient (cm^3/Ns)	0.00 7	0.00 7	0.00 7	0.00 7	0.00 7	0.016	**Erodibility Coefficient (cm^3/Ns)**



Run Toe-Erosion Model

Account for:

Stream Curvature ☐

Effective stress acting on each grain ☐

Average applied boundary shear stress	0.150	Pa
Maximum Lateral Retreat	0.000	cm
Eroded Area - Bank	0.000	m^2
Eroded Area - Bank Toe	0.000	m^2
Eroded Area - Bed	0.000	m^2
Eroded Area - Total	0.000	m^2

Export New (Eroded) Profile into Model

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

1) Select **EITHER** Option A or Option B for Bank Profile and enter the data in the relevant box- cells in the alternative option are ignored in the simulation and may be left blank if desired.
2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).
3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.

To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below

◉ Option A

Point	Station (m)	Elevation (m)	Top of toe?
A	-0.82	1.61	
B	0.92	1.61	
C	0.92	1.53	☐
D	0.92	1.45	☐
E	0.92	1.37	☐
F	0.92	1.29	☐
G	0.92	1.20	☐
H	0.92	1.12	☐
I	0.92	1.04	☐
J	0.92	0.96	☐
K	0.92	0.88	☐
L	0.92	0.80	☐
M	0.92	0.72	☐
N	0.92	0.63	☐
O	0.92	0.55	☐
P	0.92	0.47	☐
Q	0.92	0.39	☑
R	1.29	0.32	
S	1.65	0.26	
T	2.02	0.20	
U	2.38	0.14	
V	2.75	0.08	
W	5.16	0.00	

Shear emergence elev: 0.39

Shear surface angle: 35.00

Option B - Enter a bank height and angle, the model will generate a bank profile

○ Option B

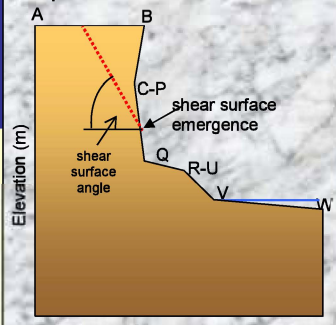
- a) Input bank height (m)
- b) Input bank angle (°)
- c) Input bank toe length (m)
- d) Input bank toe angle (°)
- Input shear surface angle

Bank layer thickness (m)

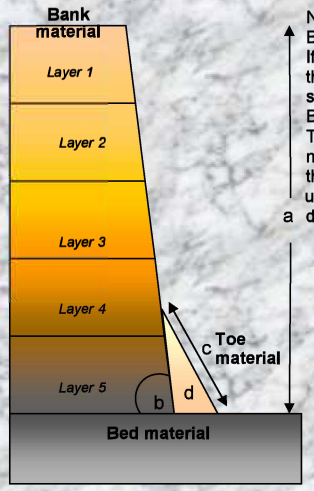
		Elevation of layer base (m)
	Top Layer	
Layer 1	1.61	0.00
Layer 2	0.00	0.00
Layer 3	0.00	0.00
Layer 4	0.00	0.00
Layer 5	0.00	0.00
	Bottom Layer	

Parallel layers, starting from point B

Definition of points used in bank profile



A - bank top: place beyond start of shear surface
B - bank edge
C-P - breaks of slope on bank (if no breaks of slope place as intermediary points)
Q - top of bank toe
R-U - breaks of slope on bank toe (if no breaks of slope then insert as intermediary points)
V - base of bank toe
W - end point (typically mid point of channel)



Notes:
Bank profile may overhang.
If the bank profile is fully populated, the shear surface emergence point should be anywhere between points B and Q.
The shear surface emergence point must not be on a horizontal section - the elevation of this point must be unique or an error message will display.

Channel and flow parameters

7.457	Input reach length (m)
0.0005	Input reach slope (m/m)
0.39	Input elevation of flow (m)
4380	Input duration of flow (hrs)

View Bank Geometry

Run Bank Geometry Macro

Select material types (or select "own data" and add values below)

Bank Material					Bank Toe Material
Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
Own data	Own data	Own data	Own data	Own data	Own data

Bank and bank-toe material data tables.

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white boxes.

Material Descriptors			Bank Model Input Data					Groundwater Model Input Data						Toe Model Input Data	
Bank material type	*Description*	*Mean grain size, D_{50} (m)*	*Friction angle ϕ' (degrees)*	*Cohesion c' (kPa)*	*Saturated unit weight (kN/m^3)*	*ϕ^b (degrees)*	*Chemical concentration (kg/kg)*	*Hydraulic Conductivity k_{sat} (m/s)*	*Bulk Modulus (Pa)*	*Porosity*	*Residual water content*	*van Genuchten α (1/m)*	*van Genuchten n*	τ_c (Pa)	*k* (cm^3/Ns)
1	Boulders	0.512	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	498	0.004
2	Cobbles	0.128	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	124	0.009
3	Gravel	0.0113	36.0	0.0	20.0	15.0	-	3.160E-03	1.354E+08	0.320	0.070	3.5237	2.3286	11.0	0.030
4a and 4b	Angular sand	0.00035	32.3	0.4	18.5	15.0	-	7.439E-05	1.354E+07	0.375	0.053	3.5237	3.1769	Coarse (0.71 mm) or	
5a and 5b	Rounded sand	0.00035	28.3	0.4	18.5	15.0	-	1.130E-06	6.056E+07	0.380	0.033	2.0563	2.3286	Fine (0.18 mm)	
6a, 6b and 6c	Silt	-	26.6	4.3	18.0	15.0	-	5.064E-06	1.049E+07	0.489	0.050	0.6577	1.6788	Erodible (0.100 Pa),	
7a, 7b and 7c	Soft clay	-	26.4	8.2	17.7	15.0	-	9.473E-07	1.354E+06	0.472	0.079	1.5812	1.4158	Moderate (5.00 Pa), or	
8a, 8b and 8c	Stiff clay	-	21.1	12.6	17.7	15.0	-	1.708E-06	5.417E+06	0.459	0.093	1.4962	1.2531	Resistant (50.0 Pa)	
	Own data layer 1		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 2		25.0	10.0	18.0	15.0	0.0							0.72	0.236
9	Own data layer 3		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 4		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 5			10.0	18.0	15.0	0.0							0.72	0.236
	Own data Bank Toe													0.72	0.118

COMING SOON!

Need to know the critical shear stress (τ_c) ?		Need to know the erodibility coefficient (*k*) ?	
Input non-cohesive particle diameter (mm)	0.075	Input critical shear stress τ_c (Pa)	0.721
Critical Shear Stress τ_c (Pa)	0.05	Erodibility Coefficient (cm^3/Ns)	0.118

Simulate the mechanical effects of *bank top* vegetation on bank stability using a root-reinforcement model

RipRoot (Pollen and Simon, 2005) is a global load-sharing fiber-bundle model. It explicitly simulates both the snapping of roots and the slipping of roots through the soil matrix, by determining the minimum applied load required to either break each root or pull each root out of the soil matrix. As the strength of each root is removed from the fiber bundle, the load is redistributed to the remaining roots according to the ratio of the diameter of each root to the sum of the diameters of all the intact roots. RipRoot builds on earlier work by Waldron (1977), Wu *et al*. (1979) and Waldron and Dakessian (1981).

Run Root-Reinforcement Model

Root-Reinforcement Model Output

List of Species River Birch; Eastern Sycamore; Black Willow; Alamo Switch Grass; Wet
Percent of Assemblage 16.7; 16.7; 16.7; 16.7; 16.7; 16.6;

Added cohesion due to roots, c_r 0.1 kPa

Protect the bank and/or bank-toe against *hydraulic erosion* by adding treatments (or select "own data" and add values below)

Protection

Bank Protection	Bank Toe Protection
Rip Rap (D50 0.256 m)	Own Data

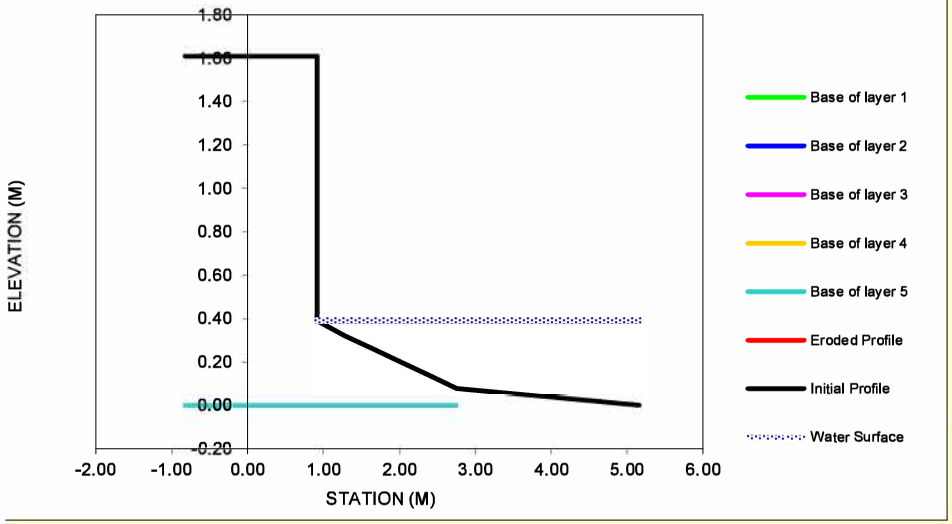
Bank and bank-toe protection data table

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white box.

Bank and Bank-Toe Protection Descriptors

Protection type	*Description*	*Permissible shear stress (Pa)*
1	No protection	-
2	Coir fiber	108
3	Geotextile (synthetic)	144
4	Jute net	22
5	Large Woody Debris	192
6	Live fascine	100
7	Plant cuttings	17
8	Rip Rap (D_{50} 0.256 m)	204
9	-	
10	-	
11	-	
12	-	
13	Own Data	100.0

	Bank Material					Bank Toe Material	
	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5		
Material	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Own Data	**Material**
Critical shear stress (Pa)	204.00	204.00	204.00	204.00	204.00	100.00	**Critical shear stress (Pa)**
Erodibility Coefficient (cm^3/Ns)	0.00 7	0.00 7	0.00 7	0.00 7	0.00 7	0.010	**Erodibility Coefficient (cm^3/Ns)**



Run Toe-Erosion Model

Account for:

Stream Curvature ☐

Effective stress acting on each grain ☐

Average applied boundary shear stress	0.750	Pa
Maximum Lateral Retreat	0.000	cm
Eroded Area - Bank	0.000	m^2
Eroded Area - Bank Toe	0.000	m^2
Eroded Area - Bed	0.000	m^2
Eroded Area - Total	0.000	m^2

Export New (Eroded) Profile into Model

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

1) Select **EITHER** Option A or Option B for Bank Profile and enter the data in the relevant box- cells in the alternative option are ignored in the simulation and may be left blank if desired.
2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).
3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.

To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below

◉ Option A

Point	Station (m)	Elevation (m)	Top of toe?
A	-0.82	1.61	
B	0.92	1.61	
C	0.92	1.53	☐
D	0.92	1.45	☐
E	0.92	1.37	☐
F	0.92	1.29	☐
G	0.92	1.20	☐
H	0.92	1.12	☐
I	0.92	1.04	☐
J	0.92	0.96	☐
K	0.92	0.88	☐
L	0.92	0.80	☐
M	0.92	0.72	☐
N	0.92	0.63	☐
O	0.92	0.55	☐
P	0.92	0.47	☐
Q	0.92	0.39	☑
R	1.29	0.32	
S	1.65	0.26	
T	2.02	0.20	
U	2.38	0.14	
V	2.75	0.08	
W	5.16	0.00	

Shear emergence elev: 0.39

Shear surface angle: 35.00

Option B - Enter a bank height and angle, the model will generate a bank profile

○ Option B

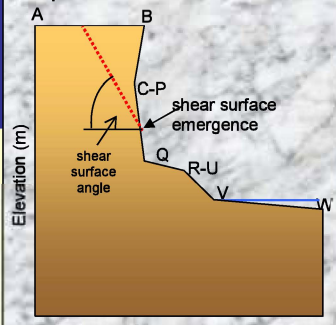
- a) Input bank height (m)
- b) Input bank angle (°)
- c) Input bank toe length (m)
- d) Input bank toe angle (°)
- Input shear surface angle

Bank layer thickness (m)

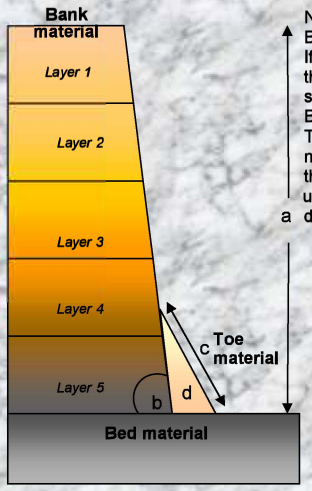
		Elevation of layer base (m)
	Top Layer	
Layer 1	1.61	0.00
Layer 2	0.00	0.00
Layer 3	0.00	0.00
Layer 4	0.00	0.00
Layer 5	0.00	0.00
	Bottom Layer	

Parallel layers, starting from point B

Definition of points used in bank profile



A - bank top: place beyond start of shear surface
B - bank edge
C-P - breaks of slope on bank (if no breaks of slope place as intermediary points)
Q - top of bank toe
R-U - breaks of slope on bank toe (if no breaks of slope then insert as intermediary points)
V - base of bank toe
W - end point (typically mid point of channel)



Notes:
Bank profile may overhang.
If the bank profile is fully populated, the shear surface emergence point should be anywhere between points B and Q.
The shear surface emergence point must not be on a horizontal section - the elevation of this point must be unique or an error message will display.

Channel and flow parameters

7.457	Input reach length (m)
0.0005	Input reach slope (m/m)
0.08	Input elevation of flow (m)
4380	Input duration of flow (hrs)

View Bank Geometry

Run Bank Geometry Macro

Select material types (or select "own data" and add values below)

Bank Material					Bank Toe Material
Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
Own data	Own data	Own data	Own data	Own data	Own data

Bank and bank-toe material data tables.

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white boxes.

Material Descriptors			Bank Model Input Data					Groundwater Model Input Data						Toe Model Input Data	
Bank material type	*Description*	*Mean grain size, D_{50} (m)*	*Friction angle ϕ' (degrees)*	*Cohesion c' (kPa)*	*Saturated unit weight (kN/m^3)*	*ϕ^b (degrees)*	*Chemical concentration (kg/kg)*	*Hydraulic Conductivity k_{sat} (m/s)*	*Bulk Modulus (Pa)*	*Porosity*	*Residual water content*	*van Genuchten α (1/m)*	*van Genuchten n*	τ_c (Pa)	*k* (cm^3/Ns)
1	Boulders	0.512	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	498	0.004
2	Cobbles	0.128	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	124	0.009
3	Gravel	0.0113	36.0	0.0	20.0	15.0	-	3.160E-03	1.354E+08	0.320	0.070	3.5237	2.3286	11.0	0.030
4a and 4b	Angular sand	0.00035	32.3	0.4	18.5	15.0	-	7.439E-05	1.354E+07	0.375	0.053	3.5237	3.1769	Coarse (0.71 mm) or	
5a and 5b	Rounded sand	0.00035	28.3	0.4	18.5	15.0	-	1.130E-06	6.056E+07	0.380	0.033	2.0563	2.3286	Fine (0.18 mm)	
6a, 6b and 6c	Silt	-	26.6	4.3	18.0	15.0	-	5.064E-06	1.049E+07	0.489	0.050	0.6577	1.6788	Erodible (0.100 Pa),	
7a, 7b and 7c	Soft clay	-	26.4	8.2	17.7	15.0	-	9.473E-07	1.354E+06	0.472	0.079	1.5812	1.4158	Moderate (5.00 Pa), or	
8a, 8b and 8c	Stiff clay	-	21.1	12.6	17.7	15.0	-	1.708E-06	5.417E+06	0.459	0.093	1.4962	1.2531	Resistant (50.0 Pa)	
	Own data layer 1		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 2		25.0	10.0	18.0	15.0	0.0							0.72	0.236
9	Own data layer 3		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 4		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 5			10.0	18.0	15.0	0.0							0.72	0.236
	Own data Bank Toe													0.72	0.118

COMING SOON!

Need to know the critical shear stress (τ_c) ?		Need to know the erodibility coefficient (*k*) ?	
Input non-cohesive particle diameter (mm)	0.075	Input critical shear stress τ_c (Pa)	0.721
Critical Shear Stress τ_c (Pa)	0.05	Erodibility Coefficient (cm^3/Ns)	0.118

Simulate the mechanical effects of *bank top* vegetation on bank stability using a root-reinforcement model

RipRoot (Pollen and Simon, 2005) is a global load-sharing fiber-bundle model. It explicitly simulates both the snapping of roots and the slipping of roots through the soil matrix, by determining the minimum applied load required to either break each root or pull each root out of the soil matrix. As the strength of each root is removed from the fiber bundle, the load is redistributed to the remaining roots according to the ratio of the diameter of each root to the sum of the diameters of all the intact roots. RipRoot builds on earlier work by Waldron (1977), Wu *et al*. (1979) and Waldron and Dakessian (1981).

Run Root-Reinforcement Model

Root-Reinforcement Model Output

List of Species River Birch; Eastern Sycamore; Black Willow; Alamo Switch Grass; Wet
Percent of Assemblage 16.7; 16.7; 16.7; 16.7; 16.7; 16.6;

Added cohesion due to roots, c_r 0.1 kPa

Protect the bank and/or bank-toe against *hydraulic erosion* by adding treatments (or select "own data" and add values below)

Protection

Bank Protection	Bank Toe Protection
Rip Rap (D50 0.256 m)	Own Data

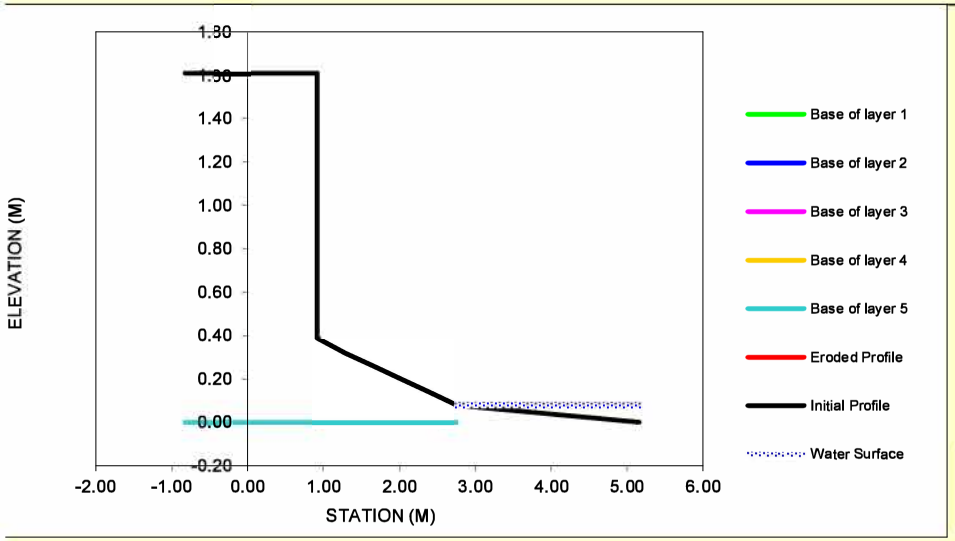
Bank and bank-toe protection data table

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white box.

Bank and Bank-Toe Protection Descriptors

Protection type	*Description*	*Permissible shear stress (Pa)*
1	No protection	-
2	Coir fiber	108
3	Geotextile (synthetic)	144
4	Jute net	22
5	Large Woody Debris	192
6	Live fascine	100
7	Plant cuttings	17
8	Rip Rap (D_{50} 0.256 m)	204
9	-	
10	-	
11	-	
12	-	
13	Own Data	100.0

	Bank Material					Bank Toe Material	
	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5		
Material	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Rip Rap (D50 0.256 m)	Own Data	Material
Critical shear stress (Pa)	204.00	204.00	204.00	204.00	204.00	100.00	Critical shear stress (Pa)
Erodibility Coefficient (cm^3/Ns)	0.00 7	0.00 7	0.00 7	0.00 7	0.00 7	0.010	Erodibility Coefficient (cm^3/Ns)



Run Toe-Erosion Model

Account for:

Stream Curvature ☐

Effective stress acting on each grain ☐

Average applied boundary shear stress	0.100	Pa
Maximum Lateral Retreat	0.000	cm
Eroded Area - Bank	0.000	m^2
Eroded Area - Bank Toe	0.000	m^2
Eroded Area - Bed	0.000	m^2
Eroded Area - Total	0.000	m^2

Export New (Eroded) Profile into Model

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

1) Select **EITHER** Option A or Option B for Bank Profile and enter the data in the relevant box- cells in the alternative option are ignored in the simulation and may be left blank if desired.
2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).
3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.

To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below

◉ Option A

Point	Station (m)	Elevation (m)	Top of toe?
A	0.00	0.75	
B	0.92	0.75	
C	0.92	0.73	☐
D	0.92	0.71	☐
E	0.92	0.69	☐
F	0.92	0.67	☐
G	0.92	0.65	☐
H	0.92	0.63	☐
I	0.92	0.61	☐
J	0.92	0.59	☐
K	0.92	0.56	☐
L	0.92	0.54	☐
M	0.92	0.52	☐
N	0.92	0.50	☐
O	0.92	0.48	☐
P	0.92	0.46	☐
Q	0.92	0.44	☑
R	1.23	0.38	
S	1.53	0.32	
T	1.84	0.26	
U	2.14	0.20	
V	2.44	0.14	
W	5.16	0.00	

Shear emergence elev: 0.44

Shear surface angle: 35.00

Option B - Enter a bank height and angle, the model will generate a bank profile

○ Option B

- a) Input bank height (m)
- b) Input bank angle (°)
- c) Input bank toe length (m)
- d) Input bank toe angle (°)
- Input shear surface angle

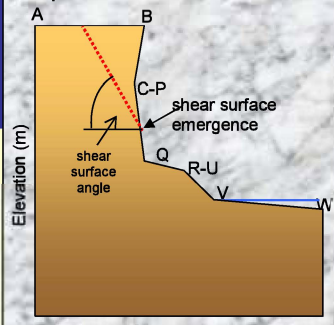
Bank layer thickness (m)

	Top Layer	Elevation of layer base (m)
Layer 1	0.75	0.00
Layer 2	0.00	0.00
Layer 3	0.00	0.00
Layer 4	0.00	0.00
Layer 5	0.00	0.00

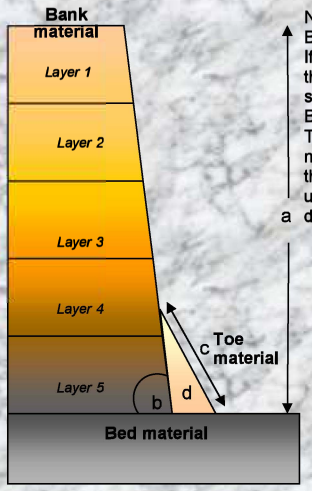
Bottom Layer

Parallel layers, starting from point B

Definition of points used in bank profile



A - bank top: place beyond start of shear surface
B - bank edge
C-P - breaks of slope on bank (if no breaks of slope place as intermediary points)
Q - top of bank toe
R-U - breaks of slope on bank toe (if no breaks of slope then insert as intermediary points)
V - base of bank toe
W - end point (typically mid point of channel)



Notes:
Bank profile may overhang.
If the bank profile is fully populated, the shear surface emergence point should be anywhere between points B and Q.
The shear surface emergence point must not be on a horizontal section - the elevation of this point must be unique or an error message will display.

Channel and flow parameters

23.589	Input reach length (m)
0.0005	Input reach slope (m/m)
0.44	Input elevation of flow (m)
4380	Input duration of flow (hrs)

View Bank Geometry

Run Bank Geometry Macro

Select material types (or select "own data" and add values below)

Bank Material					Bank Toe Material
Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
Own data	Own data	Own data	Own data	Own data	Own data

Bank and bank-toe material data tables.

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white boxes.

Material Descriptors			Bank Model Input Data					Groundwater Model Input Data						Toe Model Input Data	
Bank material type	*Description*	*Mean grain size, D_{50} (m)*	*Friction angle ϕ' (degrees)*	*Cohesion c' (kPa)*	*Saturated unit weight (kN/m^3)*	*ϕ^b (degrees)*	*Chemical concentration (kg/kg)*	*Hydraulic Conductivity k_{sat} (m/s)*	*Bulk Modulus (Pa)*	*Porosity*	*Residual water content*	*van Genuchten α (1/m)*	*van Genuchten n*	τ_c (Pa)	*k* (cm^3/Ns)
1	Boulders	0.512	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	498	0.004
2	Cobbles	0.128	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	124	0.009
3	Gravel	0.0113	36.0	0.0	20.0	15.0	-	3.160E-03	1.354E+08	0.320	0.070	3.5237	2.3286	11.0	0.030
4a and 4b	Angular sand	0.00035	32.3	0.4	18.5	15.0	-	7.439E-05	1.354E+07	0.375	0.053	3.5237	3.1769	Coarse (0.71 mm) or	
5a and 5b	Rounded sand	0.00035	28.3	0.4	18.5	15.0	-	1.130E-06	6.056E+07	0.380	0.033	2.0563	2.3286	Fine (0.18 mm)	
6a, 6b and 6c	Silt	-	26.6	4.3	18.0	15.0	-	5.064E-06	1.049E+07	0.489	0.050	0.6577	1.6788	Erodible (0.100 Pa),	
7a, 7b and 7c	Soft clay	-	26.4	8.2	17.7	15.0	-	9.473E-07	1.354E+06	0.472	0.079	1.5812	1.4158	Moderate (5.00 Pa), or	
8a, 8b and 8c	Stiff clay	-	21.1	12.6	17.7	15.0	-	1.708E-06	5.417E+06	0.459	0.093	1.4962	1.2531	Resistant (50.0 Pa)	
	Own data layer 1		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 2		25.0	10.0	18.0	15.0	0.0							0.72	0.236
9	Own data layer 3		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 4		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 5			10.0	18.0	15.0	0.0							0.72	0.236
	Own data Bank Toe													0.72	0.118

COMING SOON!

Need to know the critical shear stress (τ_c) ?		Need to know the erodibility coefficient (*k*) ?	
Input non-cohesive particle diameter (mm)	0.075	Input critical shear stress τ_c (Pa)	0.721
Critical Shear Stress τ_c (Pa)	0.05	Erodibility Coefficient (cm^3/Ns)	0.118

Simulate the mechanical effects of *bank top* vegetation on bank stability using a root-reinforcement model

RipRoot (Pollen and Simon, 2005) is a global load-sharing fiber-bundle model. It explicitly simulates both the snapping of roots and the slipping of roots through the soil matrix, by determining the minimum applied load required to either break each root or pull each root out of the soil matrix. As the strength of each root is removed from the fiber bundle, the load is redistributed to the remaining roots according to the ratio of the diameter of each root to the sum of the diameters of all the intact roots. RipRoot builds on earlier work by Waldron (1977), Wu *et al*. (1979) and Waldron and Dakessian (1981).

