APPENDIX I
Basis of Design Report – Tamarack Creek

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BASIS OF DESIGN REPORT

FOR:

TAMARACK CREEK RESTORATION

Prepared for:

Alliance of Rouge Communities
OURS TO PROTECT
Working together, restoring the river

May 4, 2020
ECT No. 18-0611

Complex Challenges . . . PRACTICAL SOLUTIONS

Document Review

The dual signatory process is an integral part of Environmental Consulting & Technology, Inc.'s (ECT's) Document Review Policy No. 9.03. All ECT documents undergo technical/peer review prior to dispatching these documents to any outside entity.

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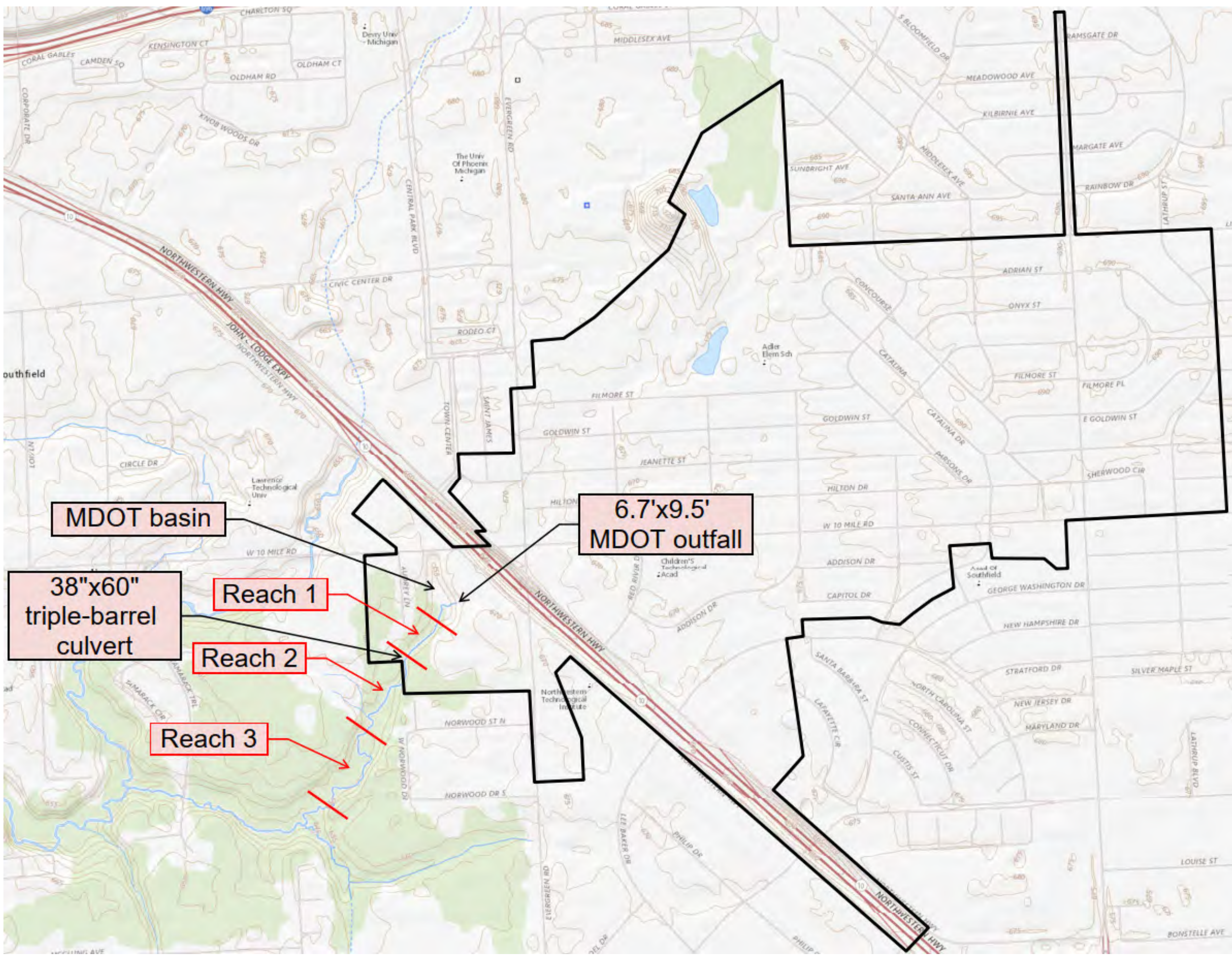
1.0 Introduction

The proposed restoration project will improve approximately 2,000 feet of Tamarack Creek along its headwaters, located west of Northwestern Highway (M-10) in the southwest quadrant of the 10-Mile Road / Evergreen Road intersection, in the City of Southfield, Michigan. **Figure 1** is an overview map that depicts the drainage area, stream reaches within the project area (Reaches 1-3), and major stormwater structures/facilities within the project area, overlaid on a USGS topographic basemap.