Run Root-Reinforcement Model

Root-Reinforcement Model Output

List of Species Wet Meadow; Douglas Spirea; Alamo Switch Grass;
Percent of Assemblage 33.3; 33.3; 33.4;

Added cohesion due to roots, c_r 0.5 kPa

Protect the bank and/or bank-toe against *hydraulic erosion* by adding treatments (or select "own data" and add values below)

Protection

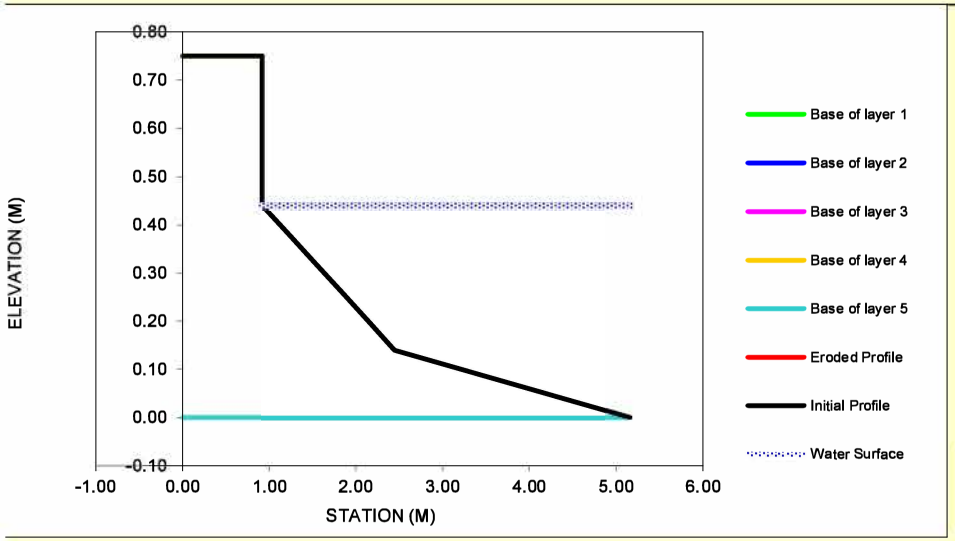
Bank Protection	Bank Toe Protection
No protection	Own Data

Bank and bank-toe protection data table

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white box.

Bank and Bank-Toe Protection Descriptors		
Protection type	*Description*	*Permissible shear stress (Pa)*
1	No protection	-
2	Coir fiber	108
3	Geotextile (synthetic)	144
4	Jute net	22
5	Large Woody Debris	192
6	Live fascine	100
7	Plant cuttings	17
8	Rip Rap (D_{50} 0.256 m)	204
9	-	
10	-	
11	-	
12	-	
13	Own Data	500.0

	Bank Material					Bank Toe Material	
	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5		
Material	Own data	Own data	Own data	Own data	Own data	Own Data	
Critical shear stress (Pa)	0.72	0.72	0.72	0.72	0.72	500.00	
Erodibility Coefficient (cm^3/Ns)	0.236	0.236	0.236	0.236	0.236	0.004	



Run Toe-Erosion Model

Account for:

Stream Curvature ☐

Effective stress acting on each grain ☐

Average applied boundary shear stress	0.690	Pa
Maximum Lateral Retreat	0.002	cm
Eroded Area - Bank	0.000	m^2
Eroded Area - Bank Toe	0.000	m^2
Eroded Area - Bed	0.000	m^2
Eroded Area - Total	0.000	m^2

Export New (Eroded) Profile into Model

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

1) Select **EITHER** Option A or Option B for Bank Profile and enter the data in the relevant box- cells in the alternative option are ignored in the simulation and may be left blank if desired.
2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).
3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.

To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below

◉ Option A

Point	Station (m)	Elevation (m)	Top of toe?
A	0.00	0.75	☐
B	0.92	0.75	☐
C	0.92	0.73	☐
D	0.92	0.71	☐
E	0.92	0.69	☐
F	0.92	0.67	☐
G	0.92	0.65	☐
H	0.92	0.63	☐
I	0.92	0.61	☐
J	0.92	0.59	☐
K	0.92	0.56	☐
L	0.92	0.54	☐
M	0.92	0.52	☐
N	0.92	0.50	☐
O	0.92	0.48	☐
P	0.92	0.46	☐
Q	0.92	0.44	☑
R	1.23	0.38	
S	1.53	0.32	
T	1.84	0.26	
U	2.14	0.20	
V	2.44	0.14	
W	5.16	0.00	

Shear emergence elev: 0.44

Shear surface angle: 35.00

Option B - Enter a bank height and angle, the model will generate a bank profile

○ Option B

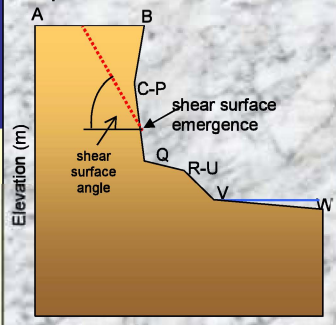
- a) Input bank height (m)
- b) Input bank angle (°)
- c) Input bank toe length (m)
- d) Input bank toe angle (°)
- Input shear surface angle

Bank layer thickness (m)

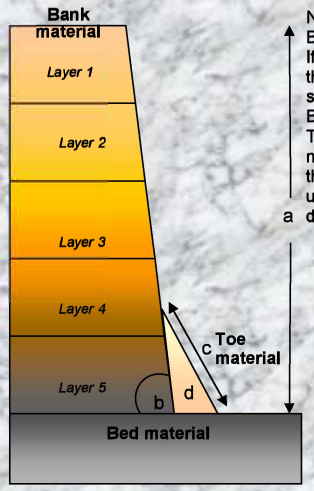
		Elevation of layer base (m)
	Top Layer	
Layer 1	0.75	0.00
Layer 2	0.00	0.00
Layer 3	0.00	0.00
Layer 4	0.00	0.00
Layer 5	0.00	0.00
	Bottom Layer	

Parallel layers, starting from point B

Definition of points used in bank profile



A - bank top: place beyond start of shear surface
B - bank edge
C-P - breaks of slope on bank (if no breaks of slope place as intermediary points)
Q - top of bank toe
R-U - breaks of slope on bank toe (if no breaks of slope then insert as intermediary points)
V - base of bank toe
W - end point (typically mid point of channel)



Notes:
Bank profile may overhang.
If the bank profile is fully populated, the shear surface emergence point should be anywhere between points B and Q.
The shear surface emergence point must not be on a horizontal section - the elevation of this point must be unique or an error message will display.

Channel and flow parameters

23.589	Input reach length (m)
0.0005	Input reach slope (m/m)
0.14	Input elevation of flow (m)
4380	Input duration of flow (hrs)

View Bank Geometry

Run Bank Geometry Macro

Select material types (or select "own data" and add values below)

Bank Material					Bank Toe Material
Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
Own data	Own data	Own data	Own data	Own data	Own data

Bank and bank-toe material data tables.

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white boxes.

Material Descriptors			Bank Model Input Data					Groundwater Model Input Data						Toe Model Input Data	
Bank material type	*Description*	*Mean grain size, D_{50} (m)*	*Friction angle ϕ' (degrees)*	*Cohesion c' (kPa)*	*Saturated unit weight (kN/m^3)*	*ϕ^b (degrees)*	*Chemical concentration (kg/kg)*	*Hydraulic Conductivity k_{sat} (m/s)*	*Bulk Modulus (Pa)*	*Porosity*	*Residual water content*	*van Genuchten α (1/m)*	*van Genuchten n*	τ_c (Pa)	*k* (cm^3/Ns)
1	Boulders	0.512	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	498	0.004
2	Cobbles	0.128	42.0	0.0	20.0	15.0	-	1.745E-03	6.556E+08	0.280	0.090	3.5237	2.3286	124	0.009
3	Gravel	0.0113	36.0	0.0	20.0	15.0	-	3.160E-03	1.354E+08	0.320	0.070	3.5237	2.3286	11.0	0.030
4a and 4b	Angular sand	0.00035	32.3	0.4	18.5	15.0	-	7.439E-05	1.354E+07	0.375	0.053	3.5237	3.1769	Coarse (0.71 mm) or	
5a and 5b	Rounded sand	0.00035	28.3	0.4	18.5	15.0	-	1.130E-06	6.056E+07	0.380	0.033	2.0563	2.3286	Fine (0.18 mm)	
6a, 6b and 6c	Silt	-	26.6	4.3	18.0	15.0	-	5.064E-06	1.049E+07	0.489	0.050	0.6577	1.6788	Erodible (0.100 Pa),	
7a, 7b and 7c	Soft clay	-	26.4	8.2	17.7	15.0	-	9.473E-07	1.354E+06	0.472	0.079	1.5812	1.4158	Moderate (5.00 Pa), or	
8a, 8b and 8c	Stiff clay	-	21.1	12.6	17.7	15.0	-	1.708E-06	5.417E+06	0.459	0.093	1.4962	1.2531	Resistant (50.0 Pa)	
	Own data layer 1		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 2		25.0	10.0	18.0	15.0	0.0							0.72	0.236
9	Own data layer 3		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 4		25.0	10.0	18.0	15.0	0.0							0.72	0.236
	Own data layer 5			10.0	18.0	15.0	0.0							0.72	0.236
	Own data Bank Toe													0.72	0.118

COMING SOON!

Need to know the critical shear stress (τ_c) ?		Need to know the erodibility coefficient (*k*) ?	
Input non-cohesive particle diameter (mm)	0.075	Input critical shear stress τ_c (Pa)	0.721
Critical Shear Stress τ_c (Pa)	0.05	Erodibility Coefficient (cm^3/Ns)	0.118

Simulate the mechanical effects of *bank top* vegetation on bank stability using a root-reinforcement model

RipRoot (Pollen and Simon, 2005) is a global load-sharing fiber-bundle model. It explicitly simulates both the snapping of roots and the slipping of roots through the soil matrix, by determining the minimum applied load required to either break each root or pull each root out of the soil matrix. As the strength of each root is removed from the fiber bundle, the load is redistributed to the remaining roots according to the ratio of the diameter of each root to the sum of the diameters of all the intact roots. RipRoot builds on earlier work by Waldron (1977), Wu *et al*. (1979) and Waldron and Dakessian (1981).

Run Root-Reinforcement Model

Root-Reinforcement Model Output

List of Species Wet Meadow; Douglas Spirea; Alamo Switch Grass;
Percent of Assemblage 33.3; 33.3; 33.4;

Added cohesion due to roots, c_r 0.5 kPa

Protect the bank and/or bank-toe against *hydraulic erosion* by adding treatments (or select "own data" and add values below)

Protection

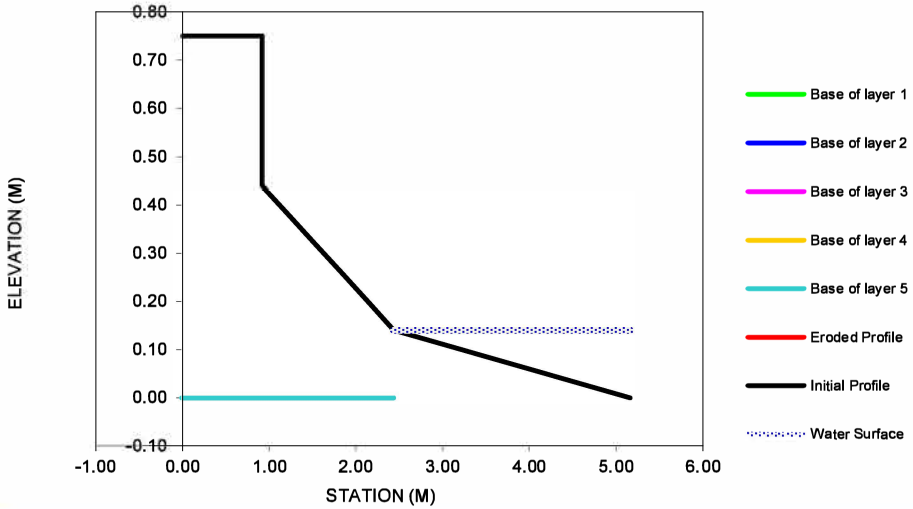
Bank Protection	Bank Toe Protection
No protection	Own Data

Bank and bank-toe protection data table

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white box.

Bank and Bank-Toe Protection Descriptors		
Protection type	*Description*	*Permissible shear stress (Pa)*
1	No protection	-
2	Coir fiber	108
3	Geotextile (synthetic)	144
4	Jute net	22
5	Large Woody Debris	192
6	Live fascine	100
7	Plant cuttings	17
8	Rip Rap (D_{50} 0.256 m)	204
9	-	
10	-	
11	-	
12	-	
13	Own Data	500.0

	Bank Material					Bank Toe Material	
	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5		
Material	Own data	Own data	Own data	Own data	Own data	Own Data	
Critical shear stress (Pa)	0.72	0.72	0.72	0.72	0.72	500.00	
Erodibility Coefficient (cm^3/Ns)	0.236	0.236	0.236	0.236	0.236	0.004	



Run Toe-Erosion Model

Account for:

Stream Curvature ☐

Effective stress acting on each grain ☐

Average applied boundary shear stress	0.170	Pa
Maximum Lateral Retreat	0.000	cm
Eroded Area - Bank	0.000	m^2
Eroded Area - Bank Toe	0.000	m^2
Eroded Area - Bed	0.000	m^2
Eroded Area - Total	0.000	m^2

Export New (Eroded) Profile into Model

EXISTING CONDITIONS								
Water Level:	812.75 ft. (High)				808 ft. (Low)			
Section:	1	2	3	4	1	2	3	4
Section length (ft.):	60	46.5	24.45	77.34	60	46.5	24.45	77.34
Max. lateral retreat (in.):	15.04	13.42	14.79	10.72	0	0	0	0
Eroded area - bank (ft^2):	0	0	0	0	0	0	0	0
Eroded area - bank toe (ft^2):	1.65	1.39	1.71	1.18	0	0	0	0
Eroded area - bed (ft^2):	0.44	1.71	1.12	2.16	0	0	0	0
Eroded area - total (ft^2):	2.08	3.1	2.83	3.34	0	0	0	0

PROPOSED CONDITIONS								
Water Level:	812.75 ft. (High)				808 ft. (Low)			
Section:	1	2	3	4	1	2	3	4
Section length:	60	46.5	24.45	77.34	60	46.5	24.45	77.34
Max. lateral retreat (in.):	0	0	0	7.87E-04	0	0	0	0
Eroded area - bank (ft^2):	0	0	0	0	0	0	0	0
Eroded area - bank toe (ft^2):	0	0	0	0	0	0	0	0
Eroded area - bed (ft^2):	0	0	0	0	0	0	0	0
Eroded area - total (ft^2):	0	0	0	0	0	0	0	0

Appendix B: Environmental Services

Section 26a Regulations

Subpart A: Procedures for Approval of Construction

Subpart B: Regulation of Floating Cabins

Subpart C: TVA-Owned Residential Access Shoreland

Subpart D: Activities on TVA Flowage Easement Shoreland

Subpart E: Miscellaneous

Subpart A: Procedures for Approval of Construction

Sections:

- 1304.1 Scope and intent
- 1304.2 Application
- 1304.3 Delegation of authority
- 1304.4 Application review and approval process
- 1304.5 Conduct of hearings
- 1304.6 Appeals
- 1304.7 Conditions of approvals
- 1304.8 Denials
- 1304.9 Initiation of construction
- 1304.10 Change in ownership of approved facilities or activities
- 1304.11 Little Tennessee River; date of formal submission

§ 1304.1 Scope and intent

The Tennessee Valley Authority Act of 1933 among other things confers on TVA broad authority related to the unified conservation and development of the Tennessee River Valley and surrounding area and directs that property in TVA's custody be used to promote the Act's purposes. In particular, section 26a of the Act requires that TVA's approval be obtained prior to the construction, operation, or maintenance of any dam, appurtenant works, or other obstruction affecting navigation, flood control, or public lands or reservations along or in the Tennessee River or any of its tributaries. By way of example only, such obstructions may include boat docks, piers, boathouses, buoys, floats, boat launching ramps, fills, water intakes, devices for discharging effluent, bridges, aerial cables, culverts, pipelines, fish attractors, shoreline stabilization projects, channel excavations and floating cabins as defined in §1304.101. Any person considering constructing, operating, or maintaining any such obstruction on a stream in the Tennessee River Watershed should carefully review the regulations in this part and the 26a Applicant's Package before doing so. The regulations also apply to certain activities on TVA-owned land alongside TVA reservoirs and to land subject to TVA flowage easements. TVA uses and permits use of the lands and land rights in its custody alongside and subjacent to TVA reservoirs and exercises its land rights to carry out the purposes and policies of the Act. In addition, the National Environmental Policy Act of 1969 (NEPA), as amended, 42 U.S.C. 4321 et seq., and the Federal Water Pollution Control Act Amendments of 1972 (FWPCA), 33 U.S.C. 1251 et seq., have declared it to be congressional policy that agencies should administer their statutory authorities so as to restore, preserve, and enhance the quality of the environment and should cooperate in the control of pollution. It is the intent of the regulations in this part 1304 to carry out the purposes of the Act and other statutes relating to these purposes, and this part shall be interpreted and applied to that end.

§ 1304.2 Application

(a) If the facility is to be built on TVA land, the applicant must, in addition to the other requirements of this part, own the fee interest in or have an adequate leasehold or easement interest of sufficient tenure to cover the normal useful life of the proposed facility in land immediately adjoining the TVA land. If the facility is to be built on private land, the applicant must own the fee interest in the land or have an adequate leasehold or easement interest in the property where the facility will be located. If the facility is an existing floating cabin, it must meet the requirements of subpart B. TVA recognizes, however, that in some cases private property has been subdivided in a way that left an intervening strip of land between the upland boundary of a TVA flowage easement and the waters of the reservoir, or did not convey to the adjoining landowner the land underlying the waters of the reservoir. In some of these situations, the owner of the intervening strip or underlying land cannot be identified or does not object to construction of water-use facilities by the adjacent landowner. In these situations, TVA may exercise its discretion to permit the facility, provided there is no objection from the fee owner of the intervening strip or underlying land. A TVA permit conveys no property interest. The applicant is responsible for locating the proposed facility on qualifying land and ensuring that there is no objection from any owner of such land. TVA may require the applicant to provide appropriate verification of ownership and lack of objection, but TVA is not

on TVA land that is located up or downstream from the land which makes the applicant eligible for consideration to receive a permit.

(b) Applications shall be addressed to the Tennessee Valley Authority, at one of the appropriate Regional Watershed Office location as listed on the application and on TVA's website. To contact an office, call 1-800-882-5263 or email plic@tva.gov. Applications are available on TVA's website.

(c) Submittal of section 26a application. Applicants must submit certain required information depending upon whether a proposed facility is a minor or major facility. Examples of the two categories are provided in paragraphs (c)(1) and (2) of this section. Most residential related facilities are minor facilities. Commercial or community facilities generally are major facilities. TVA shall determine whether a proposed facility is minor or major. An application shall not be complete until payment of the appropriate fee as determined in accordance with 18 CFR part 1310, and disclosed to the applicant in the materials provided with the application package or by such other means of disclosure as TVA shall from time to time adopt. For purposes of the information required to be submitted under this section and the determination of fees, a request for a variance to the size limitations for a residential-related facility (other than a waiver request under §1304.212 or §1304.300(a)) shall be regarded as an application for a major facility. In addition to the information required in paragraphs (c)(1) and (2) of this section, TVA may require the applicant to provide such other information as TVA deems necessary for adequate review of a particular application.

(1) Information required for review of minor facility. By way of example only, minor facilities may include: boat docks, piers, rafts, boathouses, fences, steps, gazebos, and floating cabins. One copy of the application shall be prepared and submitted in accordance with the instructions included in the section 26a Applicant's Package. The application shall include:

(i) Completed application form. One copy of the application shall be prepared and submitted. Application forms are available on TVA's website. The application shall include a project description which indicates what is to be built, removed, or modified, and the sequence of the work. Applications for floating cabins shall include written evidence that the floating cabin was located or moored on the Tennessee River System as of December 16, 2016, and detailed descriptions of mooring method, how electrical service is provided, and how wastewater is managed. An application to relocate a floating cabin to a marina shall include evidence of approval from the accepting marina operator.

(ii) Project, plan, or drawing. The project plan/drawing shall:

(A) Be prepared electronically or on paper suitable for reproduction (no larger than 11 by 17 inches);

(B) Identify the kind of structure, purpose/intended use;

(C) Show principal dimensions, size, and location in relation to shoreline;

(D) Show the elevation of the structure above the full summer pool; and

(E) Indicate the river or reservoir name, river mile, locator landmarks, and direction of water flow if known.

(iii) A site photograph. The photograph shall be at least 3 by 5 inches in size and show the location of the proposed structure or alteration and the adjacent shoreline area.

(iv) Location map. The location map shall clearly show the location of the proposed facility and the extent of any site disturbance for the proposed project. An 8 1/2 by 11-inch copy of one of the following is ideal: a TVA land map, a subdivision map, or a portion of a United States Geological Survey topographic map. The subdivision name and lot number and the map number or name shall be included, if available.

(v) Environmental consultations and permits. To the fullest extent possible the applicant shall obtain or apply for other required environmental permits and approvals before or at the same time as applying for section 26a approvals. Consultations under the National Historic Preservation Act of 1966 and the Endangered Species Act of 1973 shall take place, and permits from the U. S. Army Corps of Engineers and State agencies for water or air regulation shall be obtained or applied for at the same time as or before application for section 26a approval. The applicant shall provide TVA with copies of any such permits or approvals that are issued.

(2) Information required for a major facility. One (1) copy of the application shall be prepared and submitted according to instructions included in the section 26a Applicant's Package. By way of example only, major projects and facilities may include: marinas, community docks, barge terminals, utility crossings, bridges, culverts, roads, wastewater discharges, water intakes, dredging, and placement of fill. The application shall include:

(i) Completed application form. Application forms are available on TVA's website. The application shall include a narrative project description which indicates what is to be built, removed, or modified, and the sequence of the work.

(ii) Project plan or drawing. Adequate project plans or drawings shall accompany the application. They shall

(A) Be prepared electronically or on paper suitable for reproduction (no larger than 11 by 17 inches).

(B) Contain the date; applicant name; stream; river or reservoir name; river mile; locator landmarks; and direction of water flow, if known;

(C) Identify the kind of structure, purpose/intended use;

(D) Include a plan and profile view of the structure;

(E) Show principal dimensions, size, and location in relation to shoreline;

(F) Show the elevations of the structure above full summer pool if located on a TVA reservoir or above the normal high water elevation if on a free-flowing stream or river; and

project. An 8 1/2 by 11-inch copy of the appropriate portion of a United States Geological Survey topographic map is recommended. The map number or name shall be included. In addition, recent photos of the location are helpful for TVA's review and may be included.

(iv) Other information where applicable. The location of any material laydown or assembly areas, staging areas, equipment storage areas, new access roads, and road/access closure required by the project or needed for construction; the location of borrow or spoil areas on or off TVA land; the extent of soil and vegetative disturbance; and information on any special reservoir operations needed for the project, such as drawdown or water discharge restrictions.

(v) Site plans. Some projects, particularly larger ones, may require a separate site plan which details existing and proposed changes to surface topography and elevations (cut and fill, clearing, etc.), location of all proposed facilities, and erosion control plans.

(vi) Environmental consultations and permits. To the fullest extent possible the applicant shall obtain or apply for other required environmental permits and approvals before or at the same time as applying for section 26a approvals. Consultations under the National Historic Preservation Act of 1966 and the Endangered Species Act of 1973 shall take place, and permits from the U. S. Army Corps of Engineers and State agencies for water or air regulation shall be obtained or applied for at the same time as or before application for section 26a approval. The applicant shall provide TVA with copies of any such permits or approvals that are issued.

(d) Discharges into navigable waters of the United States. If construction, maintenance, or operation of the proposed structure or any part thereof, or the conduct of the activity in connection with which approval is sought may result in any discharge into navigable waters of the United States, applicant shall also submit with the application, in addition to the material required by paragraph (c) of this section, a copy of the request for certification from the state in which such discharge would originate, or if appropriate, from the interstate water pollution control agency having jurisdiction over the navigable waters at the point where the discharge would originate, or from the Environmental Protection Agency, that such state or interstate agency or the Environmental Protection Agency has determined that the applicant's proposed activity will be conducted in a manner that will comply with water quality standards. The applicant shall further submit such supplemental and additional information as TVA may deem necessary for the review of the application, including, without limitation, information concerning the amounts, chemical makeup, temperature differentials, type and quantity of suspended solids, and proposed treatment plans for any proposed discharges. No section 26a permit will be granted until required certification has been obtained or has been waived. If a certifying agency has not acted within a reasonable period of time, not to exceed one year, of an applicant's request for certification from the respective agency and certification is waived, TVA will proceed with processing of the section 26a permit application.

§ 1304.3 Delegation of authority

The power to approve or disapprove applications under this part is delegated to the Vice President, Natural Resources, or the designee thereof, subject to appeal to the Chief Executive Officer and discretionary review by a designated committee of the TVA Board, as provided in § 1304.6. The administration of applications is delegated to the Natural Resources staff or the group with functionally equivalent responsibilities.

§ 1304.4 Application review and approval process

(a) TVA shall notify the U.S. Army Corps of Engineers (USACE) and other federal agencies with jurisdiction over the application as appropriate.

(b) If a hearing is held for any of the reasons described in paragraph (c) of this section, any interested person may become a party of record by following the directions contained in the hearing notice.

(c) Hearings concerning approval of applications are conducted (in accordance with § 1304.5) when:

(1) TVA deems a hearing is necessary or appropriate in determining any issue presented by the application;

(2) A hearing is required under any applicable law or regulation;

(3) A hearing is requested by the USACE pursuant to the TVA/Corps joint processing Memorandum of Understanding; or

(4) The TVA Investigating Officer directs that a hearing be held.

(d) Upon completion of the review of the application, including any hearing or hearings, the Vice President or the designee thereof shall issue an initial decision approving or disapproving the application. The basis for the decision shall be set forth in the decision.

(e) Promptly following the issuance of the decision, the Vice President or the designee thereof shall furnish a written copy of the decision to the applicant and to any parties of record. The initial decision shall become final unless an appeal is made pursuant to § 1304.6.

§ 1304.5 Conduct of hearings

(a) If a hearing is to be held for any of the reasons described in § 1304.4(c), TVA shall give notice of the hearing to interested persons. Such notice may be given by publication in a daily newspaper of general circulation in the area of the proposed structure, personal written notice, posting on TVA's Internet Web site, or by any other method reasonably calculated to come to the attention

(v) Water depths fronting the community lot;

(vi) Commercial and private vessel navigation uses and restrictions in the vicinity of the community lot;

(vii) Recreational carrying capacity for water-based activities in the vicinity of the community lot, and

(viii) Other site specific conditions and considerations as determined by TVA.

(3) Vegetation management shall be in accordance with the requirements of §1304.203 except that, at TVA's discretion, the community access corridor may exceed 20 feet in width, and thinning of vegetation outside of the corridor within or beyond the SMZ may be allowed to enhance views of the reservoir.

(c) TVA may approve community facilities that are greater in size than 1000 square feet. In such circumstances, TVA also may establish harbor limits.

§ 1304.207 Channel excavation on TVA-owned residential access shoreland

(a) Excavation of individual boat channels shall be approved only when TVA determines there is no other practicable alternative to achieving sufficient navigable water depth and the action would not substantially impact sensitive resources.

(b) No more than 150 cubic yards of material shall be removed for any individual boat channel.

(c) The length, width, and depth of approved boat channels shall not exceed the dimensions necessary to achieve three-foot water depths for navigation of the vessel at the minimum winter water elevation.

(d) Each side of the channel shall have a slope ratio of at least 3:1.

(e) Only one boat channel or harbor may be considered for each abutting property owner.