Figure 1. Overview Map



The approximately 1.0 square mile drainage area is highly urbanized, with residential and commercial/industrial land uses accounting for approximately 80% of the drainage area. The creek originates at the 6.7’x9.5’ Michigan Department of Transportation (MDOT) outfall. The MDOT in-line detention basin is under-utilized for flood storage/peak flow reduction due to a lack of an effective control structure. Invasive wetland vegetation within the MDOT detention basin will be removed and replaced with native species. The existing road crossing with three elliptical concrete culverts located downstream of the MDOT basin is in poor condition and represents a barrier to fish passage, so it will be removed and replaced with an at-grade crossing. The proposed at-grade crossing is required so that the landowner can access property located east of the creek. Reaches 1 and 2 are channelized and entrenched, so they will be reconstructed as a 2-stage channel to increase floodplain access, sinuosity, and bedform diversity, which will help stabilize the bed and banks and provide habitat benefits. Reach 3 will not be reconstructed. Large woody debris structures and at-grade rock riffles will be constructed within Reach 3 to improve habitat and stabilize eroding banks.

The drainage area delineation depicted in Figure 1 was based on that published by Hubbell, Roth, and Clark (HRC) for Oakland County in 2006. It was intended to be used to establish a drainage district for a proposed Chapter 10 county drain, which was never implemented. ECT verified the drainage area boundaries by reviewing 2-foot ground elevation contours obtained from Oakland County and GIS storm sewer data provided by the City of Southfield.

Tamarack Creek is a tributary of Evans Creek and the Middle Rouge River. As much of its drainage area is urbanized, it receives large quantities of uncontrolled stormwater runoff. The high channel velocities caused by large peak flows have led to bank erosion and sedimentation of instream habitat. Additionally, excessive velocity is destabilizing substrates that are important for fish and macroinvertebrate habitat. The goal of this project is to address these habitat impairments and increase fish and wildlife diversity and productivity.

To restore the stream habitat in Reaches 1 and 2, the floodplain will be expanded, which will allow the stream to convey large stormwater flows without causing excessive in-channel velocities and destabilizing substrate. The new floodplain will be planted with native plants and trees and will include an access road for maintenance. A new stream channel will be constructed with increased sinuosity to lower the slope and further lower the velocities in Tamarack Creek. Toe wood structures will be incorporated into the design to provide habitat, stabilize stream banks, and reduce erosion. Depressions will be created in the floodplain adjacent to the reconstructed channel in Reaches 1 and 2 to encourage the formation of additional wetlands.

2.0 Alternative Analysis

<u>Two-Stage Channel Design</u>

Tamarack Creek receives large quantities of uncontrolled stormwater runoff from a highly urbanized tributary area, resulting in large peak flows, shear stresses, and channel velocities that have caused excessive bank erosion and channel incision (floodplain disconnection). The excessive erosion and subsequent sedimentation problems have removed instream habitat by destabilizing substrate that is important for fish and macroinvertebrate habitat. The proposed two-stage channel design will limit channel depths, velocities, and shear stresses and improve habitat conditions by providing floodplain access. The first stage of the channel is relatively small, sized for the bankfull flow event (1- to 2-year frequency flow). The relatively small first stage channel, with a v-shaped bottom, will generate sufficient low-flow depths and velocities to minimize sediment deposition during normal flows. Excavating bankfull benches on either side of the first stage channel will create a second stage channel that provides floodplain access, which is needed to increase flow capacity during larger storm events and limit bankfull channel depths, velocities, and shear stresses to promote bed and bank stability. The floodplain beltwidth was designed to be a minimum of 3.5 times the bankfull width based on widely accepted performance standards. The width of the floodplain benches was limited by private land impacts and cost constraints. Other benefits related to increased floodplain connectivity include enhanced hydration of the floodplain to encourage development and/or redevelopment of wetlands, nutrients processing, water quality, groundwater-surface water exchange, and better health of microbial, vegetation, and macroinvertebrate communities.

<u>Removal of existing stream crossing and culverts</u>

The proposed removal of the existing Audrey Lane crossing and associated triple-barrel culvert will naturalize the stream, prevent further sedimentation upstream of the culverts, and remove a barrier to fish passage. The existing culverts are in poor structural condition and two out of the three culvert barrels have adverse slopes. The culvert will not be replaced because Audrey Lane is an abandoned drive. An access route parallel to the stream and an at-grade fjord stream crossing are proposed to address the need for future maintenance and property access. Though in poor condition, the existing road crossing provides the landowner with access to property along the east side of Tamarack Creek. The landowner desires to maintain some sort of access. Multiple options were considered including a clear-span bridge, bridge on pilings, boardwalk, culverted crossing, and a fjord or at-grade crossing. Most of the options considered were too costly to reasonably meet the project purpose. The at-grade crossing was selected because it had the least impact on project purpose, had a reasonable construction cost, and will allow the landowner to cross the creek at baseflow.

Hard Armoring

Hard armoring slopes with riprap was considered as a means to minimize bed and bank erosion. Hard armoring was not selected because it provides little or no habitat value and it does not allow the stream to adjust its boundaries and create or modify bed features. Another potential problem with hard armoring along streambanks is that if it is undermined during a large storm event, it may slump into the channel and cause bed and bank instabilities. Furthermore, the soils are predominantly cohesive clay loams that are somewhat resistant to erosion.

Detention Pond Outlet Control Structure

Moderating highly variable flows through installation of an outlet control structure was considered during the design process. The existing MDOT detention basin at the headwaters of the creek is currently under-utilized for detention purposes. It was thought that an outlet control structure would moderate highly variable storm flows and prevent substrate from washing away during each storm event. However, the outlet control structure was ultimately removed from the proposed design due site constraints, property ownership patterns, budget limitations, and maintenance concerns.

Do Nothing

The “do nothing” approach was ruled out as it does not accomplish the project goal of creating and restoring habitat for fish and wildlife.