(f) The grade of the channel must allow drainage of water during reservoir drawdown periods.

(g) Channel excavations must be accomplished during the reservoir drawdown when the reservoir bottom is exposed and dry.

(h) Spoil material from channel excavations must be placed in accordance with any applicable local, State, and Federal regulations at an upland site above the TVA Flood Risk Profile elevation. For those reservoirs that have no flood control storage, dredge spoil must be disposed of and stabilized above the limits of the 100-year floodplain and off of TVA property.

§ 1304.208 Shoreline stabilization on TVA-owned residential access shoreland

TVA may issue permits allowing adjacent residential landowners to stabilize eroding shorelines on TVA-owned residential access shoreland. TVA will determine if shoreline erosion is sufficient to approve the proposed stabilization treatment.

(a) Biostabilization of eroded shorelines.

(1) Moderate contouring of the bank may be allowed to provide conditions suitable for planting of vegetation.

(2) Tightly bound bundles of coconut fiber, logs, or other natural materials may be placed at the base of the eroded site to deflect waves.

(3) Willow stakes and bundles and live cuttings of suitable native plant materials may be planted along the surface of the eroded area.

(4) Native vegetation may be planted within the shoreline management zone to help minimize further erosion.

(5) Riprap may be allowed along the base of the eroded area to prevent further undercutting of the bank.

(b) Use of gabions and riprap to stabilize eroded shorelines.

(1) The riprap material must be quarry-run stone, natural stone, or other material approved by TVA.

(2) Rubber tires, concrete rubble, or other debris salvaged from construction sites shall not be used to stabilize shorelines.

(3) Gabions (rock wrapped with wire mesh) that are commercially manufactured for erosion control may be used.

(4) Riprap material must be placed so as to follow the existing contour of the bank.

(5) Site preparation must be limited to the work necessary to obtain adequate slope and stability of the riprap material.

(c) Use of retaining walls for shoreline stabilization.

(1) Retaining walls shall be allowed only where the erosion process is severe and TVA determines that a retaining wall is the most effective erosion control option or where the proposed wall would connect to an existing TVA-approved wall on the lot or to an adjacent owner's TVA-approved wall.

(2) The retaining wall must be constructed of stone, concrete blocks, poured concrete, gabions, or other materials acceptable to TVA. Railroad ties, rubber tires, broken concrete (unless determined by TVA to be of adequate size and integrity), brick, creosote timbers, and asphalt are not allowed.

(3) Reclamation of land that has been lost to erosion is not allowed.

TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION
Division of Water Resources
William R. Snodgrass Tennessee Tower, 312 Rosa L. Parks Avenue, 11th Floor,
Nashville, Tennessee, 37243
1-888-891-8332 (TDEC)

Application for Aquatic Resource Alteration Permit (ARAP) & State §401 Water Quality Certification

OFFICIAL STATE USE ONLY	Site #:		Permit #:	

Section 1. Applicant Information (individual responsible for site, signs certification below)

Applicant Name (company or individual):		SOS #:	Status: N/A
Primary Contact/Signatory:		Signatory's Title or Position:	
Mailing Address:		City: State:	Zip:
Phone:	Fax:	E-mail:	

Section 2. Alternate Contact/Consultant Information (a consultant is not required)

Alternate Contact Name:			
Company:		Title or Position:	
Mailing Address:		City: State:	Zip:
Phone:	Fax:	E-mail:	

Section 3. Fee (application will be incomplete until fee is received)

No Fee Fee Submitted with Application Amount Submitted: $ _____

Current application fee schedules can be found at the Division of Water Resources webpage at:
https://www.tn.gov/environment/permit-permits/water-permits1/aquatic-resource-alteration-permit--arap-.html
or by calling (615) 532-0625. Please make checks payable to "Treasurer, State of Tennessee".

Billing Contact (if different from Applicant): Name: Email:

Address: Phone:

Section 4. Project Details (fill in information and check appropriate boxes)

Site or Project Name:	Nearest City, Town or Major Landmark:	
Street Address or Location (include zip):		
County(ies):	MS4 Jurisdiction:	Latitude (dd.dddd):
		Longitude (dd.dddd):

Resources Proposed for Alteration: ☐ Stream / River ☐ Wetland ☐ Reservoir

Name of Water Resource (for more information, access *http://tdeconline.tn.gov/dwr*):

Brief Project Description (a more detailed description is required under Section 8):

Does the proposed activity require approval from the U.S. Army Corps of Engineers, the Tennessee Valley Authority, or any other federal, state, or local government agency? Yes No

If Yes, provide the permit reference numbers:

Will the activity require a 401 Water Quality Certification: Yes No

If Yes, attach any 401 WQC pre-filing meeting request documentation

Is the proposed activity associated with a larger common plan of development: Yes No

If Yes, submit site plans and identify the location and overall scope of the common plan of development.

Plans attached? Yes No

If applicable, indicate any other federal, state, or local permits that are associated with the overall project site (common plan of development) that have been obtained in the past (e.g., construction general permit and/or other ARAP):

Section 5. Project Schedule (fill in information and check appropriate boxes)		
Proposed start date:	Estimated end date:	
Is any portion of the activity complete now?	Yes	No
If yes, describe the extent of the completed portion:		

The required information in Sections 6-11 must be submitted on a separate sheet(s) and submitted in the same numbered format as presented below. If any question in not applicable, state the reason why it is not applicable.

Section 6. Description		**Attached** Yes	No
6.1	A narrative description of the scope of the project		
6.2	USGS topographic map indicating the exact location of the project (can be a photographic copy)		
6.3	Photographs of the resource(s) proposed for alteration with location description (photo locations should be noted on map)		
6.4	A narrative description of the **existing** stream and/or wetland characteristics including, but not limited to, dimensions (e.g., depth, length, average width), substrate and riparian vegetation		
6.5	A narrative description of the **proposed** stream and/or wetland characteristics including, but not limited to, dimensions (e.g., depth, length, average width), substrate and riparian vegetation		
6.6	In the case of wetlands, include a wetland delineation with delineation forms and site map denoting location of data points		
6.7	A copy of all hydrologic or jurisdictional determination documents issued for water resources on the project site		

Section 7. Project Rationale	**Attached** Yes	No
Describe the need for the proposed activity, including, but not limited to the purpose, alternatives considered and rationale for selection of least impactful alternative, and what will be done to avoid or minimize impacts to water resources		

Section 8. Technical Information		**Attached** Yes	No
8.1	Detailed plans, specifications, blueprints, or legible sketches of present site conditions and the proposed activity. Plans must be 8.5.x 11 inches. Additional larger plans may also be submitted to aid in application review. The detailed plans should be superimposed on existing and new conditions (e.g., stream cross sections where road crossings are proposed)		
8.2	For the proposed activity and compensatory mitigation, provide a discussion regarding the sequencing of events and construction methods and any proposed monitoring		
8.3	Depiction and narrative on the location and type of erosion prevention and sediment control (EPSC) measures for the proposed alterations and any other measures to treat, control, or manage impacts to waters		

Section 9. Water Resources Degradation (degree of proposed impact)

Note that in most cases, activities that exceed the scope of the General Permit limitations are considered greater than *de minimis* degradation to water quality.

Please provide your basis for concluding the proposed activity will cause one of the following levels of water quality degradation:

a. *De minimis* degradation, no appreciable permanent loss of resource values
b. Greater than *de minimis* degradation (if greater than *de minimis* complete Sections 10-11)

For information and guidance on the definition of de minimis and degradation, refer to the Antidegradation Statement in Chapter 0400-40-03-.06 of the Tennessee Water Quality Criteria Rule:
https://publications.tnsosfiles.com/rules/0400/0400-40/0400-40.htm
For more information on specifics on what General Permits can cover, refer to the Natural Resources Unit webpage at:
https://www.tn.gov/environment/permit-permits/water-permits1/aquatic-resource-alteration-permit--arap-.html

Application for Aquatic Resource Alteration Permit (ARAP) & State §401 Water Quality Certification

Section 10. Detailed Alternatives Analysis		Attached Yes	Attached No
10.1	Analyze all reasonable alternatives and describe the level of degradation and permanent loss of resource value caused by each alternative. Assessment must consider options other than the "Preferred" and "No Action" alternatives. Provide associated rationale for selecting or rejecting all alternatives considered and demonstration that the least impactful practicable alternative was selected.		
10.2	Discuss the social and economic consequences of each alternative		
10.3	Demonstrate that the degradation associated with the preferred alternative will not violate water quality criteria for uses designated in the receiving waters, and is necessary to accommodate important economic and social development in the area		

Section 11. Compensatory Mitigation		Attached Yes	Attached No
11.1	A detailed discussion of the proposed compensatory mitigation. Provide evidence of credit reservation if proposing to utilize a third-party provider.		
11.2	Analysis of any proposed appreciable loss of resource value using the TN Stream Mitigation Guidelines. Provide Stream Quantification Tool (SQT) results if applicable. Include Existing Condition Score (ECS) and debit/credit calculations.		
11.3	Describe how the compensatory mitigation would result in no net loss of resource value		
11.4	Provide a detailed monitoring plan for the compensatory mitigation site if permittee-responsible project is proposed		
11.5	Describe the long-term protection measures for the compensatory mitigation site if permittee-responsible project is proposed (e.g., deed restrictions, conservation easement)		

Certification and Signature

An application submitted by a corporation must be signed by a principal executive officer; from a partnership or proprietorship, by the partner or proprietor respectively; from a municipal, state, federal or other public agency or facility, the application must be signed by either a principal executive officer, ranking elected official, or other duly authorized employee. ***I certify under penalty of law that this document and all attachments were prepared by me, or under my direction or supervision. The submitted information is to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment. As specified in Tennessee Code Annotated Section 39-16-702(a)(4), this declaration is made under penalty of perjury. The project proponent hereby requests that the certifying authority review and take action on this CWA 401 certification request within the applicable reasonable period of time.***

Printed Name	Official Title	Signature	Date

Note that this form must be signed by the principal executive officer, partner or proprietor, or a ranking elected official in the case of a municipality; for details see **Certification and Signature** statement above. For more information, contact your local EFO at the toll-free number 1-888-891-8332 (TDEC). Submit the completed ARAP Application form (keep a copy for your records) to the appropriate EFO for the county(ies) where the proposed activity is located, addressed to **Attention: ARAP Processing**. You may also electronically submit the complete application and all associated attachments to water.permits@tn.gov.

EFO	Street Address	Zip Code	EFO	Street Address	Zip Code
Memphis	8383 Wolf Lake Drive, Bartlett	38133-4119	Cookeville	1221 South Willow Ave.	38506
Jackson	1625 Hollywood Drive	38305-4316	Chattanooga	1301 Riverfront Pkwy., Ste. 206	37402
Nashville	711 R S Gass Boulevard	37243	Knoxville	3711 Middlebrook Pike	37921
Columbia	1421 Hampshire Pike	38401	Johnson City	2305 Silverdale Road	37601



The scope of the proposed erosion control project is to devise an interdisciplinary plan to reduce erosion on the property using a combination of structure and native plant material to economically protect the property. The main objectives are: (1) to resolve or slow serious riverbank erosion to peninsula at 4806 Wheeler Road, Louisville, TN; (2) to create an economical plan for the property owned faced with property destruction and associated cost estimates; (3) to generate a structurally and ecologically sound final project that is useful in streambank erosion control through structure and creative native plant use; and (4) to create a project that is manageable by property owner. The proposed project will only deal with the erosion on the outermost tip of the peninsula, where the erosion is greatest.



Site area indicated by red line on map. Site area includes riprap work only.
Extent of site is confined to edge of peninsula.
Edge drop off varies from 3 feet at outermost edge to 1.5 feet at the innermost point.

Taken from TVA Recreation Map
Retrieved from
https://tva.maps.arcgis.com/apps/Embed/index.html?webmap=a3162d8845a14ed58b45f1b1c54b8fd3&extent=-88.6524,33.7099,-81.5608,37.5874&home

LPBD INC.
Little Projects, Big Designs Inc.

Natalie Hester
Libby Vanderloo
Steven Tremayne
Isaac Macon

University of Tennessee

NOT FOR Construction

Revision Record

No.	Date	Description	By

Project Name:
Erosion Control & Restoration of Property
Near Little River
For
Anne Ham

Drawing Title:
Site Map for TVA 26a Permit

	NAME
Drawn By:	Libby Vanderloo

DRAWING NUMBER:

P100

Existing conditions on the proposed project site are as follows. The bank height ranges from 1-4 feet from the bottom of the river. The proposed project site is 4.2 miles upstream from the mouth of the Little River. The river width is approximately 967 feet, according to the FEMA FIS data for the Little River in Blount County. The soil type found on the project site is classified as silty loam based on tests run on soil samples collected on February 6, 2023. The vegetation on the proposed project site consists of a mix of invasive plants and riparian plantings. Most of the riparian plantings are willow trees, planted to reinforce the soil with deep rooting.

The proposed project aims to mitigate erosion and stabilize the bank along Anne Ham's private property on the Little River. The design combines both hard and soft solutions for erosion. The hard solutions are riprap and geofabric laid on the bank slope to stabilize the drop-off. The riprap and geofabric will be laid along 210 feet on the outermost tip of the peninsula. The soft solution is comprised of riparian plantings on the riverbank. The plantings will cover the bank area between the summer pool and winter pool elevations around the outermost tip of the peninsula. All plantings will be native to East Tennessee and will promote pollinator and wildlife habitats.

East Tennessee Native Riparian Plant List

Common Name	Scientific Name	USDA PLANTS Database
CANOPY		
Red maple	*Acer rubrum*	http://plants.usda.gov/core/profile?symbol=ACRU
Sugar maple	*Acer saccharum*	http://plants.usda.gov/core/profile?symbol=ACSA3
Sweet birch	*Betula lenta*	http://plants.usda.gov/core/profile?symbol=BELE
River birch	*Betula nigra*	http://plants.usda.gov/core/profile?symbol=BENI
Yellowwood	*Cladrastis kentuckea*	http://plants.usda.gov/core/profile?symbol=CLKE
Common persimmon	*Diospyros virginiana*	http://plants.usda.gov/core/profile?symbol=DIVI5
American beech	*Fagus grandifolia*	http://plants.usda.gov/core/profile?symbol=FAGR
American holly	*Ilex opaca*	http://plants.usda.gov/core/profile?symbol=ILOP
Sweetgum	*Liquidambar styraciflua*	http://plants.usda.gov/core/profile?symbol=LIST2
Tulip poplar	*Liriodendron tulipifera*	http://plants.usda.gov/core/profile?symbol=LITU
Blackgum tupelo	*Nyssa sylvatica*	http://plants.usda.gov/core/profile?symbol=NYSY
Virginia pine	*Pinus virginiana*	http://plants.usda.gov/core/profile?symbol=PIVI2
Sycamore	*Platanus occidentalis*	http://plants.usda.gov/core/profile?symbol=PLOC
Black cherry	*Prunus serotina*	http://plants.usda.gov/core/profile?symbol=PRSE2
Swamp white oak	*Quercus bicolor*	http://plants.usda.gov/core/profile?symbol=QUBI
Swamp chestnut oak	*Quercus michauxii*	http://plants.usda.gov/core/profile?symbol=QUMI
Chinkapin oak	*Quercus muhlenbergii*	http://plants.usda.gov/core/profile?symbol=QUMU
Shumard oak	*Quercus shumardii*	http://plants.usda.gov/core/profile?symbol=QUSH
Black willow	*Salix nigra*	http://plants.usda.gov/core/profile?symbol=SANI
Sassafras	*Sassafras albidum*	http://plants.usda.gov/core/profile?symbol=SAAL5

East Tennessee Native Riparian Plant List

Common Name	Scientific Name	USDA PLANTS Database
SHRUBS		
Hazel alder	*Alnus serrulata*	http://plants.usda.gov/core/profile?symbol=ALSE2
Indigobush	*Amorpha fruticosa*	http://plants.usda.gov/core/profile?symbol=AMFR
Red chokeberry	*Aronia arbutifolia*	http://plants.usda.gov/core/profile?symbol=ARAR7
American beautyberry	*Callicarpa americana*	http://plants.usda.gov/core/profile?symbol=CAAM2
Cinnamon clethra	*Clethra acuminata*	http://plants.usda.gov/core/profile?symbol=CLAC3
Silky dogwood	*Cornus amomum*	http://plants.usda.gov/core/profile?symbol=COAM2
Hazelnut	*Corylus americana*	http://plants.usda.gov/core/profile?symbol=COAM3
Wild hydrangea	*Hydrangea arborescens*	http://plants.usda.gov/core/profile?symbol=HYAR
Common winterberry	*Ilex verticillata*	http://plants.usda.gov/core/profile?symbol=ITVI
Spicebush	*Lindera benzoin*	http://plants.usda.gov/core/profile?symbol=LIBE3
Elderberry	*Sambucus nigra L. subsp. canadensis*	http://plants.usda.gov/core/profile?symbol=SANIC4
Mapleleaf viburnum	*Viburnum acerifolium*	http://plants.usda.gov/core/profile?symbol=VIAC

East Tennessee Native Riparian Plant List

Common Name	Scientific Name	USDA PLANTS Database
GRASSES and SEDGES		
Big bluestem	*Andropogon gerardii*	http://plants.usda.gov/core/profile?symbol=ANGE
Splitbeard bluestem	*Andropogon ternarius*	http://plants.usda.gov/core/profile?symbol=ANTE2
Broomsedge	*Andropogon virginicus*	http://plants.usda.gov/core/profile?symbol=ANVI2
Giant river cane	*Arundinaria gigantea*	http://plants.usda.gov/core/profile?symbol=ARGI
Side oats grama	*Bouteloua curtipendula*	http://plants.usda.gov/core/profile?symbol=BOCU
Sedges	*Carex spp.*	http://plants.usda.gov/core/profile?symbol=CAREX
Fox sedge	*Carex vulpinoidea*	http://plants.usda.gov/core/profile?symbol=CAVU2
River oats	*Chasmanthium latifolium*	http://plants.usda.gov/core/profile?symbol=CHLA5
Bottlebrush grass	*Elymus hystrix*	http://plants.usda.gov/core/profile?symbol=ELHY
Virginia wild rye	*Elymus virginicus*	http://plants.usda.gov/core/profile?symbol=ELVI3
Purple love grass	*Eragrostis spectabilis*	http://plants.usda.gov/core/profile?symbol=ERSP
Common rush	*Juncus effusus*	http://plants.usda.gov/core/profile?symbol=JUEF
Pink muhly grass	*Muhlenbergia capillaris*	http://plants.usda.gov/core/profile?symbol=MUCA2
Switchgrass	*Panicum virgatum*	http://plants.usda.gov/core/profile?symbol=PAVI2
Silver plume grass	*Saccharum alopecuroides*	http://plants.usda.gov/core/profile?symbol=SAAL21
Sugarcane plume grass	*Saccharum giganteum (Erianthus giganteum)*	http://plants.usda.gov/core/profile?symbol=SAGI
Little bluestem	*Schizachyrium scoparium*	http://plants.usda.gov/core/profile?symbol=SCSC
Green/Dark green bullrush	*Scirpus atrovirens*	http://plants.usda.gov/core/profile?symbol=SCAT2
Indian grass	Sorghastrum nutans	http://plants.usda.gov/core/profile?symbol=SONU2
Eastern gama grass	Tripsacum dactyloides	http://plants.usda.gov/core/profile?symbol=TRDA3

Descriptive Native Plant List Legend

Height of plant in feet

Light Requirements
F = full sunlight
P = partial shade
S = shade

Soil Moisture
H = hydric, wet, plants periodically or often inundated by water
M = mesic, moist, adequate soil moisture retention year-round
S = sub-xeric, moist to dry, seasonally moist, periodically dry
X = xeric, dry and drought resistant, little moisture retention, excessively drained

Soil pH
A = acidic (slightly acidic to strongly acidic)
B = basic (tolerate alkaline conditions)

Wildlife Benefit
The benefit may be as a food source and/or cover or home for the animal.
B = Bird (song birds, waterfowl)
SM = Small Mammal (squirrels, chipmunks)
LM = Large Mammal (deer)

Aesthetics
Description of beauty of plant that may include flowers, bark, leaf color, or plant structure.

Common Name	Scientific Name	Height	Light			Soil Moisture				Soil pH		Wildlife Benefit			Aesthetics
CANOPY			F	P	S	H	M	S	X	B	A	B	SM	LM	
Red maple	*Acer rubrum*	50-75'	•	•		•	•	•				•	•	•	Red twigs and red flowers in early spring; beautiful fall foliage
Sugar maple	*Acer saccharum*	70-100'		•	•		•	•		•	•	•	•		Yellow and orange fall foliage
Yellow buckeye	*Aesculus flava*	60-75'	•	•			•	•			•	•	•		Yellow flowers in spring; orange fall foliage
Ohio buckeye	*Aesculus glabra*	30-50'		•	•		•	•			•	•	•		Flowers in spring
Sweet birch	*Betula lenta*	40-50'	•	•			•	•			•	•	•	•	Yellow fall foliage
River birch	*Betula nigra*	40-70'	•	•		•	•				•	•	•	•	Yellow fall foliage; bronze exfoliating bark.
Bitternut hickory	*Carya cordiformis*	50-80'	•	•			•	•		•	•	•	•	•	Bright sulfur yellow buds in spring; rich golden colored leaves in fall; native to bottomlands, floodplains and moist slopes
Pignut hickory	*Carya glabra*	50-80'	•	•			•	•			•	•	•	•	Yellow fall foliage
Pecan	*Carya illinoinensis*	70-100'	•				•	•				•	•	•	Attracts butterflies
Shellbark hickory	*Carya laciniosa*	60-90'	•	•			•					•	•	•	Bark peels away in strips
Shagbark hickory	*Carya ovata*	70-80'	•	•			•				•	•	•	•	Exfoliating bark that curls off in long, loose strips; rich, golden fall foliage
Mockernut hickory	*Carya tomentosa*	60-80'	•	•			•	•			•	•	•	•	Attracts butterflies; golden-yellow fall foliage
Northern catalpa	*Catalpa speciosa*	40-60'	•	•			•	•		•	•				Attracts butterflies and bees; white flowers with purplish and yellow spots or streaks in late spring to early summer

Common Name	Scientific Name	Height	Light			Soil Moisture				Soil pH		Wildlife Benefit			Aesthetics
CANOPY			F	P	S	H	M	S	X	B	A	B	SM	LM	
Yellowwood	*Cladrastis kentuckea*	30-50'	•	•	•		•	•		•					Tennessee's Bicentennial Tree; beautiful panicles of snow white flowers that hang from the branch tips in spring, often compared to wisteria blooms; yellow or orange fall foliage
Common persimmon	*Diospyros virginiana*	35-60'	•	•			•	•		•	•	•	•	•	Fragrant white, bell-shaped flowers; rich yellowish or reddish purple foliage in fall
American beech	*Fagus grandifolia*	50-70'	•	•			•	•			•	•	•	•	Beautiful golden bronze fall foliage
American holly	*Ilex opaca*	15-30'	•	•			•	•			•	•	•		Broadleaf evergreen with bright red berries in winter
Sweetgum	*Liquidambar styraciflua*	60-85'	•	•		•	•	•	•		•	•	•		Beautiful fall color
Tulip poplar	*Liriodendron tulipifera*	70-90'	•	•			•	•			•	•	•		Tennesse state tree; large colorful flowers in spring; yellow fall foliage
Blackgum tupelo	*Nyssa sylvatica*	30-60'	•	•	•		•	•	•		•	•			Red foliage in early fall
Virginia pine	*Pinus virginiana*	50-75'	•	•				•	•		•	•	•		
Sycamore	*Platanus occidentalis*	75-100'	•	•		•	•			•		•	•		Attractive exfoliating bark
Eastern cottonwood	*Populus deltoides*	80-100'	•				•	•		•	•		•	•	Rapid growth rate provides quick shade
Black cherry	*Prunus serotina*	50-75'	•	•			•	•				•	•		White flowers in spring; yellow to wine-red fall foliage.
White oak	*Quercus alba*	80-100'	•	•			•	•			•	•	•	•	Bronze to red fall foliage
Swamp white oak	*Quercus bicolor*	45-65'	•	•		•	•	•			•	•	•	•	Yellow, with occasional red-purple fall foliage
Overcup oak	*Quercus lyrata*	55-95'	•			•	•	•			•	•	•	•	Yellow-brown fall foliage
Burr oak	*Quercus macrocarpa*	70-85'	•	•			•	•	•		•	•	•	•	Attractive form with spreading branches

Common Name	Scientific Name	Height	Light			Soil Moisture				Soil pH		Wildlife Benefit			Aesthetics
CANOPY			F	P	S	H	M	S	X	B	A	B	SM	LM	
Swamp chestnut oak	*Quercus michauxii*	48-100'	•	•			•	•			•	•	•	•	Yellow to vibrant red fall foliage
Chinkapin oak	*Quercus muehlenbergii*	60-80'	•	•			•	•	•	•		•	•	•	Attractive fall foliage
Nuttall oak	*Quercus nuttallii*	50-75'	•	•		•	•				•	•	•	•	Red to orange red late-fall foliage
Cherrybark oak	*Quercus pagoda*	70-80'	•	•			•	•			•	•	•	•	Shade tree and fast-growing oak
Willow oak	*Quercus phellos*	50-70'	•	•			•	•			•	•	•	•	Russet-red fall foliage; commonly planted as ornamental and shade tree
Northern red oak	*Quercus rubra*	60-85'	•	•			•				•	•	•	•	Fast grower; red fall foliage
Shumard oak	*Quercus shumardii*	50-80'	•	•			•	•	•		•	•	•	•	Fast grower and good shade tree; deep orange-red fall foliage
Black willow	*Salix nigra*	30-60'	•	•		•				•		•	•	•	Shrubby-looking tree
Bald cypress	*Taxodium distichum*	40-100'	•	•		•	•				•	•			Deciduous conifer; soft brown fall foliage; commonly used as ornamental tree
Sassafras	*Sassafras albidum*	30-60'	•	•		•	•	•			•	•	•	•	Small yellow flowers; yellow to purple-red fall foliage

Common Name	Scientific Name	Height	Light			Soil Moisture				Soil pH		Wildlife Benefit			Aesthetics
SHRUB			F	P	S	H	M	S	X	B	A	B	SM	LM	
Hazel alder	*Alnus serrulata*	10-20'	•			•	•				•	•	•	•	Yellow to red fall foliage
False Indigo bush	*Amorpha fruticosa*	6-10'	•	•			•	•		•	•	•			Attracts bees and butterflies; purple to dark blue flowers in spring
Red chokeberry	*Aronia arbutifolia*	6-11'	•	•			•	•			•				Reddish-brown exfoliating bark; red fall foliage
Black chokeberry	*Aronia melanocarpa*	3-6'	•	•		•	•	•			•	•			White flowers in May; black to purplish-balck berries; good fall foliage
American beautyberry	*Callicarpa americana*	3-6'	•	•			•	•		•	•	•	•	•	Lavender pink flowers in summer; beatiful magenta berry-like fruit persists through winter
Sweetshrub	*Calycanthus floridus*	6-9'	•	•			•				•				Sweet-scented purple-brown unique, oddly shaped flowers
New Jersey tea	*Ceanothus americanus*	2-3'	•	•			•	•	•		•	•			Attracts butterflies; white flowers
Buttonbush	*Cephalanthus occidentalis*	5-12'	•			•	•			•	•				Attracts butterflies; creamy white flowers
Cinnamon clethra, Mountain sweetpepperbush	*Clethra acuminata*	8-15'	•	•				•			•				Attracts bees; reddish-brown exfoliating bark
Silky dogwood	*Cornus amomum*	6-12'	•	•		•	•			•	•	•	•		Attractive white flowers; blue fruits
Hazelnut	*Corylus americana*	5-12'		•	•		•	•			•	•	•		Attracts butterflies
Leatherwood	*Dirca palustris*	3-6'		•	•		•			•	•				Has attractive bell-shaped flowers in pendulous clusters and leaves which turn a unique shade of soft yellow in fall
Hearts-a-bustin	*Euonymus americanus*	4-6'		•	•		•	•			•	•	•	•	Bright orange-red fruit display after the warty, pinkish capsules open in fall
Wild hydrangea	*Hydrangea arborescens*	3-6'		•			•	•		•	•				Large clusters of white flowers; light yellow fall foliage