3.0 Channel Form and Function

The document titled *A Function-Based Framework for Stream Assessment & Restoration Projects*, (EPA 843-K-12-006, May 2012), referred to herein as the "Stream Functions Pyramid" guidance document, describes data collection techniques and evaluation criteria associated with the following five stream functions parameters. These five key parameters represent the foundation of the Stream Functions Pyramid. Higher functions (physiochemical and biological) cannot be achieved until these five key parameters are functioning. The functional assessment methodology can be applied to show how the functions of an existing stream are impaired (demonstrate need for restoration) and how proposed restoration can address those impairments by improving stream functions (demonstrate the effectiveness of restoration). We are confident that the evaluation of the five parameters described below will demonstrate the need for the proposed project and show a significant functional lift.

- Parameter #1: Floodplain Connectivity
- Parameter #2: Bedform Diversity
- Parameter #3: Bank Migration/Lateral Stability
- Parameter #4: Riparian Buffer
- Parameter #5: Large Woody Debris

<u>Parameter #1: Floodplain Connectivity</u>

The evaluation criteria associated with floodplain connectivity varies by stream classification and requires bankfull verification, so these two items are discussed first.

Bankfull Verification

Bankfull elevations were verified before floodplain connectivity metrics were evaluated. Bankfull field indicators (depositional surfaces on existing point bars, benches, scour lines, etc.) were surveyed and in the field and verified through hydrologic/hydraulic analysis. The bankfull flow rate is typically in the 1- to 2-year frequency range, so hydrologic analyses were performed to determine the 1- and 2-year frequency flows. An existing condition HEC-RAS hydraulic model was developed using cross-sections collected during the stream survey. The flow rate in the model was adjusted until the water surface elevation in the model matched the elevation of bankfull field indicators. The results indicated that flow rate in the model needed to match the bankfull field indicators fell in the 1- to 2-year frequency flow range, which was considered verification of the field indicators.

For Reach 1, the initial hydraulic model runs predicted depths significantly higher than the bankfull indicators due to a culvert capacity restriction at the downstream end of Reach 1. The triple-barrel culvert is partially buried due to sedimentation and two out of the three culvert barrels have adverse slopes. When these restrictions were reflected in the hydraulic model, the backwater effects caused the predicted bankfull water surface elevations upstream of the culvert to rise significantly higher than the tops of the banks. When the culvert restrictions were relaxed in the model, the simulated depths matched the tops of the banks. These results likely indicate that the observed sedimentation gets washed away during large (bankfull) storm events and then builds back up again as floodwaters recede and/or during low flow conditions in between large events. Another potential explanation is that the bankfull channel was formed prior to the recently observed culvert restrictions that may have been caused by a recent system change (sedimentation, structural failure, and/or other causes) and the upstream channel still reflects the bankfull flow dynamics that shaped the channel prior to the recent change. Additional investigation would be needed to better understand the culvert dynamics, which is outside the scope of the analysis. For the purposes of this analysis, the key finding was that the hydraulic modeling verified that the bankfull design flow rate was consistent with the observed bankfull indicators of the channel in Reach 1 after making reasonable assumptions to justify relaxing the culvert restrictions. This finding was supported by the results of similar (less complicated) hydraulic analyses in Reaches 2 and 3. Detailed results of the hydraulic modeling are presented in a separate “Hydraulic Modeling” section of this report.

Stream Classification – Existing Conditions

Stream classification was performed using the Rosgen morphological classification flow chart to determine the appropriate criteria to assess floodplain connectivity. **Table 1** is a summary of the stream classification results, along with the riffle bankfull channel dimensions and associated metrics that were used to perform the stream classification for existing conditions.

Table 1. Stream Classification Metrics – Existing Conditions

Existing Conditions - Tamarack Creek										
Reach	Cross-Section	Max Bankfull Depth (ft)	Bankfull Mean Depth (ft)	Bankfull Flow Area (sq ft)	Bankfull Width (ft)	Floodprone Width (ft)	Entrenchment Ratio (FP/BF width)	Width to Depth Ratio	Energy Grade Line Slope (%)	Stream Class
1	24+15	1.03	0.91	12.00	13.23	37	2.8	14.5	0.16%	C
1	23+79	1.05	0.95	13.65	14.36	39	2.7	15.1	0.15%	C
1	22+82	2.00	1.47	17.94	12.22	95	7.8	8.3	0.11%	E
1	21+91	1.18	1.04	14.32	13.77	88	6.4	13.2	0.21%	C
1	21+52	2.00	1.14	33.14	28.97	85	2.9	25.4	0.04%	C
2	20+56	2.00	1.29	25.00	19.38	36	1.9	15.0	0.21%	B
2	19+89	3.00	2.25	33.70	14.97	31	2.1	6.7	0.10%	B
2	18+79	3.00	2.00	22.28	11.14	48	4.3	5.6	0.53%	E
2	18+08	2.53	1.57	27.82	17.67	42	2.4	11.3	0.39%	E
2	17+29	3.33	2.09	33.87	16.18	74	4.6	7.7	0.15%	E
2	16+27	2.08	1.44	26.37	18.27	132	7.2	12.7	0.40%	C
2	15+56	1.87	1.51	22.77	15.13	98	6.5	10.0	0.59%	E
3	14+50	2.09	1.50	22.58	15.05	182	12.1	10.0	0.58%	E
3	13+25	2.00	1.69	27.75	16.43	227	13.8	9.7	0.55%	E
3	12+51	2.15	1.59	28.27	17.73	179	10.1	11.2	0.28%	E
3	11+51	2.06	1.60	20.52	12.84	180	14.0	8.0	0.44%	E
3	10+51	2.16	1.56	35.79	22.94	234	10.2	14.7	1.10%	C
3	9+50	2.23	1.67	26.05	15.62	268	17.2	9.4	0.44%	E
3	6+50	2.08	1.72	28.35	16.51	170	10.3	9.6	0.38%	E
3	5+51	2.35	1.61	39.20	24.41	191	7.8	15.2	0.29%	C
3	4+51	1.92	1.42	32.73	23.00	251	10.9	16.2	0.56%	C
3	3+51	2.09	1.70	27.02	15.93	218	13.7	9.4	0.24%	E
3	2+51	2.00	1.18	36.37	30.72	138	4.5	26.0	0.18%	C
3	1+01	1.49	1.23	22.07	17.92	227	12.7	14.6	0.89%	C
3	0+51	2.50	1.64	33.33	20.37	246	12.1	12.4	0.43%	C