Common Name	Scientific Name	Height	Light			Soil Moisture				Soil pH		Wildlife Benefit			Aesthetics
GRASSES and SEDGES			F	P	S	H	M	S	X	B	A	B	SM	LM	
Big bluestem	*Andropogon gerardii*	4-8'	•				•	•		•	•	•	•		Reddish to purple brown in fall
Splitbeard bluestem	*Andropogon ternarius*	2-4'	•	•			•	•			•				Attractive silvery white seed tufts
Broomsedge	*Andropogon virginicus*	2-4'	•	•			•				•	•			Yellow flower and tawny brown color in fall
Giant river cane	*Arundinaria gigantea spp. gigantea*	3-20'	•	•	•	•	•				•	•	•		Can form large colonies
Side oats grama	*Bouteloua curtipendula*	1-2'	•	•				•	•	•	•	•			Purplish red flowers in late summer
Sedges	*Carex spp.*	3-5'	•			•						•			
Cherokee sedge	*Carex cherokeensis*	1-1.5'		•		•	•								Attractive pendulous flower/seed stalks in late spring
Frank's sedge	*Carex frankii*	1-2.5'	•	•		•	•				•				Attracts butterflies
Hop sedge	*Carex lupulina*	1-4'	•	•		•	•				•	•	•		Attracts butterflies
Fox sedge	*Carex vulpinoidea*	1-3'	•	•		•	•			•					Seedheads spray out attractively from the center of the clump, looking like a fox's tail
River oats, Indian woodoats	*Chasmanthium latifolium*	2.5-4'	•	•		•	•	•			•	•	•	•	Provides excellent contrast and texture almost year-round to the planting area
Slender woodoats	*Chasmanthium laxum*	2-3'		•	•		•	•							Arrowhead-shaped, persistent seed heads
Bottlebrush grass	*Elymus hystrix*	2-3'	•	•			•	•	•	•	•	•			Attracts butterflies
Virginia wild rye	*Elymus virginicus*	3-4'	•	•		•	•				•	•			Attracts butterflies
Purple love grass	*Eragrostis spectabilis*	1-2'	•	•				•	•		•				Fine-textured stiff flowerhead appears like reddish purple clouds
Common rush	*Juncus effusus*	2-4'	•			•	•				•	•			

Common Name	Scientific Name	Height	Light			Soil Moisture				Soil pH		Wildlife Benefit			Aesthetics
GRASSES and SEDGES			F	P	S	H	M	S	X	B	A	B	SM	LM	
Pink muhly grass	*Muhlenbergia capillaris*	2-3'	•	•			•	•			•				Blooms in fall, pink to pinkish red flowers
Switchgrass	*Panicum virgatum*	3-6'	•	•			•	•				•			Attracts butterflies; blooms late summer into fall, pink flowers
Silver plume grass	*Saccharum alopecuroides*	5-6'	•	•			•	•			•				Produces a large, rosy copper plume in the fall that fades to a silvery peach
Sugarcane plume grass	*Saccharum giganteum (Erianthus giganteum)*	9'	•	•		•	•				•				Large, fluffy, terminal panicle of reddish-peach to silvery white seedheads. Foliage turns orange red and fades to straw color in winter.
Little bluestem	*Schizachyrium scoparium*	2-4'	•	•				•	•	•		•			Bluish cast in summer and turns orange-red in fall
Green bullrush	*Scirpus atrovirens*	2-5'	•	•		•	•			•	•	•			
Indian grass	*Sorghastrum nutans*	3-7'	•				•	•		•	•	•			Attracts butterflies; Rich gold and purple sprays of flowers in fall
Eastern gama grass	*Tripsacum dactyloides*	4-8'	•	•			•							•	Purple and orange flowers

The Tennessee Urban Riparian Buffer Handbook Series

This handout is one of a series of supporting appendices to the **Tennessee Urban Riparian Buffer Handbook**. To download go to: http://tn.gov/agriculture/topic/ag-forests-urban

A. The Tennessee Urban Riparian Buffer
B. Tennessee Riparian Buffer Site Assessment
C. Creating a Tennessee Urban Riparian Buffer
D. Tennessee Native Riparian Plants List
E. The Threat of Invasive Plants to Tennessee Urban Riparian Buffers
F. Organizing and Conducting a Riparian Buffer Community Planting
G. Properly Installing Plants: How to Plant Trees and Shrubs

Existing Conditions:

- Light:
  - Zone 1: FULL
  - Zone 2: PARTIAL
  - Zone 3: FULL
- Soil Moisture: HIGH
- Soil pH: BASIC

Plants:

Plant name	Light	Soil Moisture	Soil pH
River birch	• Full • Partial	High	• Basic • Acidic
Sycamore	• Full • Partial	High	Basic
Black willow	• Full • Partial	High	Basic
Silky dogwood	• Full • Partial	High	Basic
Fox sedge	• Full • Partial	High	Basic
Green bulrush	• Full • Partial	High	• Basic • Acidic

Based on these criteria and need for erosion control, plants were selected as:

ZONE 1: River birch, Sycamore, Black willow

ZONE 2: River birch, Sycamore, Black willow

ZONE 3: Silky dogwood, Fox sedge, Green bulrush

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Betula nigra L.

river birch

Characteristics

Morphology/Physiology	
Active Growth Period	Spring and Summer
Bloat	None
C:N Ratio	Medium
Coppice Potential	Yes
Fall Conspicuous	No
Fire Resistant	No
Flower Color	Brown
Flower Conspicuous	No
Foliage Color	Green
Foliage Porosity Summer	Moderate
Foliage Porosity Winter	Porous
Foliage Texture	Medium
Fruit/Seed Color	Brown
Fruit/Seed Conspicuous	No
Growth Form	Multiple Stem
Growth Rate	Rapid
Height at 20 Years, Maximum (feet)	35
Height, Mature (feet)	70.0
Known Allelopath	No
Leaf Retention	No
Lifespan	Short
Low Growing Grass	No
Nitrogen Fixation	None
Resprout Ability	Yes
Shape and Orientation	Erect
Toxicity	None

Growth Requirements	
Adapted to Coarse Textured Soils	Yes
Adapted to Fine Textured Soils	Yes
Adapted to Medium Textured Soils	Yes
Anaerobic Tolerance	Medium
CaCO3 Tolerance	None
Cold Stratification Required	No
Drought Tolerance	Low
Fertility Requirement	Medium
Fire Tolerance	Medium
Frost Free Days, Minimum	150
Hedge Tolerance	None

Moisture Use	High
pH, Maximum	6.5
pH, Minimum	3.0
Planting Density per Acre, Maximum	700
Planting Density per Acre, Minimum	300
Precipitation, Maximum	80
Precipitation, Minimum	30
Root Depth, Minimum (inches)	20
Salinity Tolerance	None
Shade Tolerance	Intolerant
Temperature, Minimum (°F)	-31

Reproduction

Bloom Period	Mid Spring
Commercial Availability	Routinely Available
Fruit/Seed Abundance	High
Fruit/Seed Period Begin	Spring
Fruit/Seed Period End	Spring
Fruit/Seed Persistence	No
Propagated by Bare Root	Yes
Propagated by Bulb	No
Propagated by Container	Yes
Propagated by Corm	No
Propagated by Cuttings	Yes
Propagated by Seed	Yes
Propagated by Sod	No
Propagated by Sprigs	No
Propagated by Tubers	No
Seed per Pound	374400
Seed Spread Rate	Rapid
Seedling Vigor	High
Small Grain	No
Vegetative Spread Rate	Slow

Suitability/Use

Berry/Nut/Seed Product	No
Christmas Tree Product	No
Fodder Product	No
Fuelwood Product	Low
Lumber Product	No
Naval Store Product	No

Nursery Stock Product	No
Palatable Browse Animal	Medium
Palatable Graze Animal	Low
Palatable Human	No
Post Product	No
Protein Potential	Low
Pulpwood Product	Yes
Veneer Product	Yes

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Platanus occidentalis L.

American sycamore

Characteristics

Morphology/Physiology	
Active Growth Period	Spring and Summer
Bloat	None
C:N Ratio	High
Coppice Potential	Yes
Fall Conspicuous	Yes
Fire Resistant	No
Flower Color	Red
Flower Conspicuous	No
Foliage Color	Green
Foliage Porosity Summer	Dense
Foliage Porosity Winter	Porous
Foliage Texture	Coarse
Fruit/Seed Color	Brown
Fruit/Seed Conspicuous	Yes
Growth Form	Single Stem
Growth Rate	Rapid
Height at 20 Years, Maximum (feet)	65
Height, Mature (feet)	100.0
Known Allelopath	No
Leaf Retention	No
Lifespan	Long
Low Growing Grass	No
Nitrogen Fixation	None
Resprout Ability	Yes
Shape and Orientation	Erect
Toxicity	None

Growth Requirements	
Adapted to Coarse Textured Soils	Yes
Adapted to Fine Textured Soils	No
Adapted to Medium Textured Soils	Yes
Anaerobic Tolerance	Medium
CaCO3 Tolerance	None
Cold Stratification Required	No
Drought Tolerance	Low
Fertility Requirement	Medium
Fire Tolerance	Medium
Frost Free Days, Minimum	100
Hedge Tolerance	None

Moisture Use	High
pH, Maximum	6.5
pH, Minimum	4.9
Planting Density per Acre, Maximum	800
Planting Density per Acre, Minimum	300
Precipitation, Maximum	80
Precipitation, Minimum	30
Root Depth, Minimum (inches)	30
Salinity Tolerance	None
Shade Tolerance	Intermediate
Temperature, Minimum (°F)	-34

Reproduction

Bloom Period	Spring
Commercial Availability	Routinely Available
Fruit/Seed Abundance	Medium
Fruit/Seed Period Begin	Summer
Fruit/Seed Period End	Fall
Fruit/Seed Persistence	Yes
Propagated by Bare Root	Yes
Propagated by Bulb	No
Propagated by Container	Yes
Propagated by Corm	No
Propagated by Cuttings	Yes
Propagated by Seed	Yes
Propagated by Sod	No
Propagated by Sprigs	No
Propagated by Tubers	No
Seed per Pound	192000
Seed Spread Rate	Moderate
Seedling Vigor	Medium
Small Grain	No
Vegetative Spread Rate	Slow

Suitability/Use

Berry/Nut/Seed Product	No
Christmas Tree Product	No
Fodder Product	No
Fuelwood Product	Low
Lumber Product	Yes
Naval Store Product	No

Nursery Stock Product	Yes
Palatable Browse Animal	Low
Palatable Human	No
Post Product	No
Pulpwood Product	No
Veneer Product	No

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Salix nigra Marshall

black willow

Characteristics

Morphology/Physiology	
Active Growth Period	Spring and Summer
Bloat	None
C:N Ratio	Medium
Coppice Potential	Yes
Fall Conspicuous	No
Fire Resistant	No
Flower Conspicuous	No
Foliage Color	Green
Foliage Porosity Summer	Moderate
Foliage Porosity Winter	Porous
Foliage Texture	Medium
Fruit/Seed Conspicuous	No
Growth Form	Multiple Stem
Growth Rate	Rapid
Height at 20 Years, Maximum (feet)	50
Height, Mature (feet)	100.0
Known Allelopath	No
Leaf Retention	No
Lifespan	Short
Low Growing Grass	No
Nitrogen Fixation	None
Resprout Ability	Yes
Shape and Orientation	Erect
Toxicity	None

Growth Requirements	
Adapted to Coarse Textured Soils	Yes
Adapted to Fine Textured Soils	Yes
Adapted to Medium Textured Soils	Yes
Anaerobic Tolerance	High
CaCO3 Tolerance	Low
Cold Stratification Required	No
Drought Tolerance	Low
Fertility Requirement	Medium
Fire Tolerance	Low
Frost Free Days, Minimum	120
Hedge Tolerance	None
Moisture Use	High
pH, Maximum	8.0

pH, Minimum	4.8
Planting Density per Acre, Maximum	1200
Planting Density per Acre, Minimum	300
Precipitation, Maximum	80
Precipitation, Minimum	18
Root Depth, Minimum (inches)	32
Salinity Tolerance	Medium
Shade Tolerance	Intolerant
Temperature, Minimum (°F)	-58

Reproduction

Bloom Period	Early Spring
Commercial Availability	Routinely Available
Fruit/Seed Abundance	High
Fruit/Seed Period Begin	Spring
Fruit/Seed Period End	Summer
Fruit/Seed Persistence	No
Propagated by Bare Root	Yes
Propagated by Bulb	No
Propagated by Container	Yes
Propagated by Corm	No
Propagated by Cuttings	Yes
Propagated by Seed	No
Propagated by Sod	No
Propagated by Sprigs	No
Propagated by Tubers	No
Seed per Pound	2500000
Seed Spread Rate	Slow
Seedling Vigor	Low
Small Grain	No
Vegetative Spread Rate	Slow

Suitability/Use

Berry/Nut/Seed Product	No
Christmas Tree Product	No
Fodder Product	No
Fuelwood Product	Low
Lumber Product	No
Naval Store Product	No
Nursery Stock Product	Yes
Palatable Browse Animal	Low

Palatable Graze Animal	Low
Palatable Human	No
Post Product	No
Protein Potential	Low
Pulpwood Product	Yes
Veneer Product	No

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Cornus amomum Mill.

silky dogwood

Characteristics

Morphology/Physiology	
Active Growth Period	Spring and Summer
Bloat	None
C:N Ratio	High
Coppice Potential	Yes
Fall Conspicuous	No
Fire Resistant	No
Flower Color	White
Flower Conspicuous	Yes
Foliage Color	Green
Foliage Porosity Summer	Dense
Foliage Porosity Winter	Moderate
Foliage Texture	Coarse
Fruit/Seed Color	Green
Fruit/Seed Conspicuous	Yes
Growth Form	Stoloniferous
Growth Rate	Moderate
Height at 20 Years, Maximum (feet)	7
Height, Mature (feet)	10.0
Known Allelopath	No
Leaf Retention	No
Lifespan	Moderate
Low Growing Grass	No
Nitrogen Fixation	None
Resprout Ability	No
Shape and Orientation	Semi-Erect
Toxicity	None

Growth Requirements	
Adapted to Coarse Textured Soils	Yes
Adapted to Fine Textured Soils	Yes
Adapted to Medium Textured Soils	Yes
Anaerobic Tolerance	Medium
CaCO3 Tolerance	Low
Cold Stratification Required	Yes
Drought Tolerance	Low
Fertility Requirement	Medium
Fire Tolerance	High
Frost Free Days, Minimum	110
Hedge Tolerance	Medium

Moisture Use	High
pH, Maximum	7.0
pH, Minimum	5.0
Planting Density per Acre, Maximum	4800
Planting Density per Acre, Minimum	1200
Precipitation, Maximum	60
Precipitation, Minimum	36
Root Depth, Minimum (inches)	16
Salinity Tolerance	None
Shade Tolerance	Intermediate
Temperature, Minimum (°F)	-38

Reproduction

Bloom Period	Early Spring
Commercial Availability	Routinely Available
Fruit/Seed Abundance	Low
Fruit/Seed Period Begin	Spring
Fruit/Seed Period End	Summer
Fruit/Seed Persistence	No
Propagated by Bare Root	Yes
Propagated by Bulb	No
Propagated by Container	Yes
Propagated by Corm	No
Propagated by Cuttings	Yes
Propagated by Seed	Yes
Propagated by Sod	No
Propagated by Sprigs	No
Propagated by Tubers	No
Seed per Pound	12200
Seed Spread Rate	Slow
Seedling Vigor	Medium
Small Grain	No
Vegetative Spread Rate	Slow

Suitability/Use

Berry/Nut/Seed Product	No
Christmas Tree Product	No
Fodder Product	No
Lumber Product	No
Naval Store Product	No
Nursery Stock Product	Yes

Palatable Browse Animal	Low
Palatable Graze Animal	Low
Palatable Human	No
Post Product	No
Pulpwood Product	No
Veneer Product	No

Cultivar: Indigo

Morphology/Physiology	
Active Growth Period	Spring and Summer
Bloat	None

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Natural Resources Conservation Service

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Carex vulpinoidea Michx.

fox sedge

Characteristics

Morphology/Physiology	
Active Growth Period	Spring
After Harvest Regrowth Rate	Slow
Bloat	None
Coppice Potential	No
Fall Conspicuous	No
Fire Resistant	Yes
Flower Color	Green
Flower Conspicuous	No
Foliage Color	Green
Foliage Porosity Summer	Porous
Foliage Porosity Winter	Porous
Foliage Texture	Fine
Fruit/Seed Color	Yellow
Fruit/Seed Conspicuous	No
Growth Form	Bunch
Growth Rate	Moderate
Height, Mature (feet)	3.2
Known Allelopath	No
Leaf Retention	No
Lifespan	Long
Low Growing Grass	No
Nitrogen Fixation	None
Resprout Ability	No
Shape and Orientation	Erect
Toxicity	None

Growth Requirements	
Adapted to Coarse Textured Soils	No
Adapted to Fine Textured Soils	Yes
Adapted to Medium Textured Soils	Yes
Anaerobic Tolerance	Medium
CaCO3 Tolerance	Medium
Cold Stratification Required	No
Drought Tolerance	Low
Fertility Requirement	Medium
Fire Tolerance	Low
Frost Free Days, Minimum	110
Hedge Tolerance	None
Moisture Use	Medium

pH, Maximum	8.9
pH, Minimum	6.8
Planting Density per Acre, Maximum	19000
Planting Density per Acre, Minimum	10912
Precipitation, Maximum	65
Precipitation, Minimum	12
Root Depth, Minimum (inches)	16
Salinity Tolerance	None
Shade Tolerance	Intermediate
Temperature, Minimum (°F)	-38

Reproduction

Bloom Period	Spring
Commercial Availability	Routinely Available
Fruit/Seed Abundance	Medium
Fruit/Seed Period Begin	Summer
Fruit/Seed Period End	Fall
Fruit/Seed Persistence	No
Propagated by Bare Root	No
Propagated by Bulb	No
Propagated by Container	No
Propagated by Corm	No
Propagated by Cuttings	No
Propagated by Seed	Yes
Propagated by Sod	No
Propagated by Sprigs	Yes
Propagated by Tubers	No
Seed per Pound	1297000
Seed Spread Rate	Moderate
Seedling Vigor	Medium
Small Grain	No
Vegetative Spread Rate	None

Suitability/Use

Berry/Nut/Seed Product	No
Christmas Tree Product	No
Fodder Product	No
Lumber Product	No
Naval Store Product	No
Nursery Stock Product	No
Palatable Graze Animal	Medium

Palatable Human	No
Post Product	No
Pulpwood Product	No
Veneer Product	No

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Scirpus atrovirens Willd.

green bulrush

Characteristics

Morphology/Physiology	
Active Growth Period	Spring
After Harvest Regrowth Rate	Slow
Bloat	None
Coppice Potential	No
Fall Conspicuous	No
Fire Resistant	No
Flower Color	Brown
Flower Conspicuous	No
Foliage Color	Dark Green
Foliage Porosity Summer	Moderate
Foliage Porosity Winter	Porous
Foliage Texture	Coarse
Fruit/Seed Color	Brown
Fruit/Seed Conspicuous	No
Growth Form	Bunch
Growth Rate	Moderate
Height, Mature (feet)	5.9
Known Allelopath	No
Leaf Retention	No
Lifespan	Long
Low Growing Grass	No
Nitrogen Fixation	None
Resprout Ability	No
Shape and Orientation	Erect
Toxicity	None

Growth Requirements	
Adapted to Coarse Textured Soils	No
Adapted to Fine Textured Soils	Yes
Adapted to Medium Textured Soils	Yes
Anaerobic Tolerance	Medium
CaCO3 Tolerance	Medium
Cold Stratification Required	No
Drought Tolerance	Low
Fertility Requirement	Medium
Fire Tolerance	Medium
Frost Free Days, Minimum	180
Hedge Tolerance	None
Moisture Use	Medium

pH, Maximum	8.0
pH, Minimum	4.0
Planting Density per Acre, Maximum	4800
Planting Density per Acre, Minimum	3450
Precipitation, Maximum	60
Precipitation, Minimum	16
Root Depth, Minimum (inches)	12
Salinity Tolerance	None
Shade Tolerance	Intolerant
Temperature, Minimum (°F)	-53

Reproduction

Bloom Period	Summer
Commercial Availability	Routinely Available
Fruit/Seed Abundance	Medium
Fruit/Seed Period Begin	Summer
Fruit/Seed Period End	Fall
Fruit/Seed Persistence	Yes
Propagated by Bare Root	No
Propagated by Bulb	No
Propagated by Container	No
Propagated by Corm	No
Propagated by Cuttings	No
Propagated by Seed	Yes
Propagated by Sod	No
Propagated by Sprigs	Yes
Propagated by Tubers	No
Seed per Pound	11339811
Seed Spread Rate	Moderate
Seedling Vigor	Medium
Small Grain	No
Vegetative Spread Rate	None

Suitability/Use

Berry/Nut/Seed Product	No
Christmas Tree Product	No
Fodder Product	No
Lumber Product	No
Naval Store Product	No
Nursery Stock Product	No
Palatable Graze Animal	Medium

Palatable Human	No
Post Product	No
Pulpwood Product	No
Veneer Product	No

NC STATE EXTENSION

North Carolina Extension Gardener Plant Toolbox

Betula nigra

Common Name(s): Black Birch; Red Birch; River Birch; Water Birch

Phonetic Spelling
BET-yoo-luh NY-gruh

Description
River birch is a native deciduous, upright, flowering tree with cinnamon-brown, exfoliating bark and yellow fall foliage that tends to drop off the tree early and quickly. A member of the Betulaceae (birch) family, it is the only native birch that does well in low elevations of the south. *Betula* is Latin for birch and describes a genus of about 60 species of deciduous trees and shrubs found in many gardens and landscapes throughout the northern hemisphere.

River birch prefers wet sites and does best in moist, acidic, sandy, or rocky, well-drained loam in full sun to part shade. The best foliage color occurs in full sun. River birch is perhaps the most culturally adaptable and heat tolerant of the birches. This species has been known to tolerate flooded conditions for extended periods of time. For this reason, it is naturally found in riverbanks, streambanks, and floodplains. It is also quite wind resistant. In the landscape, keep the soil consistently moist and consider using soaker hoses and bark mulches to keep the root zones cool and moist. It needs little pruning, but if necessary, you can prune during the dormant season. Do not prune in winter or spring when the sap is running because it will bleed.

The bark of young river birch trees is reddish-brown with a papery appearance. The bark peels away year-round, and the inner bark varies in hue from light to dark. The papery bark layers remain attached, giving it an attractive ragged appearance.

Consider planting the Heritage cultivar, which has superior ornamental characteristics.

Site the tree as a specimen or small grouping for shade or screening in the lawn, a rain garden, or naturalized, woodland, or riparian areas. Do not plant it next to the house, because falling branchlets will clog gutters.

Insects, Diseases, or Other Plant Problems: Although river birch is resistant to the bronze birch borer, which infects and kills trees, aphids, leaf miner, and birch skeletonizer may occur. Watch for leaf spot problems. River birch tends to shed interior leaves during summer droughts and dry periods and can become stressed by summer heat and humidity. It also tends to drop a lot of twigs, making it better suited for less manicured areas of the landscape.

VIDEO created by Andy Pulte for "Landscape Plant Identification, Taxonomy and Morphology" a plant identification course offered by the Department of Plant Sciences, University of Tennessee.

Floricyle

Cultivars / Varieties:
'Dickinson', 'Duraheat', 'Heritage', 'Little King', 'Little King', 'Royal Frost', 'Shiloh Splash', 'Statechamp', 'Summer Cascade'

Attributes:

Genus:
Betula

Species:
nigra

Family:
Betulaceae

Uses (Ethnobotany):
The wood is hard and close-grained. It is used for fuel, inexpensive furniture, basket hoops, artificial limbs, and toys. Native Americans are known to have used this tree in many different medicinal purposes. Sap can be fermented to make birch beer.

Life Cycle:
Perennial

Woody

Recommended Propagation Strategy:
Seed

Country Or Region Of Origin:
Central & Eastern U.S.A

Distribution:
VT south to FL west to TX north through OK, NE, MI, IO, and MN

Fire Risk Rating:
low flammability

Wildlife Value:
Host plant for Mourning Cloak and Dreamy Duskywing butterflies. You may see Mourning Cloak (Nymphalis antiopa) which has one flight from June-July, Dreamy Duskywing (Erynnis icelus) with one brood April-July and rarely a second in the south, and Eastern Tiger Swallowtail (Papilo glaucus) which has three flights from February-November in the south and two flights May-September in the north. Young twigs, buds, and foliage browsed by white-tailed deer. Seeds consumed by grouse, turkey, small birds and rodents. Birds and squirrels eat the male catkins in late winter/early spring.

Play Value:
Attracts Pollinators

Buffer

Edible fruit

Pieces Used in Games

Screening

Wildlife Food Source

Wind Break

Wind Shimmer

Particularly Resistant To (Insects/Diseases/Other Problems):
fire in the landscape.

Dimensions:
Height: 30 ft. 0 in. - 70 ft. 0 in.

Width: 40 ft. 0 in. - 60 ft. 0 in.

Whole Plant Traits:

Plant Type:
Native Plant

Tree

Woody Plant Leaf Characteristics:
Deciduous

Habit/Form:
Multi-trunked

Open

Pyramidal

Growth Rate:
Rapid

Maintenance:
Medium

Texture:
Medium

Cultural Conditions:

Light:
Full sun (6 or more hours of direct sunlight a day)

Partial Shade (Direct sunlight only part of the day, 2-6 hours)

Soil Texture:
Clay

Loam (Silt)

Sand

Soil pH:
Acid (<6.0)

Neutral (6.0-8.0)

Soil Drainage:
Good Drainage

Moist

Occasionally Dry

Occasionally Wet

Available Space To Plant:
6-feet-12 feet

NC Region:
Coastal

Mountains

Piedmont

USDA Plant Hardiness Zone:
4a, 4b, 5a, 5b, 6a, 6b, 7a, 7b, 8a, 8b, 9a, 9b

Fruit:

Fruit Color:
Gold/Yellow

Fruit Value To Gardener:
Edible

Display/Harvest Time:
Spring

Summer

Fruit Type:
Aggregate

Nut

Fruit Description:
The tree produces a 1 to 1 1/2 inch cone-like aggregate which contains 3 tiny seeds. Small nutlet, about 400,000 seeds per pound, seed is shed in the spring.

Flowers:

Flower Color:
Gold/Yellow

Green

Flower Inflorescence:
Catkin

Flower Value To Gardener:
Showy

Flower Bloom Time:
Spring

Flower Size:
1-3 inches

Flower Description:
The River Birch has light green, 2 to 3 inch slim, cylindrical flowers and fruiting staminate catkins 2 to 3 inches long that bloom in early spring.