Table 1 indicates that the existing condition of Tamarack Creek consists of Class B, C, and E stream types. The areas within Reach 2 that keyed out as Class B reflect the relatively high entrenchment of the stream due to bed degradation immediately downstream of the triple-barrel

culvert depicted in **Figure 1**. The proposed floodplain construction will restore the B sub-reaches back to their original C or E conditions.

A bed material analysis was performed to further define the stream type. The results of bed sediment sampling and subsequent sieve analysis (**Table 2**) indicated that the mean particle diameter (D50) in Reaches 1-3 ranged from 0.44 to 1.3 mm, which is within the size range of sand (0.06 to 2 mm). All sediment samples were majority sand with smaller percentages of gravel. **Appendix A** contains the detailed results of the sieve analysis, including gradation curves. The 2004 soil boring data obtained from HRC (**Appendix B**) indicated that the local geology consisted of 3 to 12 inches of loam or clay loam topsoil above a clay base, which is consistent with visual field observations.

The bed material sampling results and bankfull shear stress estimates at the bed material sampling locations were used to gain insight into existing sediment transport characteristics. Note that Tamarack Creek has a very low sediment supply because the drainage area is highly urbanized and entirely enclosed upstream of the project, so a detailed sediment transport analysis was not within the scope of this project. **Table 2** indicates that the D84 particle size (incipient particle diameter), which is typically a strong indicator of channel form, is mobile in Reaches 2 and 3, but not Reach 1. These results seem reasonable considering the extremely flat slope and sedimentation observed in Reach 1 upstream of the partially buried triple-barrel culvert. In Reaches 2 and 3, the moveable particle size is not extremely large (approximately 1-inch), but there is a limited supply of coarse material at the project site (based on the results of the soil borings and sieve analysis) and a lack of coarse material being delivered from the enclosed system upstream of the project site, so almost all of the relatively fine material available to the stream is readily transported. These findings suggest that existing cohesive clay soils have a strong influence on the channel morphology and stability of Tamarack Creek. Based on these results, and the prevalence of E stream characteristics in **Table 1**, Tamarack Creek is best classified as an E6 (clay bed) stream type.

Table 2. Existing Bed Material Characteristics

Reach	Cross-Section	Bankfull Shear Stress (lb/sq ft)	D50 (mm)	D84 (mm)	Moveable Particle Size based on Shields Curve (mm)	D84 Particle Mobile (Yes/No)
1	22+82	0.09	1.1	6.7	6.3	No
2	18+79	0.56	0.58	1.6	33.0	Yes
3	13+25	0.52	0.44	4.1	30.2	Yes
	9+51	0.42	1.3	6.1	23.4	Yes
	6+51	0.37	0.61	4.2	20.0	Yes

The existing conditions of the channelized stream in Reaches 1 and 2 is relatively straight, so it does not have the high sinuosity typical of natural E-streams (stream length >1.5 times valley length); although, the proposed re-alignment will significantly increase the sinuosity through the construction of several meander bends.

Floodplain Connectivity Evaluation – Existing Conditions

Two metrics were evaluated to assess floodplain connectivity:

- Entrenchment Ratio
- Bank Height Ratio.

The Entrenchment Ratio is the floodprone width (channel width at twice the bankfull depth) divided by the bankfull width. The Bank Height Ratio is the low bank height (point at which flow spills out onto the floodplain), divided by the max bankfull depth.   Max bankfull depth is defined as the distance between the bankfull and thalweg elevations.

Table 3 lists the results of the Entrenchment Ratio and Bank Height Ratio calculations for existing conditions. The functioning, functioning-at-risk, and non-functioning parameters are highlighted in the table based on the Stream Functions Pyramid performance standards for Class C and E stream types (**Appendix C**), which are listed at the bottom of the table. The results indicate floodplain connectivity is a non-functioning parameter for a large portion of Reach 2, which helps demonstrate the need for the proposed stream restoration project. The results also indicate that

Reach 1, and most of Reach 3, has good floodplain connectivity. The results for Reach 1 are likely due to the influence of the triple-barrel culvert, which currently provides grade control, as indicated by the sedimentation that has partially buried the culvert and the extremely flat slope of the channel upstream of the culvert. The culvert will be removed as part of the proposed project because it is a barrier to fish passage and it is in poor structural condition. The proposed channel reconstruction in Reaches 1 and 2 will increase the floodprone width of the channel and add meander bends for further energy dissipation to maintain stability in Reach 1 after the culvert is removed.

Table 3. Floodplain Connectivity Metrics – Existing Conditions

Existing Conditions - Tamarack Creek							
Reach	Cross-Section	Max Bankfull Depth (ft)	Bankfull Width (ft)	Floodprone Width (ft)	Low Bank Height (ft)	Entrenchment Ratio (FP/BF width)	Bank Height Ratio (LB/BF height)
1	24+15	1.03	13.23	37	1.03	2.8	1.0
1	23+79	1.05	14.36	39	1.05	2.7	1.0
1	22+82	2.00	12.22	95	2.00	7.8	1.0
1	21+91	1.18	13.77	88	1.18	6.4	1.0
1	21+52	2.00	28.97	85	2.00	2.9	1.0
2	20+56	2.00	19.38	36	6.20	1.9	3.1
2	19+89	3.00	14.97	31	7.00	2.1	2.3
2	18+79	3.00	11.14	48	7.00	4.3	2.3
2	18+08	2.53	17.67	42	6.01	2.4	2.4
2	17+29	3.33	16.18	74	5.22	4.6	1.6
2	16+27	2.08	18.27	132	2.14	7.2	1.0
2	15+56	1.87	15.13	98	2.40	6.5	1.3
3	14+50	2.09	15.05	182	3.10	12.1	1.5
3	13+25	2.00	16.43	227	2.27	13.8	1.1
3	12+51	2.15	17.73	179	2.15	10.1	1.0
3	11+51	2.06	12.84	180	2.06	14.0	1.0
3	10+51	2.16	22.94	234	2.16	10.2	1.0
3	9+50	2.23	15.62	268	2.22	17.2	1.0
3	6+50	2.08	16.51	170	2.08	10.3	1.0
3	5+51	2.35	24.41	191	2.35	7.8	1.0
3	4+51	1.92	23.00	251	2.14	10.9	1.1
3	3+51	2.09	15.93	218	2.09	13.7	1.0
3	2+51	2.00	30.72	138	2.00	4.5	1.0
3	1+01	1.49	17.92	227	2.00	12.7	1.3
3	0+51	2.50	20.37	246	3.00	12.1	1.2

Entrenchment Ratio
< 2.0 not functioning
2.0 to 2.2 functioning-at-risk
> 2.0 functioning

Bank Height Ratio
> 1.5 not functioning
1.3 to 1.5 functioning-at-risk
1.0 to 1.2 functioning

Appendix D contains the RiverMorph output for existing conditions that support the values listed in **Tables 1-3**, including:

- Riffle cross section plots, which include a horizontal line across each plot at the bankfull elevation. Each plot is identified by reach and river station in the title block.
- Each cross section is overlaid with a table that contain bankfull channel dimensions corresponding to that cross section, including moveable particle sizes based on the Shields Curve.
- Profile plots of the bankfull elevations by reach are included in the last three pages of the appendix.

Stream Classification – Proposed Conditions

The floodplain connectivity analysis that was described above for existing conditions was repeated for the proposed conditions. Hydraulic modeling was performed to verify bankfull channel dimensions and stream classification was performed to determine the applicable performance standards to be used in the floodplain connectivity evaluation.

Table 4 is a summary of the proposed bankfull riffle dimensions and stream classification results. The results indicate that the proposed reconstruction of Reaches 1 and 2 will result in a Class E channel with bankfull dimensions similar to that of the Reach 3 reference conditions.

Table 4. Stream Classification Metrics – Proposed Conditions

Proposed Conditions - Tamarack Creek										
Reach	Cross-Section	Max Bankfull Depth (ft)	Bankfull Mean Depth (ft)	Bankfull Flow Area (sq ft)	Bankfull Width (ft)	Floodprone Width (ft)	Entrenchment Ratio (FP/BF width)	Width to Depth Ratio	Energy Grade Line Slope (%)	Stream Class
1	25+71	2.55	1.84	29.52	16.07	89	5.5	8.7	0.27%	E
1	25+22	2.50	1.84	29.33	15.95	125	7.9	8.7	0.27%	E
1	24+41	2.50	1.83	29.28	16.00	125	7.8	8.7	0.28%	E
1	23+58	2.50	1.84	29.39	16.01	119	7.4	8.7	0.27%	E
1	22+40	2.50	1.83	29.24	16.00	121	7.6	8.8	0.28%	E
2	21+28	2.49	1.85	29.30	15.83	117	7.4	8.6	0.27%	E
2	20+31	2.50	1.84	29.47	16.00	120	7.5	8.7	0.27%	E
2	19+65	2.50	1.83	29.27	16.01	123	7.7	8.8	0.28%	E
2	18+90	2.50	1.84	29.41	16.00	125	7.8	8.7	0.28%	E
2	18+12	2.50	1.83	29.31	16.00	129	8.1	8.7	0.28%	E
2	17+00	2.51	1.84	29.70	16.16	144	8.9	8.8	0.28%	E
2	15+73	2.50	1.84	29.39	15.96	164	10.3	8.7	0.29%	E
3	14+50	2.09	1.50	22.58	15.05	182	12.1	10.0	0.58%	E
3	13+25	2.00	1.69	27.75	16.43	227	13.8	9.7	0.55%	E
3	12+51	2.15	1.59	28.27	17.73	179	10.1	11.1	0.28%	E
3	11+51	2.06	1.60	20.52	12.84	180	14.0	8.0	0.44%	E
3	10+51	2.16	1.56	35.79	22.94	234	10.2	14.7	1.10%	C
3	9+50	2.23	1.67	26.05	15.62	268	17.2	9.4	0.44%	E
3	6+50	2.08	1.72	28.35	16.51	170	10.3	9.6	0.38%	E
3	5+51	2.35	1.61	39.20	24.41	191	7.8	15.2	0.29%	C
3	4+51	1.92	1.42	32.73	23.00	251	10.9	16.2	0.56%	C
3	3+51	2.09	1.70	27.02	15.93	218	13.7	9.4	0.24%	E
3	2+51	2.00	1.18	36.37	30.72	138	4.5	25.9	0.18%	C
3	1+01	1.49	1.23	22.07	17.92	227	12.7	14.6	0.89%	C
3	0+51	2.50	1.64	33.33	20.37	246	12.1	12.4	0.43%	C