Leaves:

Woody Plant Leaf Characteristics:
Deciduous

Leaf Color:
Gold/Yellow

Green

Leaf Feel:
Rough

Leaf Value To Gardener:
Showy

Deciduous Leaf Fall Color:
Gold/Yellow

Leaf Type:
Simple

Leaf Arrangement:
Alternate

Leaf Shape:
Deltoid

Ovate

Rhomboidal

Leaf Margin:
Doubly Serrate

Hairs Present:
Yes

Leaf Length:
1-3 inches

Leaf Width:
1-3 inches

Leaf Description:
The leaf of the River Birch is 2 to 3.5 inches long with modest yellow fall color. Leaves are 0.75 to 2.5 inches wide, pointed, sharply acute, broadly cuneate to nearly truncate, glaucous with 7-9 veins underneath.

Bark:

Bark Color:
Light Brown

Orange

Surface/Attachment:
Exfoliating

Papery

Peeling

Ridges

Smooth

Bark Description:
Provides winter interest in the landscape. Smooth on young trees, salmon to rust-colored, develops papery scales. As the tree ages, bark divides into flat, scaly ridges. The bark peels away year-round in tough, paper-like layers that remain on the tree.

Stem:

Stem Color:
Gray/Silver

Stem Is Aromatic:
No

Stem Surface:
Hairy (pubescent)

Stem Description:
The bark of branches and twigs is grayish brown and more smooth, while new shoots are light green and pubescent.

Landscape:

Landscape Location:

- Lawn
- Naturalized Area
- Recreational Play Area
- Riparian
- Woodland

Landscape Theme:

- Butterfly Garden
- Children's Garden
- Edible Garden
- Pollinator Garden
- Rain Garden
- Winter Garden

Design Feature:

- Mass Planting
- Screen/Privacy
- Shade Tree
- Specimen

Attracts:

- Butterflies
- Moths
- Pollinators
- Small Mammals
- Songbirds

Resistance To Challenges:

- Black Walnut
- Compaction
- Deer
- Diseases
- Drought
- Fire
- Heat
- Pollution
- Wet Soil
- Wind

Problems:

- Messy

NC STATE EXTENSION

North Carolina Extension Gardener Plant Toolbox

Platanus occidentalis

Common Name(s): American Plane Tree; American Sycamore; Buttonball Tree; Buttonwood; Eastern Sycamore; Sycamore

Phonetic Spelling
PLAT-a-nuz ok-si-den-TAH-lis

Description
American sycamore is a large deciduous tree that may grow 75 to 100 feet tall, is equally as wide, and has a trunk diameter of 10 feet or more. It is one of the largest hardwood trees, by diameter, in North America. This plant is pyramidal in youth, and as it develops it becomes more rounded with an irregular crown and supported by a few large diameter branches. Branches are usually spaced two to four feet apart along the trunk to develop a strong structure. The bark of the tree has a mottled look created by the darker outer layers peeling to expose the lighter inner layers. The bark peels off in patches and the whitened inner bark is the most ornamental trait of this tree. The tree has alternate leaves with 3 to 5 lobes and a coarsely toothed margin. American sycamore is monecious, having both male and female flowers on the same tree. In spring, very small flowers mature in clusters, typically one cluster to a stalk. The tree produces a round fruit ball borne on a 3 to 6-inch stalk. The interior of the fruit ball is fibrous and has many tiny winged seeds or achenes.

The American sycamore is native to Southeastern Canada and the Central and Eastern United States. This tree reaches its largest size along streams, rivers, and flood plains. It is native to North Carolina and can be found throughout the state.

The genus name, *Platanus*, is derived from the Greek word, *plantanos*, and originates from the oriental plane tree or *Platanus orientalis*. The epithet, *occidentalis*, means western. The common name, sycamore, was so named by European settlers because the foliage of this tree looked similar to the sycamore of the British Isles.

This plant prefers full sun and moist, fertile soils. It is tolerant of clay, sand, loam, alkaline, and wet soils. This plant has moderate drought tolerance. It is pollution tolerant, and has a rapid growth rate, but has numerous pest and disease problems.

A dominant central leader, which typically develops on sycamore, usually assures that the structure of major limbs is desirable. Little corrective pruning is required other than removing the occasional upright, aggressive branches with tight crotches. The leaves of the American sycamore appear similar to a maple leaf; however, the maple leaf is opposite in arrangement and the sycamore is alternate. The lateral lobes of the American sycamore tend to bend downward and inward so that it looks like the leaf is folded or drooping.

When considering this tree in the home landscape, keep in mind that this will be a large tree and will require a large space. It may be used in a recreational area, and its tolerance of urban conditions makes it an option as a street tree. Its ultimate size at maturity and the messy littering of twigs and fruits should be considered.

Seasons of Interest:

Bark: Winter **Buds**: Winter **Foliage:** Summer and Fall **Fruits:** Fall and Winter

Quick ID Hints:

- large deciduous tree, 75 to 100 feet tall and equally as wide, irregular crown
- bark is reddish brown to gray, scaly, at the base, upper bark is light gray, exfoliates to expose the inner bark that is white to cream-colored
- stems zigzag, stout, and orangish-brown
- buds are large, smooth, and best seen during the winter
- alternate, large, green, 3 to 5 lobed leaves, 4 to 9 inches wide, coarse teethed margins, lateral lobes appear folded
- insignificant small male and female flowers, single dense cluster on a stalk
- fruit ball with a fibrous interior and densely packed with seeds or achenes

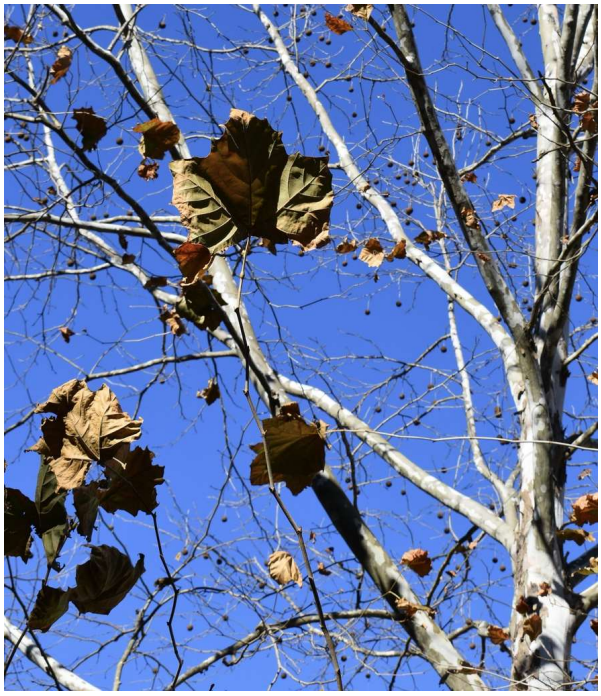
Insects, Diseases, or Other Plant Problems: Potential insects include borers, scales, Japanese beetles, caterpillars, and spider mites. Sycamore anthracnose can severely damage foliage and twigs and frequently causes premature leaf drop. This tree is also susceptible to canker, leaf spots, and powdery mildew. This tree creates much litter from its twigs, large leaves, bark, and fruiting balls if planted in the home landscape and will require significant clean-up. This tree is also susceptible to wind damage.



Fruit and branches (Warren County, NC)-Winter
Cathy Dewitt
CC BY 4.0



Fruit Close-up (Warren County, NC)-Winter
Cathy Dewitt
CC BY 4.0



Leaves (Wake County,NC)-Early Winter
Cathy Dewitt
CC BY 4.0



Back of leaf - July - Warren Co., NC
Cathy DeWitt
CC BY 4.0



Back of leaves - July - Warren Co., NC
Cathy DeWitt
CC BY 4.0

Attributes:

Genus:
Platanus

Species:
occidentalis

Family:
Platanaceae

Uses (Ethnobotany):
Wood is hard and moderately strong, but decays rapidly in the ground. It is often used for chopping blocks, furniture, and chipboard. It is also used to make barrels and crates. Native American hollowed out the trunk of the American sycamore to make canoes.

Life Cycle:
Woody

Recommended Propagation Strategy:
Seed

Country Or Region Of Origin:
Southeastern Canada and Central to Eastern United States

Distribution:
Native: United States--AL, AR, CT, DE, DC, FL, GA, IL, IN, IA, KS, KY, LA, ME, MD, MA, MI, MS, MO, NE, NH, NJ, NY, NC, OH, OK, PA, RI, SC, TN, TX, VT, VA, WV, and WI. Canada--Ontario. Introduced Ecuador, North Caucasus, Transcaucasus, and Turkmenistan.

Fire Risk Rating:
medium flammability

Wildlife Value:
Many songbirds including the Purple Finch, Juncos, American Goldfinch, and the Carolina Chickadee enjoy eating the seeds. The tree hosts wood-boring insects and leafhoppers.

Play Value:
Edible fruit

Textural

Wildlife Food Source

Particularly Resistant To (Insects/Diseases/Other Problems):
The American sycamore is moderately resistant to damage from deer.

Edibility:
Sap is sweet and tapped in the spring for use as syrup and sugar.

Dimensions:
Height: 75 ft. 0 in. - 100 ft. 0 in.

Width: 75 ft. 0 in. - 100 ft. 0 in.

Whole Plant Traits:

Plant Type:
Native Plant

Tree

Woody Plant Leaf Characteristics:
Deciduous

Habit/Form:
Dense

Horizontal

Irregular

Pyramidal

Rounded

Spreading

Growth Rate:
Rapid

Maintenance:
High

Texture:
Coarse

Cultural Conditions:

Light:
Full sun (6 or more hours of direct sunlight a day)

Soil Texture:
Clay

High Organic Matter

Loam (Silt)

Sand

Soil pH:
Acid (<6.0)

Alkaline (>8.0)

Neutral (6.0-8.0)

Soil Drainage:
Good Drainage

Moist

Occasional Flooding

Occasionally Wet

Available Space To Plant:
more than 60 feet

NC Region:
Coastal

Mountains

Piedmont

USDA Plant Hardiness Zone:
4a, 4b, 5a, 5b, 6a, 6b, 7a, 7b, 8a, 8b, 9a, 9b

Fruit:

Fruit Color:
Brown/Copper

Fruit Value To Gardener:
Showy

Display/Harvest Time:
Fall

Winter

Fruit Type:
Achene

Fruit Length:
< 1 inch

Fruit Width:
< 1 inch

Fruit Description:
The fruit ball is a showy, fuzzy, long-stalked, round ball that is 0.5 to 1-inches in diameter. There are 1 to 2 fruit balls per peduncle, usually one. The stalk is 3 to 6 inches long. They ripen to brown in the fall and persist into early winter. Each ball is fibrous interiorly and contains many seed-like fruits called achenes. As fall progresses the balls break down and the seeds fly out in downy tufts on the wind. Typically the fruits fall to the ground and then split open to release their seeds.

Flowers:

Flower Color:
Gold/Yellow

Green

Red/Burgundy

Flower Inflorescence:
Insignificant

Flower Bloom Time:
Spring

Flower Description:
In April, insignificant, small monoecious flowers appear in clusters, typically one cluster to a stalk. The inflorescence is a pendulous, globose syncarp, solitary terminating on an elongated peduncle that is 3 to 6 inches long. Syncarps are hard when young, and crumb apart when they mature. The male flower is greenish-yellow, and the female flower is red.

NC STATE EXTENSION

North Carolina Extension Gardener Plant Toolbox

Salix nigra

Common Name(s): Black Willow

Phonetic Spelling
SAY-liks NY-grah

Description
Salix nigra, commonly called black willow, is a medium-to-large, fast-growing, deciduous willow tree. It typically grows to 70-80′ tall on single or multiple curved trunks, typically 1-2' thick, topped by a spreading, rounded but sometimes irregular crown. It may soar to as much as 140′ tall in optimum growing conditions. It is native to moist to wet soils of floodplains, stream/river banks, swamps, marshes, sloughs, and ponds in the U. S. from Maine to Minnesota south to Colorado, Texas, and Florida and in Canada from New Brunswick to Manitoba. It is the largest of NC's willow species and grows nearly everywhere in the state, save for the high peaks of the Mountain region.

The black willow grows in consistently moist to wet soils in full sun to part shade. It is tolerant of many soil types so long as ample moisture is present. It is tolerant of flooding and silting. It has a shallow, spreading root system that is good for stabilizing soils and makes the tree an effective selection for erosion control. Soils should not be allowed to dry out. It prefers full sun. Avoid full shade. Prune as needed in late winter to early spring.

The bark of black willow is dark brown to black, developing deep grooves and a rough texture with shaggy scales as it ages. The wood is soft and weak, but is used for building crates, the cores of furniture, wooden utensils, and formerly used for building prosthetics.

Black willow is generally not recommended for use as a specimen in residential landscapes because of its susceptibility to breakage, potential insect/disease problems, need for soils that never dry out, litter problems, shallow spreading root system which may seek out water/sewer pipes, and mature size potential. In the right location, its shallow roots can act as a quality soil binder, providing excellent erosion control.

While it bares similarity to the also native Coastal Plains Willow, the two species can be told apart by the leaves– *S. nigra* has thinner leaves and lacks *S. caroliniana*'s whitish undersides.

Live stakes often available.

Salix nigra can be pruned and kept at shrub size by cutting them to the ground every 2-3 years.

Insects, Diseases, and Other Plant Problems: Insects that may be a problem include tent caterpillars, willow sawfly, leaf beetles, aphids, and stem/twig borers. Disease problems include blights, powdery mildew, leaf spots, crown gall, and cankers. Litter from leaves, twigs, and branches cause a lot of maintenance. Shallow roots can clog sewers or drains if trees are sited in improper locations. Wood is soft and weak and tends to crack in wind, ice, or snow. Do not allow soils to dry out.

More information on *Salix*.

Cultivars / Varieties:

Attributes:

Genus:
Salix

Species:
nigra

Family:
Salicaceae

Life Cycle:
Woody

Country Or Region Of Origin:
North America

Fire Risk Rating:
low flammability

Wildlife Value:
This is a larval host plant for several butterflies. Eastern Tiger Swallowtail (Papilio glaucus) has three flights in the deep south from February-November and two flights in the north from May-September. Mourning Cloak (Nymphalis antiopa) has one flight from June-July. Red-spotted Purple (Limenitis arthemis astyanax) has two broods from April-October. Viceroy (Limenitis archippus) has two to three broods from May-September. Eastern Comma (Polygonia comma) overwintered adults lay eggs in from early spring through April. The summer adults appear and lay eggs for the winter form from May-September which appear as adults in September that find a place to overwinter and start the cycle over. Eastern Comma rarely uses this host plant in North Carolina. Its buds and catkins are eaten by birds. It provides excellent leaf season cover for birds in wetland sites. Salix genus support the following specialized bees: Andrena (Parandrena) andrenoides, Andrena (Thysandrena) bisalicis, Andrena (Tylandrena) erythrogaster, Andrena (Andrena) frigida, Andrena (Micrandrena) illinoiensis, Andrena (Andrena) macoupinensis, Andrena (Trachandrena) mariae, Andrena (Parandrena) nida, Andrena (Micrandrena) nigrae, Andrena (Micrandrena) salictaria, Andrena (Parandrena) wellesleyana.

Play Value:
Attracts Pollinators

Shade

Wildlife Cover/Habitat

Wildlife Food Source

Wildlife Larval Host

Particularly Resistant To (Insects/Diseases/Other Problems):
Resistant to fire and moderately resistant to damage from deer.

Dimensions:
Height: 70 ft. 0 in. - 80 ft. 0 in.

Width: 30 ft. 0 in. - 60 ft. 0 in.

Whole Plant Traits:

Plant Type:
Native Plant

Tree

Woody Plant Leaf Characteristics:
Deciduous

Habit/Form:
Multi-trunked

Rounded

Spreading

Weeping

Growth Rate:
Rapid

Maintenance:
High

Cultural Conditions:

Light:
Full sun (6 or more hours of direct sunlight a day)

Partial Shade (Direct sunlight only part of the day, 2-6 hours)

Soil Texture:
Clay

Loam (Silt)

Sand

Soil Drainage:
Frequent Standing Water

Good Drainage

Moist

Occasionally Wet

Available Space To Plant:
24-60 feet

more than 60 feet

NC Region:
Coastal

Mountains

Piedmont

USDA Plant Hardiness Zone:
4a, 4b, 5a, 5b, 6a, 6b, 7a, 7b, 8a, 8b, 9a, 9b

Fruit:

Fruit Color:
Brown/Copper

Red/Burgundy

Display/Harvest Time:
Spring

Summer

Fruit Type:
Capsule

Fruit Length:
< 1 inch

Fruit Width:
< 1 inch

Fruit Description:
Its fruits are reddish-brown capsules that hold hundreds small seeds. The seeds have downy filaments that allow them to be picked up and carried on the wind. In North Carolina, the fruits are available from April to June.

Flowers:

Flower Color:
Gold/Yellow

Green

Flower Inflorescence:
Catkin

Flower Bloom Time:
Spring

Flower Size:
1-3 inches

Flower Description:
Black willow is dioecious (male and female flowers appear on separate trees). Non-showy tiny yellowish-green flowers appear in catkins (both male and female catkins to 2" long) in early spring (late March-April) as the leaves emerge. In North Carolina, the flowers bloom from March to May.

Leaves:

Woody Plant Leaf Characteristics:
Deciduous

Leaf Color:
Green

Deciduous Leaf Fall Color:
Gold/Yellow

Leaf Type:
Simple

Leaf Arrangement:
Alternate

Leaf Shape:
Lanceolate

Leaf Margin:
Dentate

Hairs Present:
No

Leaf Length:
3-6 inches

Leaf Width:
< 1 inch

Leaf Description:
The Black willow has narrow (1/2 to 3/4" wide), lanceolate, finely toothed, medium to dark green leaves (3 to 6" long) that taper to elongate tips. Variable fall color is usually an undistinguished greenish-yellow.

Bark:

Bark Color:
Black

Dark Brown

Light Brown

Orange

Surface/Attachment:
Ridges

Shaggy

Bark Description:
The bark of black willow ranges from light brown with a touch of orange to dark brown and black. It develops deep grooves and a rough texture with shaggy scales as it ages.

Stem:

Stem Is Aromatic:
No

Stem Buds:
Scaly

Stem Bud Scales:
Enclosed in a single cap like scale

Stem Description:
The line between new and old growth is brittle, allowing twigs to be easily broken off.

Landscape:

Landscape Location:
Coastal

Naturalized Area

Pond

Riparian

Landscape Theme:
Butterfly Garden

Drought Tolerant Garden

Native Garden

Pollinator Garden

Rain Garden

Water Garden

Attracts:
Butterflies

Pollinators

Small Mammals

Songbirds

Specialized Bees

Resistance To Challenges:
Compaction

Deer

Drought

Fire

Heat

Wet Soil

Problems:
Frequent Disease Problems

Messy

NC STATE EXTENSION

North Carolina Extension Gardener Plant Toolbox

Cornus amomum

Common Name(s): Kinnikinnik; Pale Dogwood; Red Willow; Silky Cornel; Silky Dogwood; Swamp Dogwood

Previously known as: *Swida amomum*

Phonetic Spelling
KOR-nus ah-MOH-mum

Description
Silky dogwood is a native large to a medium-sized deciduous shrub in the Cornaceae (dogwood) family. It is native to central and the eastern part of the United States and parts of Canada and is typically found in swamp borders, wetlands, and near streams and ponds. This shrub is multi-stemmed, open, and rounded and may grow 6 to 12 feet tall.

Clusters of creamy white flowers bloom in the spring followed by blue drupes that ripen late summer. The leaves and twigs have silky hairs. A distinctive feature of this shrub is the dark brown pith of 1 to 2-year-old stems and dark-reddish twigs.

The genus name, *Cornus*, is Latin from the word, *cornu*, which means "horn." This refers to the hardness of the wood. This shrub has several common names including swamp dogwood. This references its usual habitat.

The silky dogwood prefers well-drained medium to wet acidic soils. It may be grown in full sun, partial shade, and even tolerates close to full shade. The roots need to be kept cool and moist during the summer. It is recommended that 2 to 4 inches of mulch be added to protect the plant's roots. If the shrub branches touch the ground they may form roots at the nodes. Thickets may result if the growth of the shrub is not controlled. The shrub also may be propagated by seeds, cuttings, or layering.

The creamy white clusters of blooms appear at the tips of the branches from May to June. The leaves are dark green, alternate, simple, pubescent, and acutely veined with a smooth margin. The berry-like drupes appear in drooping clusters from August to September and attract many birds. The twigs are usually dark reddish-purple with fine hairs. The older bark is smooth and gray.

This is a good shrub selection for moist to wet areas of the landscape. It is not overly ornamental and is somewhat wild and unkempt for placement in prominent areas. Consider the silky dogwood for moist woodlands, naturalized areas, or sites near streams/ponds. It is also effective for erosion control.

NC Native Shrub

Seasons of interest:

Bloom: Spring **Fruit:** Summer **Twigs:** Winter

Quick ID Hints:

- open, rounded, medium-sized shrub
- silky hairs on the leaves and twigs
- creamy white clusters of flowers in the spring
- drupes ripen to dark blue in late summer
- dark-reddish purple twigs
- smooth gray bark
- dark brown pith in 1 to 2-year-old stems

Insects, Diseases, and Other Plant Problems: The silky dogwood has no serious insects or disease problems. It may be susceptible to scale. Borers and leaf miners are potential pests. Leaf spot, crown canker, blights, root rot, and powdery mildew may occur. Thickets may form if the shrub is not maintained.

Cultivars / Varieties:
'Indigo'

Attributes:

Genus:
Cornus

Species:
amomum

Family:
Cornaceae

Uses (Ethnobotany):
The bark was used by Native Americans as tobacco.

Life Cycle:
Woody

Recommended Propagation Strategy:
Layering

Seed

Stem Cutting

Country Or Region Of Origin:
Eastern Central & Eastern U.S.A

Distribution:
Native: Canada--Ontario and New Foundland: US--AL, CT, DE, DC, FL, IL, IN, IO, KY, ME, MD, MA, MI, MS, MO, NH, NJ, NY, NC, OH, PA, RI, SC, TN, VT, VA, and WV

Fire Risk Rating:
medium flammability

Wildlife Value:
It is the host plant for the spring/summer Azure butterflies. Butterflies nectar at its blooms. Its fruits are eaten by songbirds, ruffed grouse, quail, turkey, chipmunks, black bear, foxes, white-tailed deer, skunks, and squirrels. The foliage is browsed by white-tailed deer. Members of the genus Cornus support the following specialized bees: Andrena (Gonandrena) fragilis, Andrena (Gonandrena) integra, and Andrena (Gonandrena) platyparia.

Play Value:
Attracts Pollinators

Wildlife Cover/Habitat

Wildlife Food Source

Wildlife Larval Host

Wildlife Nesting

Particularly Resistant To (Insects/Diseases/Other Problems):
Deer, Erosion, Wet Soil, Black Walnut. Heat, drought, and soil compaction tolerant.

Dimensions:
Height: 6 ft. 0 in. - 12 ft. 0 in.

Width: 6 ft. 0 in. - 12 ft. 0 in.

Whole Plant Traits:

Plant Type:
Native Plant

Shrub

Woody Plant Leaf Characteristics:
Deciduous

Habit/Form:
Arching

Mounding

Multi-stemmed

Open

Rounded

Growth Rate:
Medium

Maintenance:
Medium

Texture:
Coarse

Cultural Conditions:

Light:
Deep shade (Less than 2 hours to no direct sunlight)

Full sun (6 or more hours of direct sunlight a day)

Partial Shade (Direct sunlight only part of the day, 2-6 hours)

Soil Texture:
Clay

High Organic Matter

Loam (Silt)

Sand

Soil pH:
Acid (<6.0)

Soil Drainage:
Moist

Occasionally Wet

Available Space To Plant:
6-feet-12 feet

12-24 feet

NC Region:
Coastal

Mountains

Piedmont

USDA Plant Hardiness Zone:
5a, 5b, 6a, 6b, 7a, 7b, 8a, 8b

Fruit:

Fruit Color:
Blue

White

Fruit Value To Gardener:
Showy

Display/Harvest Time:
Fall

Summer

Fruit Type:
Drupe

Fruit Length:
< 1 inch

Fruit Width:
< 1 inch

Fruit Description:
The round drupes are 1/4 inch in diameter. They change from white to blue as they ripen. A cluster of drupes droops from greenish or reddish stalks. Displays from August to September.

Flowers:

Flower Color:
Gold/Yellow

White

Flower Inflorescence:
Cyme

Flower Value To Gardener:
Showy

Flower Bloom Time:
Spring

Summer

Flower Petals:
4-5 petals/rays

Flower Size:
< 1 inch

Flower Description:
The tiny creamy-white flowers are arranged in flat-topped cymes that are up to 2.5 inches across. The individual flowers are about 3/8 inch wide and have four petals, four sepals, and four long stamens. The flower stalks have silky hairs. The blooms appear from May to June.

Leaves:

Woody Plant Leaf Characteristics:
Deciduous

Leaf Color:
Green

Leaf Feel:
Smooth

Deciduous Leaf Fall Color:
Insignificant

Leaf Type:
Simple

Leaf Arrangement:
Opposite

Leaf Shape:
Elliptical

Ovate

Leaf Margin:
Entire

Undulate

Hairs Present:
Yes

Leaf Length:
1-3 inches

Leaf Width:
1-3 inches

Leaf Description:
The leaves are simple, opposite, and elliptical to ovate. The margins are entire. Each leaf measures from 2 to 3.5 inches long and 3/4 to 2 inches wide. The upper surface of the leaves is dark green, and the underside is a paler green. Both surfaces have short stiff hairs. The fall foliage may be green, brown, or purplish-red.

Bark:

Bark Color:
Light Gray

Bark Description:
The bark is thin, smooth, and gray.

Stem:

Stem Color:
Brown/Copper

Green

Purple/Lavender

Red/Burgundy

Stem Is Aromatic:
No

Stem Lenticels:
Conspicuous

Stem Surface:
Hairy (pubescent)

Stem Description:
The young twigs may be greenish-purple to dark reddish-purple. They are covered with fine hairs. Older branches are dark purple and eventually develop vertical brownish lenticels or pores. The pith is brown on branches over a year old.

Landscape:

Landscape Location:
Coastal

Naturalized Area

Near Septic

Pond

Woodland

Landscape Theme:
Native Garden

Pollinator Garden

Rain Garden

Design Feature:
Hedge

Mass Planting

Small groups

Specimen

Attracts:
Butterflies

Pollinators

Small Mammals

Songbirds

Specialized Bees

Resistance To Challenges:
Black Walnut

Deer

Erosion

Wet Soil







Carex vulpinoidea

Fox sedge

Native to North America

CHECK AVAILABILITY

FIRST IMPRESSIONS: *Carex vulpinoidea* is a robust perennial sedge with dense tufts of soft grassy leaves. The delicate arching foliage is shiny, narrow, arching and often evergreen. Each plant produces several sturdy culms that are shorter than the foliage. In late spring the culms are topped by 5" stiff greenish inflorescences. The flowers transition into erect deep brown bristly seed clusters reminiscent of fox tails. This sedge thrives in sunny wet meadows or wet disturbed sites. In landscape situations, plants can serve as a lovely accent due to their fine textured foliage.