Floodplain Connectivity Evaluation – Proposed Conditions

Table 5 lists the results of the entrenchment ratio and bank height ratio calculations for proposed conditions and highlights the functioning, functioning-at-risk, and non-functioning parameters areas based on the performance standards listed in the Stream Functions Pyramid for Class C and E streams (**Appendix C**), which are listed at the bottom of the table. The results indicate that the proposed floodplain construction and channel relocation will improve floodplain connectivity, compared to the existing conditions (**Table 3**). For example, the proposed floodplain construction will nearly double the floodprone width of the channel in Reaches 1 and 2. For Reach 2, the proposed channel reconstruction will bring the non-functioning entrenchment ratios and bank height ratios metrics into the functioning range.

Table 5. Floodplain Connectivity Metrics – Existing Conditions

Proposed Conditions - Tamarack Creek							
Reach	Cross-Section	Max Bankfull Depth (ft)	Bankfull Width (ft)	Floodprone Width (ft)	Low Bank Height (ft)	Entrenchment Ratio (FP/BF width)	Bank Height Ratio (LB/BF height)
1	25+71	2.55	16.07	89	2.55	5.5	1.0
1	25+22	2.50	15.95	125	2.50	7.9	1.0
1	24+41	2.50	16.00	125	2.50	7.8	1.0
1	23+58	2.50	16.01	119	2.50	7.4	1.0
1	22+40	2.50	16.00	121	2.50	7.6	1.0
2	21+28	2.49	15.83	117	2.49	7.4	1.0
2	20+31	2.50	16.00	120	2.50	7.5	1.0
2	19+65	2.50	16.01	123	2.50	7.7	1.0
2	18+90	2.50	16.00	125	2.50	7.8	1.0
2	18+12	2.50	16.00	129	2.50	8.1	1.0
2	17+00	2.51	16.16	144	2.51	8.9	1.0
2	15+73	2.50	15.96	164	2.50	10.3	1.0
3	14+50	2.09	15.05	182	3.10	12.1	1.5
3	13+25	2.00	16.43	227	2.27	13.8	1.1
3	12+51	2.15	17.73	179	2.15	10.1	1.0
3	11+51	2.06	12.84	180	2.06	14.0	1.0
3	10+51	2.16	22.94	234	2.16	10.2	1.0
3	9+50	2.23	15.62	268	2.22	17.2	1.0
3	6+50	2.08	16.51	170	2.08	10.3	1.0
3	5+51	2.35	24.41	191	2.35	7.8	1.0
3	4+51	1.92	23.00	251	2.14	10.9	1.1
3	3+51	2.09	15.93	218	2.09	13.7	1.0
3	2+51	2.00	30.72	138	2.00	4.5	1.0
3	1+01	1.49	17.92	227	2.00	12.7	1.3
3	0+51	2.50	20.37	246	3.00	12.1	1.2

Entrenchment Ratio
< 2.0 not functioning
2.0 to 2.2 functioning-at-risk
> 2.0 functioning

Bank Height Ratio
> 1.5 not functioning
1.3 to 1.5 functioning-at-risk
1.0 to 1.2 functioning

Appendix E contains the RiverMorph output for proposed conditions that support the values listed in **Tables 4 and 5**, including:

- Riffle cross section plots, which include a horizontal line across each plot at the bankfull elevation. Each plot is identified by reach and river station in the title block.
- Each cross section is overlaid with a table that contain bankfull channel dimensions corresponding to that cross section.
- One profile plot that includes the bankfull elevations of the proposed reconstructed reach (individually labeled by station) and the existing reference reach (Reach 3 not individually labeled by station) is included as the last page of the appendix.

<u>Parameter #2: Bedform Diversity</u>

Bedform Diversity Evaluation – Existing Conditions

Three bedform diversity metrics were evaluated:

- Pool-to-Pool Spacing Ratio
- Percent Riffle and Pool
- Pool Max Depth Ratio

Table 6 lists the bedform diversity metrics for existing conditions and highlights the functioning, functioning-at-risk, and non-functioning parameters based on the performance standards listed in the Stream Functions Pyramid for perennial C and E stream types in alluvial valleys (**Appendix C**), which are listed at the bottom of the table. The results indicate that pool-to-pool spacing is a non-functioning parameter for Reaches 1-3 because the pools are spaced too far apart. The percentage of riffles versus pools is a functioning parameter for Reaches 2 and 3 and functioning-at-risk for Reach 1. Reach 1 is a straight channel, with no meander pools. The only pool in Reach 1 is a large scour hole near the downstream end of the reach. The pool max depth ratio is a functioning parameter for all reaches, with the exception of one pool within Reach 3 (Sta 4+51 to 3+01), which is not deep enough. It is only 10% deeper than the bankfull mean riffle depth. The performance standards require pools to be 50% deeper than the mean riffle depth to be considered functioning.

Table 6. Bedform Diversity Metrics – Existing Conditions

Existing Conditions - Tamarack Creek					
Reach	**Station Range**	**Pool-to-Pool Spacing Ratio (Pool Spacing Unitized by Bankfull Width)**	**Percent Riffle**	**Percent Pool**	**Pool Max Depth Ratio (Max Bankfull Pool Depth Unitized by Average Bankfull Depth)**
1	27+21 - 22+09	32	76%	24%	1.9
2	22+09 - 17+72	10	62%	38%	1.5
	17+72 - 14+35	20			2.2
3	14+35 - 13+25	9	64%	36%	1.7
	13+25 - 4+51	19			1.6
	4+51 - 3+01	20			1.1
	3+01 - 0+00	55			1.6

Pool-to-Pool Spacing Ratio (Watersheds < 10 sq mi)
< 3.5 and > 8 not functioning
3.5 to 5 and 7 to 8 functioning-at-risk
5 to 7 functioning

Percent Riffle
> 80 and < 40 not functioning
70 to 80 and 40 to 60 functioning-at-risk
60 to 70 functioning

Max Pool Depth Ratio
< 1.2 not functioning
1.2 to 1.5 functioning-at-risk
> 1.5 functioning

Bedform Diversity Evaluation – Proposed Conditions

Table 7 lists the bedform diversity metrics for proposed conditions and highlights the functioning, functioning-at-risk, and non-functioning parameters based on the performance standards listed in the Stream Functions Pyramid for perennial C and E stream types in alluvial valleys (**Appendix C**), which are listed at the bottom of the table. The results indicate that the proposed relocation of

Reaches 1 and 2 will result in functional lift in two out of three of the bedform diversity metrics, based on the comparison to existing conditions (**Table 6)**. The proposed re-alignment will improve the pool-to-pool spacing from non-functioning to functioning for both Reaches 1 and 2 and improve the percent riffle from functioning-at-risk to functioning for Reach 1.

Table 7. Bedform Diversity Metrics – Proposed Conditions

Proposed Conditions - Tamarack Creek					
Reach	Station Range	Pool-to-Pool Spacing Ratio (Pool Spacing Unitized by Bankfull Width)	Percent Riffle	Percent Pool	Pool Max Depth Ratio (Max Bankfull Pool Depth Unitized by Average Bankfull Depth)
1	26+37 - 25+67	5	64%	36%	2.2
	25+67 - 24+95	5			2.2
	24+95 - 24+23	5			2.2
	24+23 - 23+45	5			2.2
	23+45 - 22+73	6			2.2
2	22+73 - 21+83	5	64%	36%	2.2
	21+83 - 21+02	5			2.2
	21+02 - 20+18	5			2.2
	20+18 - 19+41	5			2.2
	19+41 - 18+66	6			2.2
	18+66 - 17+76	5			2.2
	17+76 - 16+97	5			2.2
	16+97 - 16+24	5			2.2
	16+24 - 15+47	5			2.2
3	15+47 - 13+25	9	64%	36%	1.7
	13+25 - 4+51	19			1.6
	4+51 - 3+01	20			1.1
	3+01 - 0+00	55			1.6

Pool-to-Pool Spacing Ratio (Watersheds < 10 sq mi)
< 3.5 and > 8 not functioning
3.5 to 5 and 7 to 8 functioning-at-risk
5 to 7 functioning

Percent Riffle
> 80 and < 40 not functioning
70 to 80 and 40 to 60 functioning-at-risk
60 to 70 functioning

Max Pool Depth Ratio
< 1.2 not functioning
1.2 to 1.5 functioning-at-risk
> 1.5 functioning

Parameter #3 - Bank Migration / Lateral Stability

Two bank migration / lateral stability metrics were evaluated:

- Bank Erosion Hazard Index (BEHI)
- Near Bank Stress (NBS)

Bank Erosion Hazard Index

BEHI measurements were collected to document existing streambank characteristics and to develop ratings that indicate how susceptible the banks are to erosion. BEHI projections were also developed for the proposed channel reconstruction for comparison to existing conditions. The higher the BEHI score, the higher the susceptibility to erosion. BEHI variables include bank height relative to the bankfull elevation, bank angle, surface protection, root depth, root density. BEHI scores were also adjusted based on bank material and stratification. A modified version of the Rosgen BEHI rating system was used, in which up to 20 points were deducted from the overall score to account for the cohesive clay soils that tend to provide streambank stability.

Table 8 lists the BEHI ratings for existing and proposed conditions. Most of the BEHI ratings were "Low," with the exception of a "Moderate" rating within Reach 2, largely due to the stabilizing influence of the cohesive clay soils.

Appendix F contains the BEHI rating forms that contain the detailed calculations for existing conditions. The detailed calculations indicate that Reaches 1 and 2 had "High" and "Very High" scores for bank height variable (bank height relative to the bankfull elevation), which is a strong indicator of channel incision (floodplain disconnection). The proposed 2-stage channel will help restore floodplain access in Reaches 1 and 2. **Appendix F** indicates that Reach 3 also had some relatively high bank height scores, but those scores reflect isolated areas of very high banks (up to 12 feet) where the creek meanders along steep valley walls, whereas the vast majority of Reach 3 has relatively low banks and good floodplain access.