HABITAT & HARDINESS: *Carex vulpinoidea* is one of the most widely distributed sedges in North America. Plants occur in the southern Canadian provinces and in all of the contiguous U. S. states except Utah.

Plants are indigenous to openings in floodplain forests, sedge meadows, wet prairies, swamps, marshes, seasonally flooded sites adjacent to ponds, creeks and rivers, seeps, disturbed or degraded wetlands, wet fields and ditches. *Carex vulpinoidea* is the dominant sedge in some types of sedge meadows.

Hardy from USDA Zones 3-9.

PLANT DESCRIPTION: *Carex vulpinoidea* grows in lovely mounds of arching glossy foliage. Plants gradually form small colonies from short underground rhizomes.

Foliage is fine textured and light green. Blades are generally 3'long and a little over 1/8" wide. The narrow grass-like leaves are evergreen through most of the range.

In spring many culms rise to a height a bit shorter than the foliage. Each bears sturdy pencil shaped green flower spikes with needle like bracts. Seed form by late summer and spikes change to a pleasing deep brown color.

This sedge is 2-4' tall with an equal spread.

CULTURAL & MAINTENANCE NEEDS: *Carex vulpinoidea* is a resilient sedge for wetlands and disturbed sites. Plants prosper in sun or part shade. Moist soil is preferred but plants will tolerate average soils, drought and wet sites.

This clump forming perennial is indigenous to both acid and alkaline soils and is adapted to heavy clay. Plants are competitive and in an ideal growing situation may become aggressive or invasive.

Plants are pest resistant and unpalatable to deer and other herbivores.

In garden situations, plants should be cut to the ground during late winter.

LANDSCAPE USES: *Carex vulpinoidea* is valuable for Wetland Restoration and Erosion Control in Bioswales and drainage ditches. Its ability to populate disturbed places makes this sedge a good choice to colonize wetland mitigation sites. Plants can be used to hold ground on various shorelines and are useful in Deer Resistant Plantings, Wet Meadows, Stormwater Projects and Wildlife Gardens.

COMPANION & UNDERSTUDY PLANTS: A few suitable companions for *Carex vulpinoidea* are: *Aster punecius*, *Eupatorium maculatum, Eupatorium perfoliatum, Vernonia noveboracensis, Zizia aurea, Juncus effusus* and *Scirpus cyperinius.*

Carex stricta is similar in appearance, height and cultural needs but is not as tolerant of disturbed sites.

TRIVIA: This sedge is very widely distributed across the United States and Canada.

Following disturbance it acts as a pioneer species and forms a valuable community service covering the ground and holding the soil.

Provides habitat and cover for birds and serves as a host plant for skipper butterflies.

Height:	Spread:	Spacing:	USDA Hardiness Zone:
2-4 ft	2-4 ft	3-4 ft	3-9

Bloom Color:
Green, Tan

Carex vulpinoidea Characteristics

Attracts Wildlife
- Pollinators
- Songbirds

Attributes
- Naturalizing
- Dried Flower
- Cut Flower

Exposure
- Partial Shade to Full Sun

Deer Resistant
- Deer Resistant

Flowering Months
- June

Foliage Color
- Green

Grass Season
- Cool Season Grass

Juglans nigra Tolerance (Black Walnut)
- Yes

Season of Interest (Foliage)
- Spring

Soil Moisture Preference
- Wet to Moist

Interesting Notes:
For more information on this plant, visit the USDA PLANTS Database: http://plants.usda.gov/java/profile?symbol=CAVU2

Plants that work well with Carex vulpinoidea "


Thousand-flowered aster (Boltonia asteroides)


Spotted Joe pye weed (Eupatorium maculatum)


Boneset (Eupatorium perfoliatum)


New York ironweed (Vernonia noveboracensis)


Golden Alexander's (Zizia aureus)


Soft rush (Juncus effusus)


Wool grass (Scirpus cyperinus)


Soft stemmed bulrush (Scirpus validus (tabernaemontani))


Wild sweet William, meadow phlox (Phlox maculata)


winged loosestrife (Lythrum alatum)


Gardenview Scarlet beebalm (Monarda didyma 'Gardenview Scarlet')

Substitutions for Carex vulpinoidea


Common Wood Sedge (Carex blanda)


Tussock sedge (Carex stricta)

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Scirpus atrovirens

Green bulrush

Native to North America

CHECK AVAILABILITY



USDA, NRCS. 2012. The PLANTS Database (http://plants.usda.gov, 11 October 2012). National Plant Data Team, Greensboro, NC 27401-4901 USA.





FIRST IMPRESSIONS: *Scirpus atrovirens* is a rhizomatous warm season perennial sedge relative. Plants produce multiple culms with arching or drooping olive green leaves. In summer, fertile culms bear rounded yellow-green compound inflorescences followed by deep brown achenes. This contender is much too aggressive for small manicured gardens. Instead the tenacious roots and rhizomes are a boon for expansive wetland restoration projects and soggy sites with erosion issues.

HABITAT & HARDINESS: *Scirpus atrovirens* occurs from Newfoundland to Manitoba and throughout most of the contiguous United States. The species is absent from Florida and 7 western states and is most abundant in the Northeast and Midwest.

Habitats include wet to moist prairies, sedge meadows, marshes, seeps, bogs, swamps, sloughs, open floodplain forests, low ground along creeks and rivers, moisture retentive right of ways and drainage ditches. This species is a widely distributed freshwater wetland species that is often found in disturbed or degraded wetlands.

This species is hardy from USDA Zones 3-9.

PLANT DESCRIPTION: *Scirpus atrovirens* is an unbranched tufted perennial with short thick rhizomes. This cool season plant actively grows during cooler spring and fall weather.

Plants have green triangular upright culms with 8 or so alternate leaves. Blades are 18" long and ¾" across with yellow-green to dark green color. They are linear with a furrowed midrib, rough textured edge and prominent green or brown sheaths.

In summer, fertile culms are topped by a cluster of compound umbels with 3 or more spreading leafy bracts beneath. The umbels consist of green ovoid spikelets that are less than ¼" long.

In autumn foliage develops soothing gold and brown highlights. The spikelets mature into bristly chocolate brown achenes arranged in starry rounded clusters. The seed display persists until the end of the growing season.

Plants are 3-4' tall with 2-4' spread.

CULTURAL & MAINTENANCE NEEDS: *Scirpus atrovirens* prospers in sunny moist or wet sites. During establishment plugs or seedlings require full sun and wet conditions. Well rooted rhizomes, however, can migrate into moist lightly shaded woodlands.

Plants thrive in standing water up to 1' deep and in acid to slightly alkaline saturated soils. They develop yellow leaves and usually decline in dense shade or during drought.

This species readily self-sows and increases by rhizomes. In disturbed wet sites plants are valued for their ability to bind soil and prevent erosion. This assertive expansion and tenacious nature causes plants to be too aggressive for most garden situations. Avoid planting in sites with limited space and vulnerable slow growing companions.

LANDSCAPE USES: *Scirpus atrovirens* is most valuable for Restoration Projects, Erosion Control, large Water Gardens and Stormwater Management projects. Plants are often installed as part of a Grouping or Mass in Wetland situations.

COMPANION & UNDERSTUDY PLANTS: Try pairing with *Anemone canadensis, Carex muskingumensis, Carex stricta, Iris versicolor or Juncus effusus.*

Carex comosa has similar cultural needs and can be substituted if needed.

TRIVIA: Described in Botanical writings as *cespitose* or "Having the form of a piece of turf, i.e. many stems from one rootstock or from many entangled … roots".

Even though *Scirpus atrovirens* is in the sedge family, *Scirpus* is the old Latin word for "bulrush".

The seeds are a good food for ducks, rails and other wetland birds. Plants are considered deer resistant.

Height:
3-4 ft
Spread:
2-4 ft
Spacing:
3-4 ft
USDA Hardiness Zone:
3-9
Bloom Color:
Green, Tan

Scirpus atrovirens Characteristics

Attributes
- Rain Garden
- Dried Flower
- Naturalizing

Exposure
- Full Sun to Partial Shade

Flowering Months
- September
- August
- July
- June

Foliage Color
- Green

Grass Season
- Warm Season Grass

Salt Tolerance
- Medium

Season of Interest (Foliage)
- Fall
- Summer
- Spring
- Winter

Soil Moisture Preference
- Wet to Moist

Interesting Notes:
For more information on this plant, visit the USDA PLANTS Database: http://plants.usda.gov/java/profile?symbol=SCAT2

Plants that work well with Scirpus atrovirens "


Meadow anemone (No Advance Orders) (Anemone canadensis)


Palm sedge (Carex muskingumensis)


Tussock sedge (Carex stricta)


Blue flag (Iris versicolor)


Soft rush (Juncus effusus)

Substitutions for Scirpus atrovirens

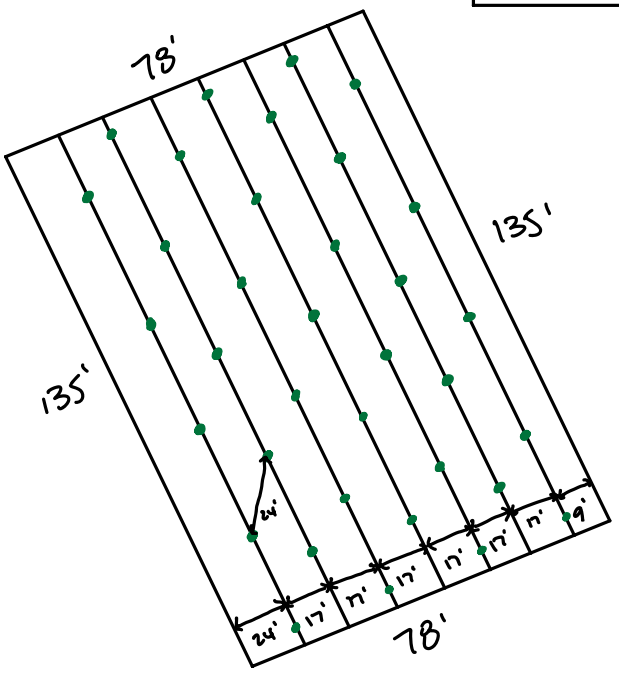

Bristly sedge, Longhair sedge (Carex comosa)

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Zone 1



plants to be spaced 24' on center

$$\#\text{ in one row} = \frac{135\text{ ft}}{24\text{ ft/tree}} = 5\text{ trees}$$

$$\#\text{ rows} = 1 + \frac{135 - 24}{17} = 7$$

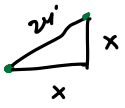
5 trees/row × 7 rows = 35 trees

using equal amounts of each species:

12 river birch

11 sycamore

12 black willow

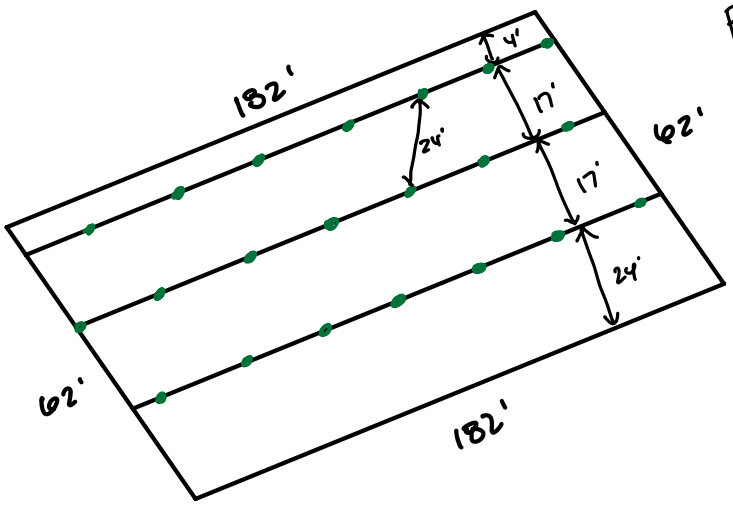


$$x^2 + x^2 = 24^2$$

$$\sqrt{2x^2} = 24$$

$$x = 17'$$

Zone 2



plants to be spaced 24' on center

$$\#\text{ in one row} = \frac{182\text{ ft}}{24\text{ ft/tree}} = 7\text{ trees}$$

$$\#\text{ rows} = 1 + \frac{62 - 24}{17} = 3$$

7 trees/row × 3 rows = 21 trees

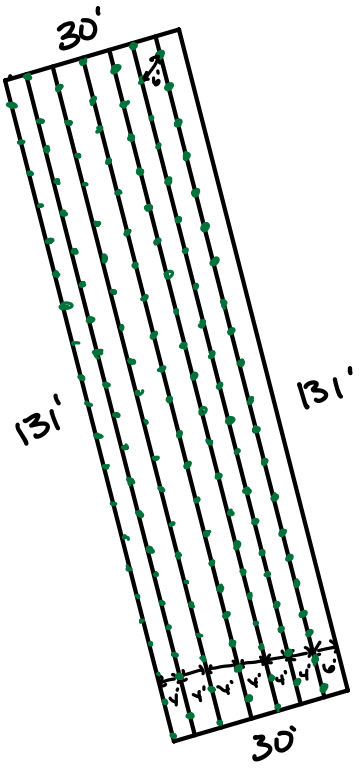
using equal amounts of each species:

7 river birch

7 sycamore

7 black willow

Zone 3



plants to be spaced 6' on center

$$\#\text{ in one row} = \frac{131\text{ ft}}{6\text{ ft/plant}} = 21\text{ plants}$$

$$\#\text{ rows} = 1 + \frac{30-6}{4} = 7$$

21 plants/row × 7 rows = 147 plants

using equal amounts of each species:

49 silky dogwood
49 fox sedge
49 green bulrush



$$x^2 + x^2 = 6^2$$

$$\sqrt{2x^2} = 6$$

$$x = 4'$$

Appendix C: Construction Services

2.1 GENERAL

If critical path methods are applied to the development of a construction plan, to the preparation of an estimate, or to the control of actual operations in progress, a number of logical procedures must be followed. These procedures may be conveniently grouped into planning and scheduling, the principal tasks to which CPM is directed. They may be defined as follows.

Planning is the process of choosing the one method and order of work to be adopted for a project from all the various ways and sequences in which it could be done. The sequence of steps required to achieve the optimum result is the proper plan for the works, and this can be schematically shown on the CPM network diagram.

Scheduling is the determination of the timing of the operations comprising the project and their assembling to give the overall completion time. Scheduling can be done only after a particular project plan has been defined and modeled in such a way that it can be committed to paper in the form of a network diagram.

2.2 PROJECT BREAKDOWN

The first step in planning a job is to break it down into the separate operations or processes necessary for its completion. The degree of breakdown will vary for each project and will be influenced by the nature of work and class of labor involved, the location of the work on the site, the costing data required by

management, the itemized bill of quantities or rates, and the broad general sequence of the job. Each of these separate operations or processes is called an *activity*, and the completion of an activity is an *event* that signals the successful achievement of work. Activities therefore consume time, whereas events do not, and events are separated from one another by activities.

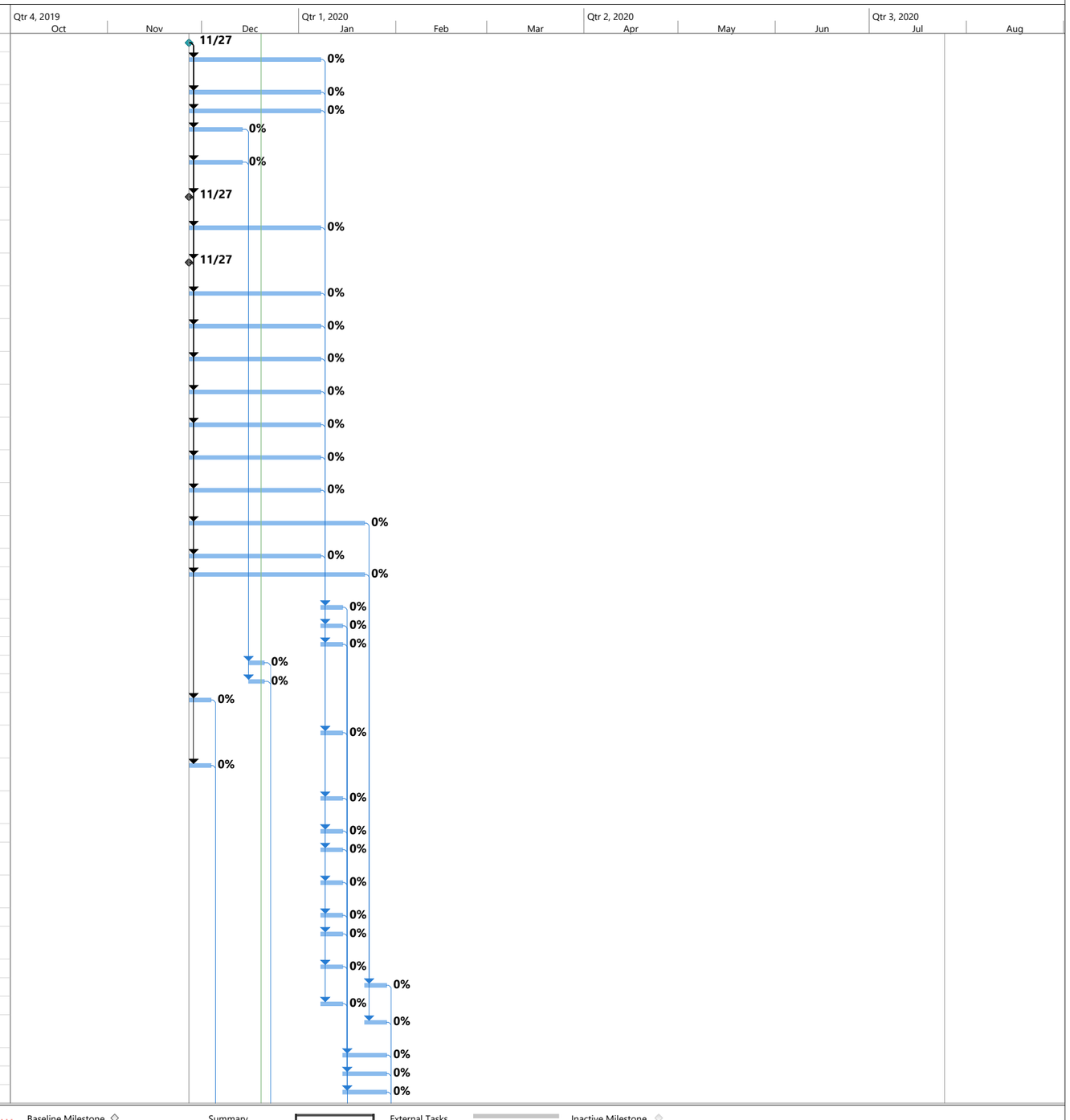
When a list of all the activities in a project has been prepared, the next step is to determine the essential relationship between these activities. Although many of them may proceed concurrently, certain activities must be constrained to a given sequence or *chain:* for example, casting of concrete presuppposes formwork erection and reinforcement installation, and pipelaying presupposes pipe delivery. These are examples of *technology* or *physical constraints* applicable to activities, and are apparent as soon as each activity in the project is subjected to the following questions.

1. What activities *must* precede this activity?
2. What activities *may* be done concurrently with this activity?
3. What activities *must* follow this activity?

In this way each activity is examined and the necessary sequences of activities are determined. Every activity therefore has a definite event to mark its possible beginning; this event may be the start of the project itself or the completion of a preceding activity.

EUD WTP 12-20-19

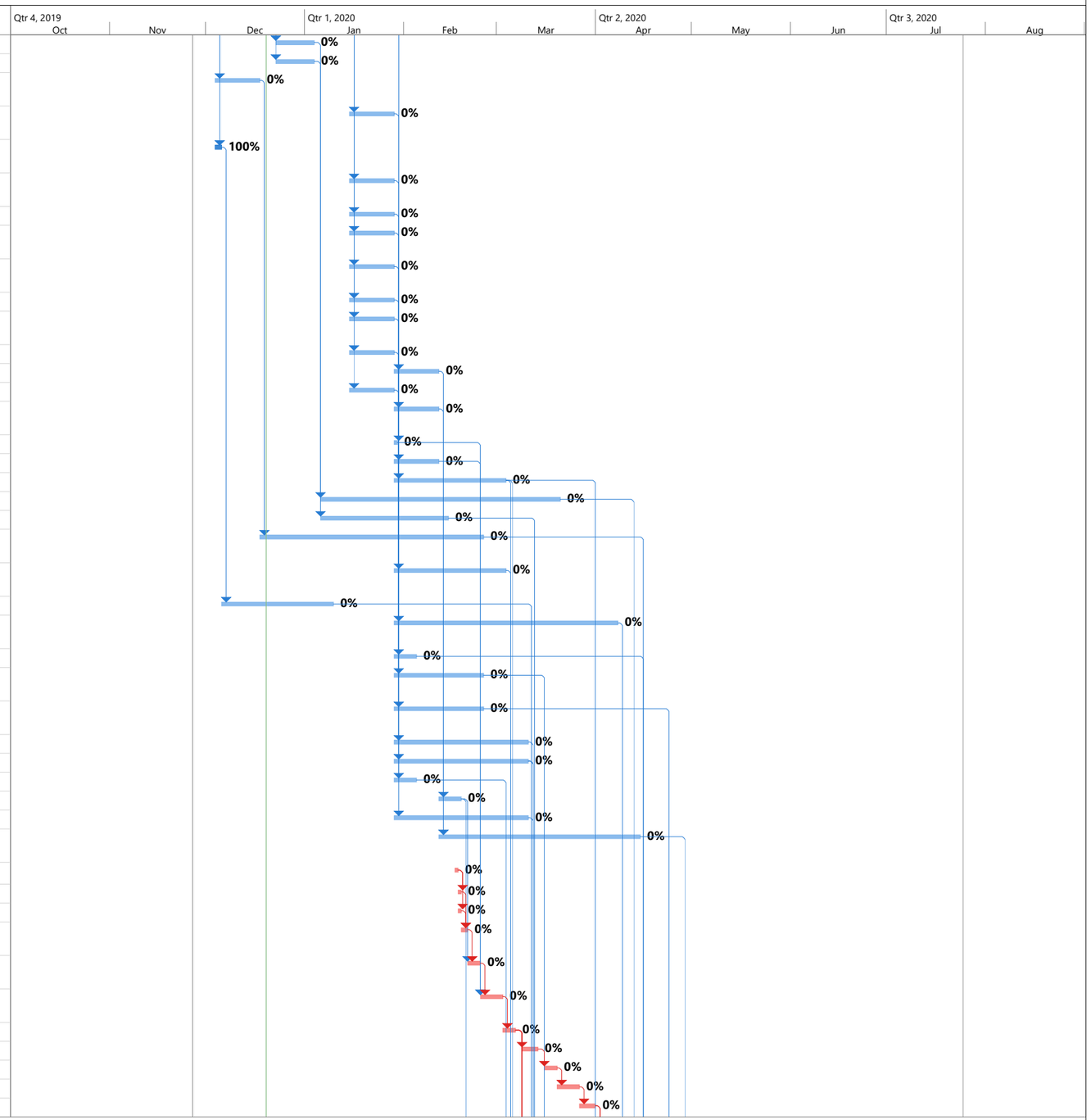
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1		Notice to Proceed	0 days	Wed 11/27/19	Wed 11/27/19		2,3,4,5,6,7,8,		2 days
2		Concrete Submittal Procurement	30 days	Wed 11/27/19	Tue 1/7/20	1	20	Lambcon	18 days
3		Rebar Submittal Procurement	30 days	Wed 11/27/19	Tue 1/7/20	1	21	Becdon	9 days
4		Metals Submittal Procurement	30 days	Wed 11/27/19	Tue 1/7/20	1	22	TFCO	25 days
5		FRP Tanks Submittal Procurement	13 days	Wed 11/27/19	Fri 12/13/19	1	23	Guthrie	15 days
6		Day Tank Submittal Procurement	13 days	Wed 11/27/19	Fri 12/13/19	1	24	Guthrie	44 days
7		Chemical Transfer Pumps Submittal Procurement	0 days	Wed 11/27/19	Wed 11/27/19	1	25	Guthrie	41 days
8		Ultra-Sonic Transducers Submittal Procurement	30 days	Wed 11/27/19	Tue 1/7/20	1	26	Guthrie	39 days
9		Chemical Scale Submittal Procurement	0 days	Wed 11/27/19	Wed 11/27/19	1	27	Guthrie	168 days
10		Chemical Metering Pumps Submittal Procurment	30 days	Wed 11/27/19	Tue 1/7/20	1	28	CFS	10 days
11		PVC Pipe Submittal Procurement	30 days	Wed 11/27/19	Tue 1/7/20	1	29	Harrington	51 days
12		PVC Dual Containment Pipe Submittal Procurement	30 days	Wed 11/27/19	Tue 1/7/20	1	30	Harrington	40 days
13		Chemical Unloading Station Submittal Procurement	30 days	Wed 11/27/19	Tue 1/7/20	1	31	GRM	42 days
14		FRP Grating Submittal Procurement	30 days	Wed 11/27/19	Tue 1/7/20	1	32	Fibergrate	25 days
15		Overhead Door Submittal Procurement	30 days	Wed 11/27/19	Tue 1/7/20	1	33	TBD	25 days
16		Painting Submittal Procurement	30 days	Wed 11/27/19	Tue 1/7/20	1	34	TBD	45 days
17		Electrical Submittal Procurement	40 days	Wed 11/27/19	Tue 1/21/20	1	35	Adman	2 days
18		HVAC Submittal Procurement	30 days	Wed 11/27/19	Tue 1/7/20	1	36	Charles Stone	16 days
19		Chemical Feed Allowance Items Submittal Procurement	40 days	Wed 11/27/19	Tue 1/21/20	1	37	CFS	10 days
20		Concrete GC Review Time	5 days	Wed 1/8/20	Tue 1/14/20	2	38	JCC	18 days
21		Rebar GC Review Time	5 days	Wed 1/8/20	Tue 1/14/20	3	39	JCC	9 days
22		Metals GC Review Time	5 days	Wed 1/8/20	Tue 1/14/20	4	40	JCC	25 days
23		FRP Tanks GC Review Time	5 days	Mon 12/16/19	Fri 12/20/19	5	41	JCC	15 days
24		Day Tank GC Review Time	5 days	Mon 12/16/19	Fri 12/20/19	6	42	JCC	44 days
25		Chemical Transfer Pumps GC Review Time	5 days	Wed 11/27/19	Tue 12/3/19	7	43	JCC	41 days
26		Ultra-Sonic Transducers GC Review Time	5 days	Wed 1/8/20	Tue 1/14/20	8	44	JCC	39 days
27		Chemical Scale GC Review Time	5 days	Wed 11/27/19	Tue 12/3/19	9	45	JCC	168 days
28		Chemical Metering Pumps GC Review Time	5 days	Wed 1/8/20	Tue 1/14/20	10	46	JCC	10 days
29		PVC Pipe GC Review Time	5 days	Wed 1/8/20	Tue 1/14/20	11	47	JCC	51 days
30		PVC Dual Containment Pipe GC Review Time	5 days	Wed 1/8/20	Tue 1/14/20	12	48	JCC	40 days
31		Chemical Unloading Station GC Review Time	5 days	Wed 1/8/20	Tue 1/14/20	13	49	JCC	42 days
32		FRP Grating GC Review Time	5 days	Wed 1/8/20	Tue 1/14/20	14	50	JCC	25 days
33		Overhead Door GC Review Time	5 days	Wed 1/8/20	Tue 1/14/20	15	51	JCC	25 days
34		Painting GC Review Time	5 days	Wed 1/8/20	Tue 1/14/20	16	52	JCC	45 days
35		Electrical GC Review Time	5 days	Wed 1/22/20	Tue 1/28/20	17	53	JCC	2 days
36		HVAC GC Review Time	5 days	Wed 1/8/20	Tue 1/14/20	18	54	JCC	16 days
37		Chemical Feed Allowance Items GC Review Time	5 days	Wed 1/22/20	Tue 1/28/20	19	55	JCC	10 days
38		Concrete Engineer Review	10 days	Wed 1/15/20	Tue 1/28/20	20	56	WK Dickson	18 days
39		Rebar Engineer Review	10 days	Wed 1/15/20	Tue 1/28/20	21	57	WK Dickson	9 days
40		Metals Engineer Review	10 days	Wed 1/15/20	Tue 1/28/20	22	58	WK Dickson	25 days



Critical Progress | Task Progress | Finish-only | Critical Split | Baseline Milestone | Summary | External Tasks | Inactive Milestone
Task | Manual Task | Duration-only | Baseline | Milestone | Manual Summary | External Milestone | Inactive Summary
Split | Start-only | Critical | Baseline Split | Summary Progress | Project Summary | Inactive Task | Deadline

EUD WTP 12-20-19

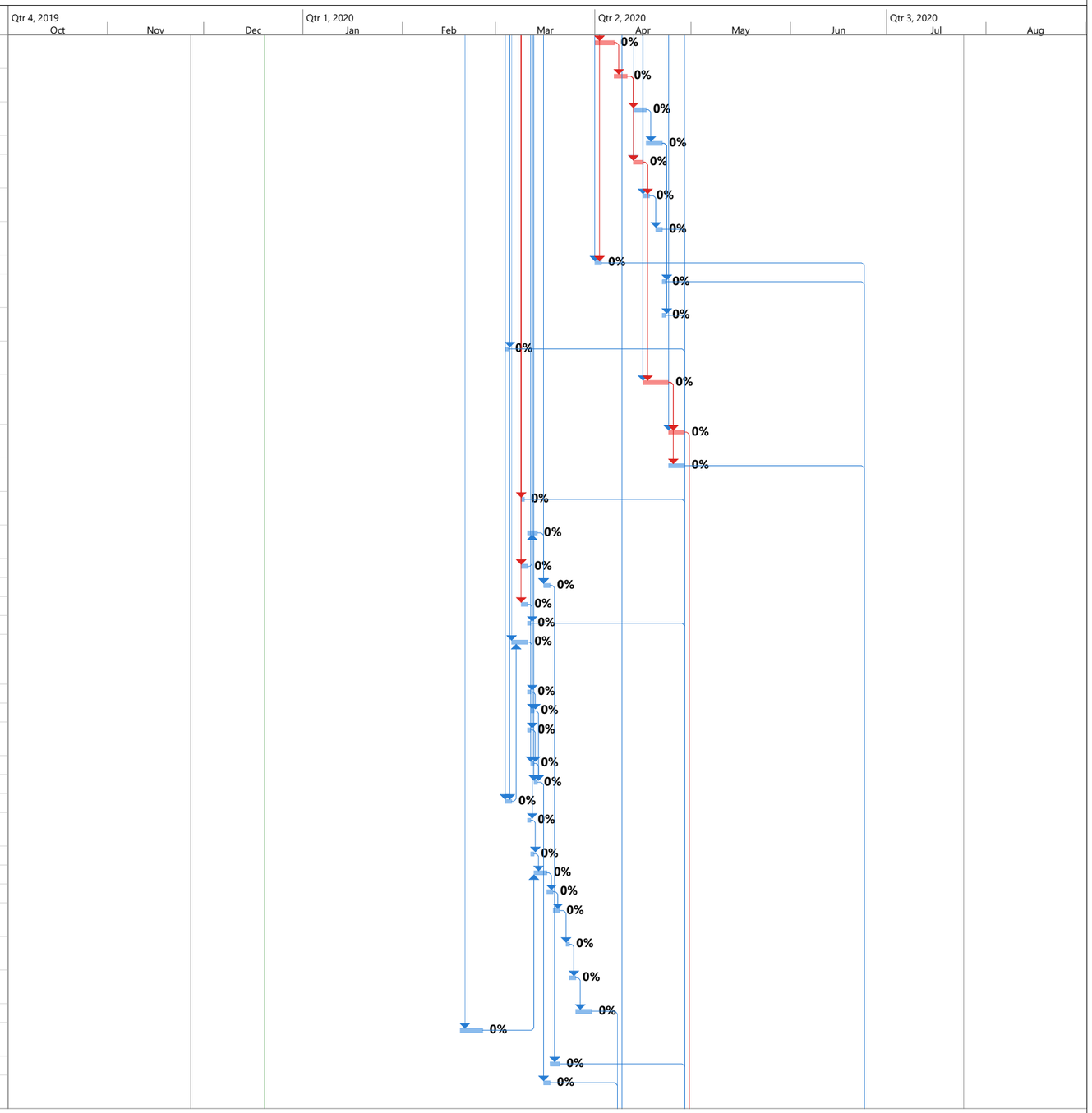
ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors	Successors	Resource Names	Total Slack
41		FRP Tanks Engineer Review	10 days	Mon 12/23/19	Fri 1/3/20	23	59	WK Dickson	15 days
42		Day Tank Engineer Review	10 days	Mon 12/23/19	Fri 1/3/20	24	60	WK Dickson	44 days
43		Chemical Transfer Pumps Engineer Review	10 days	Wed 12/4/19	Tue 12/17/19	25	61	WK Dickson	41 days
44		Ultra-Sonic Transducers Engineer Review	10 days	Wed 1/15/20	Tue 1/28/20	26	62	WK Dickson	39 days
45		Chemical Scale Engineer Review	2 days	Wed 12/4/19	Thu 12/5/19	27	63	WK Dickson	0 days
46		Chemical Metering Pumps Engineer Review	10 days	Wed 1/15/20	Tue 1/28/20	28	64	WK Dickson	10 days
47		PVC Pipe Engineer Review	10 days	Wed 1/15/20	Tue 1/28/20	29	65	WK Dickson	51 days
48		PVC Dual Containment Pipe Engineer Review	10 days	Wed 1/15/20	Tue 1/28/20	30	66	WK Dickson	40 days
49		Chemical Unloading Station Engineer Review	10 days	Wed 1/15/20	Tue 1/28/20	31	67	WK Dickson	42 days
50		FRP Grating Engineer Review	10 days	Wed 1/15/20	Tue 1/28/20	32	68	WK Dickson	25 days
51		Overhead Door Engineer Review	10 days	Wed 1/15/20	Tue 1/28/20	33	69	WK Dickson	25 days
52		Painting Engineer Review	10 days	Wed 1/15/20	Tue 1/28/20	34	70	WK Dickson	45 days
53		Electrical Engineer Review	10 days	Wed 1/29/20	Tue 2/11/20	35	71	WK Dickson	2 days
54		HVAC Engineer Review	10 days	Wed 1/15/20	Tue 1/28/20	36	72	WK Dickson	16 days
55		Chemical Feed Allowance Items Engineer Review	10 days	Wed 1/29/20	Tue 2/11/20	37	73	WK Dickson	10 days
56		Concrete Lead Time	1 day	Wed 1/29/20	Wed 1/29/20	38	79	Lambcon	18 days
57		Rebar Lead Time	10 days	Wed 1/29/20	Tue 2/11/20	39	79	Becdon	9 days
58		Metals Lead Time	25 days	Wed 1/29/20	Tue 3/3/20	40	92,105,111	TFCO	25 days
59		FRP Tanks Lead Time	55 days	Mon 1/6/20	Fri 3/20/20	41	89	Guthrie	15 days
60		Day Tank Lead Time	30 days	Mon 1/6/20	Fri 2/14/20	42	110	Guthrie	44 days
61		Chemical Transfer Pumps Lead Time	50 days	Wed 12/18/19	Tue 2/25/20	43	90	Guthrie	41 days
62		Ultra-Sonic Transducers Lead Time	25 days	Wed 1/29/20	Tue 3/3/20	44	95	Guthrie	39 days
63		Chemical Scale Lead Time	25 days	Fri 12/6/19	Thu 1/9/20	45	109	Guthrie	69 days
64		Chemical Metering Pumps Lead Time	50 days	Wed 1/29/20	Tue 4/7/20	46	123	CFS	10 days
65		PVC Pipe Lead Time	5 days	Wed 1/29/20	Tue 2/4/20	47	96	Harrington	51 days
66		PVC Dual Containment Pipe Lead Time	20 days	Wed 1/29/20	Tue 2/25/20	48	102	Harrington	40 days
67		Chemical Unloading Station Lead Time	20 days	Wed 1/29/20	Tue 2/25/20	49	97	GRM	42 days
68		FRP Grating Lead Time	30 days	Wed 1/29/20	Tue 3/10/20	50	108	Fibergrate	25 days
69		Overhead Door Lead Time	30 days	Wed 1/29/20	Tue 3/10/20	51	107,106	TBD	25 days
70		Painting Lead Time	5 days	Wed 1/29/20	Tue 2/4/20	52	111	TBD	45 days
71		Electrical Lead Time	5 days	Wed 2/12/20	Tue 2/18/20	53	78,120	Adman	2 days
72		HVAC Lead Time	30 days	Wed 1/29/20	Tue 3/10/20	54	112	Charles Stone	16 days
73		Chemical Feed Allowance Items Lead Time	45 days	Wed 2/12/20	Tue 4/14/20	55	124	CFS	10 days
74		***Mobilzation***	1 day	Mon 2/17/20	Mon 2/17/20		75,76	Cumby	0 days
75		Construction Entrance	1 day	Tue 2/18/20	Tue 2/18/20	74	77	Cumby	0 days
76		Silt Fence	1 day	Tue 2/18/20	Tue 2/18/20	74	77	Cumby	0 days
77		Excavation for New Storage Tank/s Pad	2 days	Wed 2/19/20	Thu 2/20/20	75,76	78	Cumby	0 days
78		Electrical In and Under Rough In	2 days	Fri 2/21/20	Mon 2/24/20	71,77	79	Adman	0 days
79		F/R/P New Storage Tanks Pad SOG - 1 Pour	5 days	Tue 2/25/20	Mon 3/2/20	56,57,78	80	Cumby	0 days
80		Pad - SOG Cure Time	4 days	Tue 3/3/20	Fri 3/6/20	79	81,99,101,10	Cumby	0 days
81		F/R/P Walls - Pour 1	5 days	Mon 3/9/20	Fri 3/13/20	80	82	Cumby	0 days
82		Pour 1 Cure Time	4 days	Mon 3/16/20	Thu 3/19/20	81	83	Cumby	0 days
83		F/R/P Walls - Pour 2	5 days	Fri 3/20/20	Thu 3/26/20	82	84	Cumby	0 days
84		Pour 2 Cure Time	3 days	Fri 3/27/20	Tue 3/31/20	83	85,92	Cumby	0 days



Critical Progress | Task Progress | Finish-only | Critical Split | Baseline Milestone | Summary | External Tasks | Inactive Milestone
Task | Manual Task | Duration-only | Baseline | Milestone | Manual Summary | External Milestone | Inactive Summary
Split | Start-only | Critical | Baseline Split | Summary Progress | Project Summary | Inactive Task | Deadline

EUD WTP 12-20-19

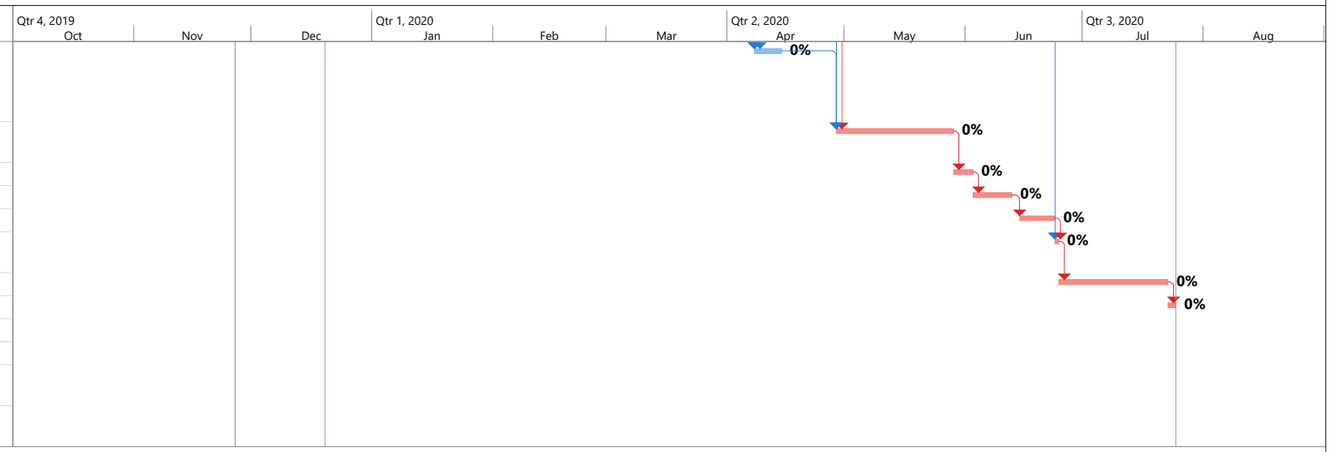
ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors	Successors	Resource Names	Total Slack
85		F/R/P Storage Tank 1 Base - 1 Pour	4 days	Wed 4/1/20	Mon 4/6/20	84	86	Cumby	0 days
86		F/R/P Storage Tank 2 Base - 1 Pour	4 days	Tue 4/7/20	Fri 4/10/20	85	87,89	Cumby	0 days
87		F/R/P Chemical Transfer Pumps Elevated Slab - 1 Pour	4 days	Mon 4/13/20	Thu 4/16/20	86	88	Cumby	4 days
88		Cure Time	3 days	Fri 4/17/20	Tue 4/21/20	87	93,94	Cumby	4 days
89		Install FRP Tanks on New Concrete Bases	3 days	Mon 4/13/20	Wed 4/15/20	59,86	90,96	Cumby	0 days
90		Install New Chemical Feed Transfer Pumps	2 days	Thu 4/16/20	Fri 4/17/20	61,89	91	Cumby	5 days
91		Electrical - Chemical Feed Pumps	2 days	Mon 4/20/20	Tue 4/21/20	90	124	Adman	5 days
92		Install New Ships Ladders	2 days	Wed 4/1/20	Thu 4/2/20	58,84	128	Cumby	58 days
93		Install New Handraill Around Chemical Transfer Pumps	1 day	Wed 4/22/20	Wed 4/22/20	88	128	Cumby	44 days
94		Install New Stairs for Transfer Pumps Access	1 day	Wed 4/22/20	Wed 4/22/20	88	124	Cumby	4 days
95		Install New Level Transducers in New FRP Storage Tanks	1 day	Wed 3/4/20	Wed 3/4/20	62	124	Cumby	39 days
96		Install New Chemical PVC Piping between Tanks and Pumps	6 days	Thu 4/16/20	Thu 4/23/20	65,89	97,98	Cumby	0 days
97		Install New Chemical Injection Ports	3 days	Fri 4/24/20	Tue 4/28/20	67,96	124	Cumby	0 days
98		Install New Heat Trace and Insulation	3 days	Fri 4/24/20	Tue 4/28/20	96	128	Breeding Insualtion	40 days
99		Install Emergency Eye Wash System	1 day	Mon 3/9/20	Mon 3/9/20	80	124	Cumby	36 days
100		Excavation for New 6" PVC Line into Existing "Head House"	3 days	Wed 3/11/20	Fri 3/13/20	101	102	Cumby	27 days
101		Saw Cut Existing Parking Lot	2 days	Mon 3/9/20	Tue 3/10/20	80	100	Cumby	27 days
102		Install 6" PVC Line	2 days	Mon 3/16/20	Tue 3/17/20	66,100	121	Cumby	27 days
103		Excavate for 4" Drain Line	2 days	Mon 3/9/20	Tue 3/10/20	80	104	Cumby	34 days
104		Install 4" Drain Line	1 day	Wed 3/11/20	Wed 3/11/20	103	124	Cumby	34 days
105		Modify Existing Chlorination Room - Install New Support Beams	3 days	Fri 3/6/20	Tue 3/10/20	58,111	108	Cumby	25 days
106		Demo Existing Masonry	1 day	Wed 3/11/20	Wed 3/11/20	69	107	Cumby	25 days
107		Install New Roll Up Door	1 day	Thu 3/12/20	Thu 3/12/20	69,106	110	TBD	25 days
108		Install New FRP Grating and Steps	1 day	Wed 3/11/20	Wed 3/11/20	68,105	109	Cumby	25 days
109		Install new Tank Scale	1 day	Thu 3/12/20	Thu 3/12/20	63,108	110	Cumby	25 days
110		Install new Poly Tank	1 day	Fri 3/13/20	Fri 3/13/20	60,107,109	122	Cumby	25 days
111		Paint new steel support beams	2 days	Wed 3/4/20	Thu 3/5/20	70,58	105	Cumby	25 days
112		HVAC - DEMO Existing Exhaust Fan	1 day	Wed 3/11/20	Wed 3/11/20	72	113	Charles Stone	16 days
113		HVAC - DEMO Existing Louver	1 day	Thu 3/12/20	Thu 3/12/20	112	114	Charles Stone	16 days
114		HVAC - Install EF-1	2 days	Fri 3/13/20	Mon 3/16/20	113,120	115	Charles Stone	16 days
115		HVAC - Install EH-1	2 days	Tue 3/17/20	Wed 3/18/20	114	116	Charles Stone	16 days
116		HVAC - Relocate Existing Chlorination Detection System	2 days	Thu 3/19/20	Fri 3/20/20	115	117	Charles Stone	16 days
117		HVAC - Reconnect Existing on/off/auto switch.	1 day	Mon 3/23/20	Mon 3/23/20	116	118	Charles Stone	16 days
118		HVAC - Reconnect Existing T-Stat	2 days	Tue 3/24/20	Wed 3/25/20	117	119	Charles Stone	16 days
119		HVAC - Install Ductwork	3 days	Thu 3/26/20	Mon 3/30/20	118	123	Charles Stone	16 days
120		Electrical inside Chlorine Room - Wiring and Coundits	5 days	Wed 2/19/20	Tue 2/25/20	71	114	Adman	28 days
121		Head House Basement Piping	3 days	Wed 3/18/20	Fri 3/20/20	102	124	Cumby	27 days
122		DEMO Existing Chlorinators and Piping	2 days	Mon 3/16/20	Tue 3/17/20	110	123	Cumby	25 days



Critical Progress	Task Progress	Finish-only	Critical Split	Baseline Milestone	Summary	External Tasks	Inactive Milestone
Task	Manual Task	Duration-only	Baseline	Milestone	Manual Summary	External Milestone	Inactive Summary
Split	Start-only	Critical	Baseline Split	Summary Progress	Project Summary	Inactive Task	Deadline

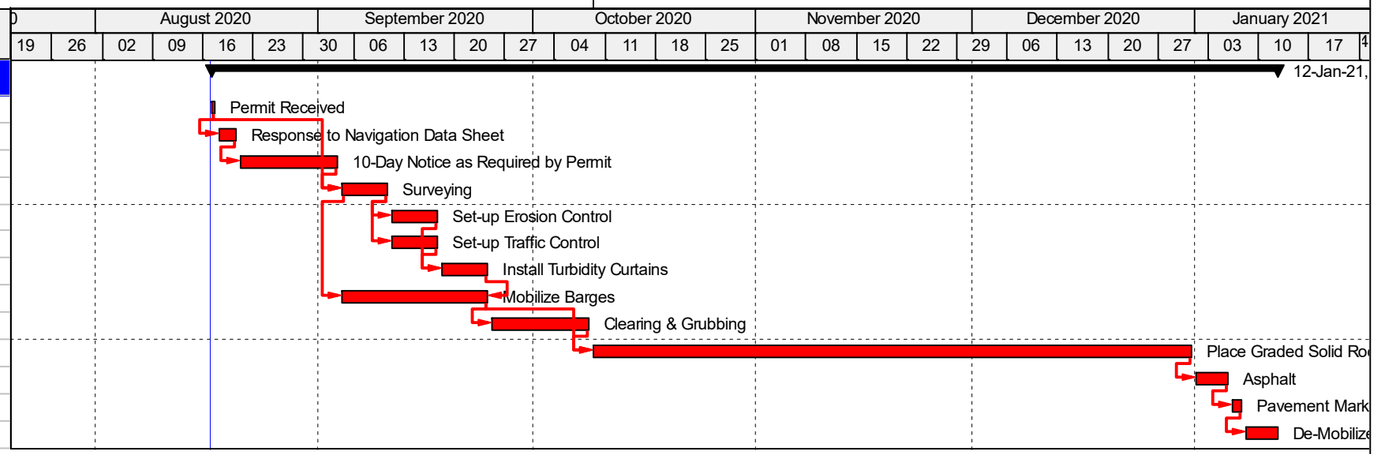
EUD WTP 12-20-19

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors	Successors	Resource Names	Total Slack
123		Install New Sodium Hypochlorite Pre & Post Filtration Chemical Feed Assemblies	5 days	Wed 4/8/20	Tue 4/14/20	64,119,122	124	Chemical Feed Systems	10 days
124		System Start Up and Operational Testing Period	22 days	Wed 4/29/20	Thu 5/28/20	73,94,95,9	125	Cumby	0 days
125		February 2020 Weather Delay	3 days	Fri 5/29/20	Tue 6/2/20	124	126	Cumby	0 days
126		March 2020 Weather Delay	8 days	Wed 6/3/20	Fri 6/12/20	125	127	Cumby	0 days
127		April 2020 Weather Delay	7 days	Mon 6/15/20	Tue 6/23/20	126	128	Cumby	0 days
128		JCC Substantial Completion Date	1 day	Wed 6/24/20	Wed 6/24/20	92,93,98,1	129	Cumby	0 days
129		Punch List Items	20 days	Thu 6/25/20	Wed 7/22/20	128	130	Cumby	0 days
130		JCC Final Completion Date	2 days	Thu 7/23/20	Fri 7/24/20	129		Cumby	0 days
131									
132									
133		Contractual Substantial Completion Date 6-24-2020							165 days?
134		Contractual Final Completion Date 7-24-2020							165 days?



Critical Progress	Task Progress	Finish-only	Critical Split	Baseline Milestone	Summary	External Tasks	Inactive Milestone
Task	Manual Task	Duration-only	Baseline	Milestone	Manual Summary	External Milestone	Inactive Summary
Split	Start-only	Critical	Baseline Split	Summary Progress	Project Summary	Inactive Task	Deadline

Activity ID	Activity Name	Original Duration	Remaining Duration	Schedule % Complete	Start	Finish
Knox County - Emergency Slope Stabil		107	107	0%	17-Aug-20	12-Jan-21
A0500	Permit Received	1	1	0%	17-Aug-20*	17-Aug-20
A0505	Response to Navigation Data Sheet	3	3	0%	18-Aug-20	20-Aug-20
A0510	10-Day Notice as Required by Permit	10	10	0%	21-Aug-20	03-Sep-20
A1000	Surveying	5	5	0%	04-Sep-20	10-Sep-20
A1010	Set-up Erosion Control	5	5	0%	11-Sep-20	17-Sep-20
A1020	Set-up Traffic Control	5	5	0%	11-Sep-20	17-Sep-20
A1030	Install Turbidity Curtains	5	5	0%	18-Sep-20	24-Sep-20
A1040	Mobilize Barges	15	15	0%	04-Sep-20	24-Sep-20
A1050	Clearing & Grubbing	10	10	0%	25-Sep-20	08-Oct-20
A1060	Place Graded Solid Rock	60	60	0%	09-Oct-20	31-Dec-20
A1070	Asphalt	3	3	0%	01-Jan-21	05-Jan-21
A1080	Pavement Marking	2	2	0%	06-Jan-21	07-Jan-21
A1090	De-Mobilize	3	3	0%	08-Jan-21	12-Jan-21



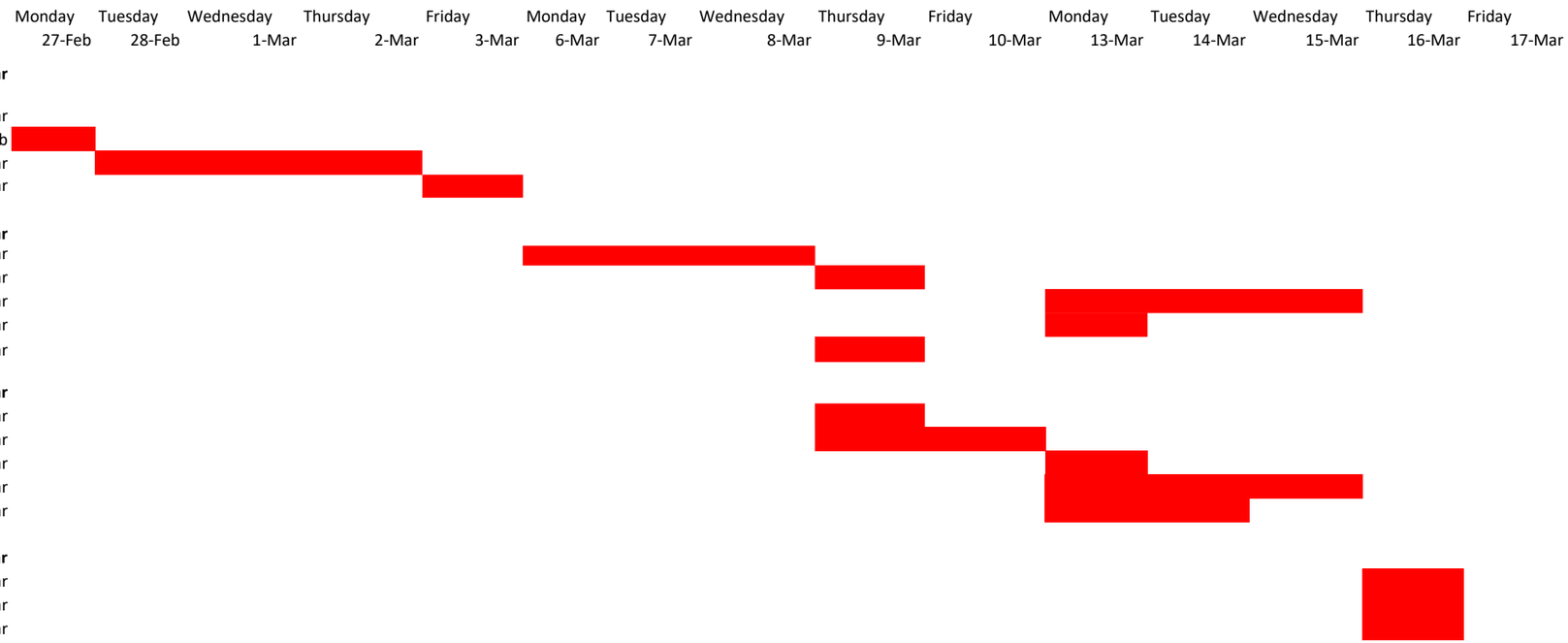
Actual Work
Remaining Work
Critical Remaining Work
Milestone
Summary

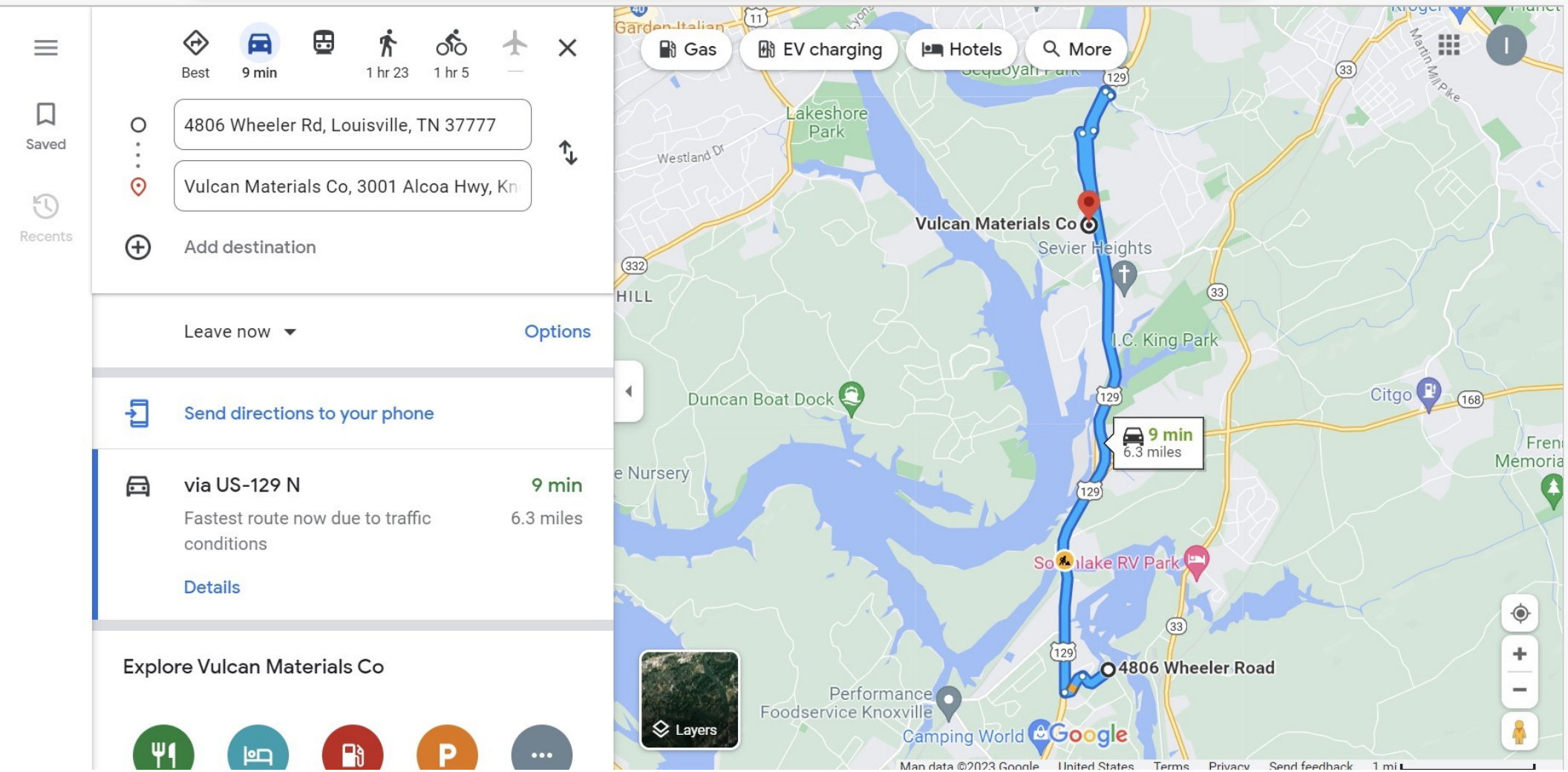
TASK filter: All Activities

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Little River Slope Stabilization

Activity ID	Activity Name	Original Duration	Start	Finish
	Total	**18**	**27-Feb**	**16-Mar**
	Preconstruction Tasks	**5**	27-Feb	3-Mar
A	Permit Received	1	27-Feb	27-Feb
B	3-Day Notice as Requirec	3	28-Feb	2-Mar
C	Surveying	1	3-Mar	3-Mar
	Procurement	**8**	**6-Mar**	**15-Mar**
D	Procure Geotextile Fabric	3	6-Mar	8-Mar
E	Procure Gravel	1	9-Mar	9-Mar
F	Haul Graded Rock	3	13-Mar	15-Mar
G	Procure Plants	1	13-Mar	13-Mar
H	Mobilize Equipment	1	9-Mar	9-Mar
	Installation	**5**	**9-Mar**	**15-Mar**
I	Construct Temporary Ent	1	9-Mar	9-Mar
J	Clearing	2	9-Mar	10-Mar
K	Install Geotextile Fabric	1	13-Mar	13-Mar
L	Place Graded Rock	3	13-Mar	15-Mar
M	Plant Vegetation	2	13-Mar	14-Mar
	Restoration	**1**	**16-Mar**	**16-Mar**
N	Reseed and Resod	1	16-Mar	16-Mar
O	De-Mobilization	1	16-Mar	16-Mar
P	Clean Up	1	16-Mar	16-Mar




Best
9 min
1 hr 23
1 hr 5
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Recents
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Leave now
Options
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via US-129 N
9 min
Fastest route now due to traffic conditions
6.3 miles
Details
Explore Vulcan Materials Co
Gas
EV charging
Hotels
More
Lakeshore Park
Westland Dr
Vulcan Materials Co
Sevier Heights
HILL
J.C. King Park
Duncan Boat Dock
Citgo
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Louisville, TN 37777 | 5/1/2023 - 5/3/2023 | No UR Delivery & Pickup | Edit

Equipment › Trucks & Trailers › Trucks › Half Ton Crew Cab Pickup Truck, 4WD







Cat Class Code: 950-2245

Half Ton Crew Cab Pickup Truck, 4WD

United Rentals will get you on the road with our fleet of half-ton trucks. Our 4-wheel drive crew cab pickup truck lets you haul materials or equipment and tow up to 10,650 lbs. The 385 horsepower engine can haul up to 1,880 lbs. Transport crew or extra equipment in the cab across town or across your site.

- Tow up to 10,650 lbs.
- Haul up to 1,880 lbs.
- Drive up to 20 mpg city and 28 mpg highway
- Up to 385 horsepower engine
- Add this crew cab pickup truck to your cart now

Pricing

WEB RATE Daily **$205** Weekly **$643** Monthly **$1,624**

Quantity

− 1 +

Cost Estimate

$456.89

Item Cost	$410.00
No Delivery	--
No Retrieval	--
Environmental Fee	$8.20
Tax	$38.69

Add to Cart

Feedback

https://www.unitedrentals.com/marketplace/equipment/trucks-trailers/trailers/dump-trailer-10-ft-12-ft-tandem-axle

Louisville, TN 37777 | 5/1/2023 - 5/3/2023 | No UR Delivery & Pickup | Edit

Equipment › Trucks & Trailers › Trailers › Dump Trailer, 10 Ft. By 12 Ft., Tandem Axle









Cat Class Code: 920-5600

Dump Trailer, 10 ft. by 12 ft., Tandem Axle

Get some assistance unloading your materials with this dump trailer. This tandem axle utility trailer has up to a 9,000-lb. capacity. Using hydraulic power, it can tilt to a steep degree dumping a load efficiently. This trailer is ideal for hauling mulch, soil, gravel and other loads around the site or your home.

- Tandem axle
- Ideal for towing mulch, gravel and other soils
- Convenient hydraulic system for dumping
- Durable side walls
- Add this dump trailer to your cart now

Pricing

WEB RATE Daily **$207** Weekly **$570** Monthly **$1,874**

Quantity

− 1 +

Cost Estimate

$452.30

Item Cost	$414.00
No Delivery	--
No Retrieval	--
Tax	$38.30

Add to Cart

Feedback

https://www.unitedrentals.com/marketplace/equipment/earthmoving-equipment/mini-excavators/mini-excavator-...



Cat Class Code: 907-0062

Mini Excavator, 3-3.5 tons, Diesel Powered

Our compact excavators (also known as mini excavators) are perfect for your earthmoving needs in close working conditions. All models feature the all-hydrostatic drive system. Select from multiple dig depths, three arm configurations and three tail swing configurations. This 6,000 lb. mini excavator is easy and safe to transport by pickup and trailer.

- Rubber tracks included for wet or muddy terrain
- Ideal for interior demolition on sites with weight restrictions
- Digging depth up to 8.5'
- Easy-to-use joystick controls
- Versatile machine ideal for moderate digging, trenching, backfilling, leveling and grading
- Add this 6,000 lb. mini excavator to your cart now
- NOTE: Rentable models include open and closed-cab versions. Contact your local branch if a specific model is needed.

Pricing

WEB RATE Daily **$366** Weekly **$982** Monthly **$2,526**

Quantity

− 1 +

Cost Estimate

$815.70

Item Cost	$732.00
No Delivery	--
No Retrieval	--
Environmental Fee	$14.64
Tax	$69.06

Add to Cart

Feedback







Cat Class Code: 903-0090

Skid Steer Loader, 2,001-2,799 lbs., Diesel Powered

United Rentals offers a fleet of dependable skid steer loaders. From the farm to the construction site to the industrial plant, these compact and maneuverable machines are ready to tackle your jobs quickly and cost-effectively. Skid steers are excellent for digging, grading and leveling. These skid steer loaders are perfect for medium-sized duty. Manufacturers include Bobcat, Caterpillar and other popular brand names.

- Tipping load 5,661 lbs.
- Up to 90 horsepower
- One- or two-speed joystick controls available
- Up to 2,500 lbs. lift
- Uses: Ideal for medium-duty clearing, loading, grading and dumping
- Add this skid steer to your cart now

Pricing

WEB RATE Daily **$324** Weekly **$925** Monthly **$2,727**

Quantity

− 1 +

Cost Estimate

$722.10

Item Cost	$648.00
No Delivery	--
No Retrieval	--
Environmental Fee	$12.96
Tax	$61.14

Add to Cart

Feedback

MATERIAL QUANTITIES

RIPRAP							GEOFABRIC FOR RIPRAP					FOR CONST ENTRANCE
Section	FT around shoreline	Area of riprap (ft^2)	Total ft^3	yd^3	**TONS**		Section	height	ft length	area for fabric (FT^2)	width	20
1	59.7	1.4	83.58	3.095556			1	1	59.7	59.7	length	50
2	67.0657	6	402.3942	14.90349			2	2	67.0657	134.1314	4' - 300' ROLL	
3	24.45	22.2857	544.88537	20.18094			3	4	24.45	97.8	3' - 100' ROLL	2 ROLLS
	151.2157	29.6857	1030.8596	38.17998	76.35996778					291.6314	area (FT^2)	1000
											geofabric total	1291.6314

GRAVEL		SEED AREA (ft^2)		PLANTS			COST
depth ft	0.666666667	const ent	1000	River Burch	19	29.5	560.5
width ft	20	path (estimated)	9000	Sycamore	18	119.5	2151
length ft	50	laydown	525	Black Willow	19	59.5	1130.5
area	1000	sum	10525	Silky Dogwood	49	69.5	3405.5
volume (cy)	24.69135802	sy	1169.4444	Fox Sedge	49	44.39	2175.11
				Green Bulrush	49	3	147
				SUM			9569.61

HAULING		
pickup truck per hr	15.86	
trailer per trip	7 tons	
trips	10.90856683	11 trips
Vulcan distance from Annes?	9 mins	
time for trips	189	mins
float time (time to unload)	240	mins
Production rate 4 tons per hr	19.08999194	hrs
	2.386248993	days

before using.

709.03 Classification

Riprap is classified according to the following designations:

1. Rubble-Stone Riprap (Grouted)

2. Sacked Sand-Cement Riprap

3. Machined Riprap

    a. Machined Riprap (Class A-1) shall vary in size from 2 inches to 1.25 feet with no more than 20% by weight being less than 4 inches. The thickness of the stone layer shall be 1.5 foot with a tolerance of 3 inches.

    b. Machined Riprap (Class A-2) shall be identical to Class A-1 except that the Contractor may substitute hand placed rubble stone riprap placed 1 foot thick in accordance with **709.11** for 1.5 feet of machined riprap.

    c. Machined Riprap (Class A-3) shall vary in size from 2 to 6 inches with no more than 20% by weight being less than 4 inches. The thickness of the 4-inch stone layer shall be as shown on the Plans.

    d. Machined Riprap (Class B) shall vary in size 3 inches to 2.25 feet with no more than 20% by weight being less than 6 inches. The thickness of the layer shall be 2.5 feet with a tolerance of 4 inches.

    e. Machined Riprap (Class C) shall vary in size from 5 inches to 3 feet with no more than 20% by weight being less than 9 inches. The thickness of the layer shall be 3.5 feet with a tolerance of 6 inches.

Thursday, March 30, 2023

RE:

We are pleased to quote you on material for the above project as follows:

CRUSHED LIMESTONE – Coy Stone unless otherwise stated

Product	Material Price	Haul Rate **	Total
Pug Mix, Type A, Grade D*	$22.00	$6.00	$28.00
#57 Stone	$26.00	$6.00	$32.00
A-1 Rip Rap -	$27.00	$7.50	$34.50
A-3 Rip Rap -	$27.00	$7.50	$34.50
Class C Rip Rap -	$27.00	$11.00	$38.00
Graded Solid Rock -	$21.00	$11.00	$32.00

* Meets TDOT Section 903.05, Aggregate for Mineral Aggregate Base and Surface Courses.
** The haul rate is based on the current diesel fuel prices. A fuel surcharge may apply based on fuel prices at the time of delivery.

All prices are on a per ton basis. These prices are firm through October 31, 2024. Tennessee state and local county sales taxes are to be added if applicable. This quote is subject to the proper and timely payment of invoices. Payment is due by the 25th day of the following month of date of purchase. All sales are subject to / Sales Agreement, as per our credit application.

We appreciate your business and for the opportunity to work with you. If you have any questions regarding this information, feel free to give me a call.

Sincerely,







Non-Woven Geotextile Fabric - Various Weights and Sizes Available

$219.62

FREE SHIPPING

Size: Various
Square Feet Per Roll: Varies by Roll Size

Drainage & Filtration Non-Woven fabrics allow high water flow and provide dimensional stability. They will not rot or mildew.

Benefits
- Allows high water flow
- Soil separation for added stability
- High strength/dimensionally stable

Select Weight & Roll Size
3oz - 4' x 300' Roll [Price $219.62]

Quantity
1

Add to cart

Share this:

FREE SHIPPING ON ALL ORDERS OVER $99







Non-Woven Geotextile Fabric - Various Weights and Sizes Available

$122.22

FREE SHIPPING

Size: Various
Square Feet Per Roll: Varies by Roll Size

Drainage & Filtration Non-Woven fabrics allow high water flow and provide dimensional stability. They will not rot or mildew.

Benefits
- Allows high water flow
- Soil separation for added stability
- High strength/dimensionally stable

Select Weight & Roll Size
3oz - 3' x 100' Roll [Price $122.22]

Quantity
1

Add to cart

Share this:





6" Landscape Staples

$148.98

FREE SHIPPING

Designed to fix geotextiles, geogrid and erosion control products in place. 1,000 QTY, 11 gauge.

FREE SHIPPING

Quantity
1

Add to cart

Share this:

Item Number	Description	Unit of Measure	Region	Average Unit Price	Total Cost	Total Quantity
			3	$220.00	$22,000.00	100.00
			STATE	$34.91	$96,130.80	2754.00
795-09.29	1IN COPPER SERVICE PIPE	L.F.	2	$97.00	$37,054.00	382.00
			3	$200.00	$20,000.00	100.00
			STATE	$118.37	$57,054.00	482.00
795-09.51	RECONNECT SERVICE ASSEMBLY	EACH	1	$1,252.32	$17,532.48	14.00
			STATE	$1,252.32	$17,532.48	14.00
795-10.01	3/4IN AUTO AIR RELEASE VALVE ASSEMBLY	EACH	1	$1,669.75	$26,716.00	16.00
			STATE	$1,669.75	$26,716.00	16.00
795-10.03	1IN AUTO AIR RELEASE VALVE ASSEMBLY	EACH	1	$1,759.73	$5,279.19	3.00
			2	$9,100.00	$36,400.00	4.00
			STATE	$5,954.17	$41,679.19	7.00
795-11.01	BLOW-OFF ASSEMBLY	EACH	1	$2,208.88	$6,626.64	3.00
			2	$3,700.00	$3,700.00	1.00
			STATE	$2,581.66	$10,326.64	4.00
795-11.02	FIRE HYDRANT ASSEMBLY	EACH	1	$7,140.68	$135,672.92	19.00
			2	$8,400.00	$33,600.00	4.00
			3	$10,000.00	$50,000.00	5.00
			4	$7,613.07	$68,517.66	9.00
			STATE	$7,778.12	$287,790.58	37.00
795-11.12	RETIRE IN PLACE EXISTING WATER MAIN	L.F.	2	$10.80	$39,031.20	3614.00
			4	$8.50	$18,742.50	2205.00
			STATE	$9.93	$57,773.70	5819.00
795-12.01	REMOVE FIRE HYDRANT	EACH	1	$921.91	$1,843.82	2.00
			2	$1,050.00	$3,150.00	3.00
			3	$1,125.00	$3,375.00	3.00
			4	$3,083.23	$15,416.16	5.00
			STATE	$1,829.61	$23,784.98	13.00
795-12.02	REMOVAL OF EXISTING LINE	LS	4	$2,167.33	$2,167.33	1.00
			STATE	$2,167.33	$2,167.33	1.00
795-12.03	PIPE GROUTING	LS	2	$1,000.00	$1,000.00	1.00
			STATE	$1,000.00	$1,000.00	1.00
795-12.08	REMOVE WATER METER	EACH	1	$460.95	$35,032.20	76.00
			STATE	$460.95	$35,032.20	76.00
795-13.01	DI FITTINGS	LB.	3	$12.00	$18,000.00	1500.00
			4	$15.26	$63,799.20	4180.00
			STATE	$14.40	$81,799.20	5680.00
795-13.04	BRIDGE HANGER SYSTEM	LS	4	$68,380.58	$68,380.58	1.00
			STATE	$68,380.58	$68,380.58	1.00
795-14.02	CLASS B CONCRETE	C.Y.	4	$650.00	$1,950.00	3.00
			STATE	$650.00	$1,950.00	3.00
795-14.08	RESTORE ASPHALT	S.Y.	1	$140.92	$123,305.00	875.00
			2	$46.00	$37,904.00	824.00
			4	$181.15	$19,926.50	110.00
			STATE	$100.13	$181,135.50	1809.00
795-14.09	RESTORE CONCRETE	S.Y.	2	$100.00	$3,000.00	30.00
			4	$93.32	$8,398.80	90.00
			STATE	$94.99	$11,398.80	120.00
795-14.10	RESTORE GRAVEL	S.Y.	2	$13.80	$151.80	11.00

Item Number	Description	Unit of Measure	Region	Average Unit Price	Total Cost	Total Quantity
			4	$38.43	$5,034.33	131.00
			STATE	$36.52	$5,186.13	142.00
795-15.01	8IN STEEL CASING PIPE OPEN CUT METHOD	L.F.	2	$235.00	$10,575.00	45.00
			STATE	$235.00	$10,575.00	45.00
795-15.02	12IN STEEL CASING PIPE OPEN CUT METHOD	L.F.	2	$245.00	$6,125.00	25.00
			STATE	$245.00	$6,125.00	25.00
795-15.04	18IN STEEL CASING PIPE OPEN CUT METHOD	L.F.	2	$338.00	$27,040.00	80.00
			STATE	$338.00	$27,040.00	80.00
795-15.25	16IN STEEL CASING PIPE OPEN CUT METHOD	L.F.	4	$341.25	$61,425.00	180.00
			STATE	$341.25	$61,425.00	180.00
795-16.46	6IN NEW WM TERMINATION	EACH	1	$2,496.54	$2,496.54	1.00
			STATE	$2,496.54	$2,496.54	1.00
795-16.47	12IN NEW WM TERMINATION	EACH	1	$2,822.52	$2,822.52	1.00
			STATE	$2,822.52	$2,822.52	1.00
795-25.01	REMOVE WATER MAIN FROM BRIDGE	LS	4	$8,171.34	$8,171.34	1.00
			STATE	$8,171.34	$8,171.34	1.00
797-01.01	4IN DIP FORCE MAIN	L.F.	1	$94.20	$70,838.40	752.00
			STATE	$94.20	$70,838.40	752.00
797-01.02	6IN DIP FORCE MAIN	L.F.	1	$56.89	$19,797.72	348.00
			STATE	$56.89	$19,797.72	348.00
797-01.31	4IN DIP FORCE MAIN (SLIP JOINT)	L.F.	1	$117.25	$8,676.50	74.00
			STATE	$117.25	$8,676.50	74.00
797-01.53	VENT PIPE ASSEMBLY	EACH	4	$5,000.00	$5,000.00	1.00
			STATE	$5,000.00	$5,000.00	1.00
797-02.07	6IN HDPE FORCE MAIN	L.F.	4	$87.83	$54,893.75	625.00
			STATE	$87.83	$54,893.75	625.00
797-03.04	2IN PVC FORCE MAIN	L.F.	1	$25.91	$22,593.52	872.00
			STATE	$25.91	$22,593.52	872.00
797-03.06	4IN PVC FORCE MAIN	L.F.	1	$30.78	$75,841.92	2464.00
			STATE	$30.78	$75,841.92	2464.00
797-03.08	6IN PVC FORCE MAIN	L.F.	1	$38.89	$289,419.38	7442.00
			STATE	$38.89	$289,419.38	7442.00
797-03.38	4IN PVC FORCE MAIN (0-8FT)	L.F.	2	$106.00	$29,680.00	280.00
			STATE	$106.00	$29,680.00	280.00
797-05.01	8IN DIP GRAVITY SEWER 0FT-6FT DEPTH	L.F.	1	$123.52	$4,940.80	40.00
			4	$179.00	$66,230.00	370.00
			STATE	$173.59	$71,170.80	410.00
797-05.02	8IN DIP GRAVITY SEWER 6FT-12FT DEPTH	L.F.	1	$169.62	$6,784.80	40.00
			3	$405.00	$70,470.00	174.00
			4	$187.95	$335,114.85	1783.00
			STATE	$206.49	$412,369.65	1997.00
797-05.03	8IN DIP GRAVITY SEWER 12FT-18FT DEPTH	L.F.	1	$307.90	$15,395.00	50.00
			STATE	$307.90	$15,395.00	50.00
797-05.04	8IN DIP GRAVITY SEWER >18FT DEPTH	L.F.	1	$307.90	$30,790.00	100.00
			STATE	$307.90	$30,790.00	100.00
797-05.09	12IN DIP GRAVITY SEWER 0FT-6FT DEPTH	L.F.	4	$230.00	$150,650.00	655.00
			STATE	$230.00	$150,650.00	655.00
797-05.10	12IN DIP GRAVITY SEWER 6FT-12FT DEPTH	L.F.	4	$230.00	$14,490.00	63.00
			STATE	$230.00	$14,490.00	63.00

[Project Name]

Engineer's Cost Estimate

[Company Logo]

Number	Item	Unit	Amt	Unit Cost	Cost
M-101	Mobilization (includes Const Entrance)	LS	1	$ 48,358.83	$ 48,358.83
P-151	Clearing and Grubbing	LS	1	$ 9,400.00	$ 9,400.00
P-152-1.1	Misc grading and stream grading	CY	800	$ 54.00	$ 43,200.00
P-152-1.2	Sod Mat Removal and Storage Alternative	SY	1000.00	$ 15.00	$ 15,000.00
P-152-1.3	Topsoil Removal and Storage	SY	630.00	$ 15.00	$ 9,450.00
P-156	Temporary Water Pollution, Soil Erosion and Siltation Control	LS	1	$ 25,726.00	$ 25,726.00
STR-01	Class B RIPRAP Pipe Outlet Protection	TON	5	$ 141.00	$ 705.00
STR-02	Armored Riffle	LF	160	$ 93.00	$ 14,880.00
S-01	Temporary Seed	SY	4407.51	$ 3.00	$ 13,222.53
S-02	Permanent Seed Upland	SY	3757.51	$ 4.00	$ 15,030.04
S-02-1	Permanent Seed Upland w/ Sod Alt	SY	2757.51	$ 4.00	$ 11,030.04
S-03	Permanent Seed Riparian	SY	888.89	$ 4.00	$ 3,555.56
S-04	Sod lawns (Alternative to Permanent Seed *LEFT SIDE OF STREAM*)	SF	9000.00	$ 2.00	$ 18,000.00
R-01	Trees & Shrubs Planting	LS	1.00	$ 1,500.00	$ 1,500.00
M-102	Remove and replace various fences	LF	385.00	$ 50.00	$ 19,250.00
M-103	Remove and replace concrete drive	SY	525.0	$ 135.00	$ 70,875.00

Subtotal w/ Sod lawns	$	255,794.13
Subtotal w/o Sod lawns	$	241,794.13
Mobilization*	$	48,358.83
Total w/ Sod lawns	$	304,152.96
Total w/o Sod lawns	$	290,152.96

*(20% of Sub w/o sod lawns)

2023 HIGHWAY PREVAILING WAGE RATES
Approved



CLASSIFICATION	CRAFT NUMBER	2023
Blaster	1	26.29
Bricklayer	2	18.95
Carpenter/Leadsperson	3	24.35
Class "A" Operators	4	27.37
Class "B" Operators	5	24.99
Class "C" Operators	6	26.22
Class "D" Operators	7	24.71
Concrete Finisher	8	22.61
Drill Operator (Caisson)	9	38.56
Electrician	10	35.59
Farm Tractor Operator (Power Broom)	11	17.23
Ironworkers Reinforcing	12	23.00
Ironworkers (Structural)	13	22.45
Large Crane Operator	14	28.78
Mechanic (Class I) Heavy Duty	15	30.48
Mechanic (Class II) Light Duty	16	28.22
Painter/Sandblaster	17	35.05
Skilled Laborer	18	23.09
Survey Instrument Operator	19	29.44
Sweeping Machine (Vacuum) Operator	20	23.96
Truck Driver (2 axles)	21	22.63
Truck Driver (3/4 axles)	22	23.19
Truck Driver (5 or more axles)	23	27.97
Unskilled Laborer	24	20.69
Worksite Traffic Coordinator	25	27.59

Effective Date: January 1, 2023

Little River Shoreline Stabilization

Engineer's Cost Estimate

Item	Unit	Amt	Unit Cost	Cost
Truck rental incl mobilization and hauling	WEEK	1	$ 643.00	$ 643.00
Trailer rental	WEEK	1	$ 570.00	$ 570.00
Mini Excavator rental incl moblization	WEEK	1	$ 982.00	$ 982.00
Skid Steer rental incl moblization	WEEK	1	$ 925.00	$ 925.00
Geotextical Fabric	LS	1	$ 341.84	$ 341.84
Landscape Staples	UNIT	2000	$ 148.98	$ 297.96
Gravel	CY	25	$ 36.52	$ 913.00
Riprap	TON	76.35996778	$ 27.00	$ 2,061.72
Vegetation	LS	1	NA	$ 9,569.61
Permanent Seed	SY	1170	$ 4.00	$ 4,680.00
Operator	HR	40	$ 27.37	$ 1,094.80
Unskilled laborer	HR	48	$ 20.69	$ 993.12
Skilled Laborer	HR	48	$ 23.09	$ 1,108.32
Foreman	HR	48	$ 26.48	$ 1,271.04
Total	**SUM**			**$ 25,451.41**