Appendix G contains the detailed BEHI projections for the proposed conditions. Conservative assumptions were made to develop the projections for proposed conditions, including no adjustment for the clay soils. Despite the conservative assumptions, the BEHI ratings were "Low" for the proposed channel reconstruction in Reaches 1 and 2.

Near Bank Stress

NBS ratings describe conditions within the channel that steer flows toward the banks and accelerate bank erosion, such as sediment deposition, chute cutoffs, down-valley meander migration, and converging flow. The NBS for existing conditions in Reach 1 was rated "Extreme" due to extensive deposition (continuous, cross channel). For Reach 2, the NBS was rated as "Moderate" because deposition was not as extensive; although, some short and discontinuous mid-channel bars were observed in Reach 2. Reach 3 appeared to be relatively unaffected by excessive deposition, or other NBS risk factors, so it was given an overall "Low" NBS rating. The results are listed in **Table 8**.

Table 8 also summarizes the bank migration / lateral stability metrics for existing/proposed conditions and highlights the functioning, functioning-at-risk, and non-functioning parameters based on the performance standards listed in the Stream Functions Pyramid (**Appendix C**), according to the standards proposed by Rosgen, 2001 (proceedings) and 2006 (book), which are listed at the bottom of the table. The results indicate that the proposed channel reconstruction in Reaches 1 and 2 will improve the lateral stability / bank migration metrics from non-functioning to functioning in Reach 1 and from functioning-at-risk to functioning in Reach 2.

Table 8. Bank Erosion Hazard Index Ratings – Existing and Proposed Conditions

Reach	Existing Conditions				Proposed Conditions		
	Station	BEHI Score	BEHI Rating	NBS Rating	BEHI Score	BEHI Rating	NBS Rating
1	27+71	17	Low	Extreme	18	Low	Low
	26+00	14	Low	Extreme			
2	NA	15	Low	Moderate	18	Low	Low
	18+79	23	Moderate	Moderate			
3	13+25	19.5	Low	Low	19.5	Low	Low
	9+51	17	Low	Low	17	Low	Low
	6+75	1	Very Low	Low	1	Very Low	Low

Bank Migration / Lateral Stability Performance Standards			
Parameter	Functioning	Functioning-at-Risk	Not Functioning
Lateral Erosion rate - Low BEHI Curve	Very low to Moderate NBS	Moderate to Very High NBS	Extreme NBS
Lateral Erosion rate - Moderate BEHI Curve	Very low to Low NBS	Low to High NBS	High to Extreme NBS
Lateral Erosion rate - High/Very High BEHI Curve	N/A	Low to Moderate NBS	Moderate to Extreme NBS
Lateral Erosion rate - Extreme BEHI Curve	N/A	Low NBS	Low to Extreme NBS

Parameter #4: Large Woody Debris Index

Large woody debris is beneficial because it provides wildlife habitat, promotes bedform diversity, creates sediment and organic matter storage areas, it is an important form of boundary roughness/flow resistance, and it increases localized bank erosion/sediment supply. It also provides structure that is important for the processing of organic matter and supporting macroinvertebrate and fish health; although, excessive accumulation can result in large debris dams that can impede fish passage.

The amount of large woody debris within Reaches 1-3 was quantified by determining the number of pieces per 100 meters, number of debris dams per 100 meters, and by computing the Large Woody Debris Index (LWDI), using to the methods described in the "Application of the Large Woody Debris Index: A Field User Manual." Per the manual, the 100-meter sub-reach that appeared to have the highest amount of woody debris was targeted for measurement within each reach. Pieces were defined as non-living wood, at least 1-meter in length, and at least 10-

centimeters in diameter at its largest end. Pieces were rated based on length, diameter, location, type, structure, stability, and orientation. Debris dams consist of three or more touching pieces. Debris dams were rated based on length, height, structure, location, and stability.

Table 9 summarizes the results of the LWDI measurements. The results indicate that the reference reach (Reach 3) had the highest LWDI (798), attributable to the relatively high number of individual pieces and debris dams. Reach 2 had more individual pieces, but only one debris dam, so the LWDI for Reach 2 (402) was approximately half of that for the reference reach. Reach 1 had the lowest LWDI (238). According to the Stream Functions Pyramid performance standards, Reaches 1 and 2 would be considered non-functioning for large woody debris because the LWDI does not equal that of the reference reach. Tree clearing will be needed for the proposed channel relocation and 2-stage channel construction in Reaches 1 and 2. Some of the larger trees that are cleared will be used as in-stream revetments and anchored within the floodplain to increase the amount of large woody debris in Reaches 1 and 2. **Appendix H** contains the Large Woody Debris field data sheets and calculations.

Table 9. Large Woody Debris Index Summary

Reach	Pieces per 100 meters	Debris Dams per 100 meters	Large Woody Debris Index
1	5	2	238
2	17	1	402
3	12	6	798

<u>Parameter #5: Riparian Buffer</u>

The riparian buffer width was measured on aerial imagery, perpendicular to the fall-line of the valley, along transects spaced approximately 100 feet apart. Buffer width calculations were made separately for each side of the stream and an overall average was computed for each reach. The bankfull channel width was excluded from the totals. The measurements were extended to the edge of the riparian vegetation community or to the edge of the valley if the riparian buffer was not disrupted by developed areas. **Table 10** summarizes the results. **Figure 2** depicts the transects referenced in **Table 10,** which were overlaid on a USGS Orthoimagery Topo basemap. The 660-foot ground elevation contour was used to define the valley limits.

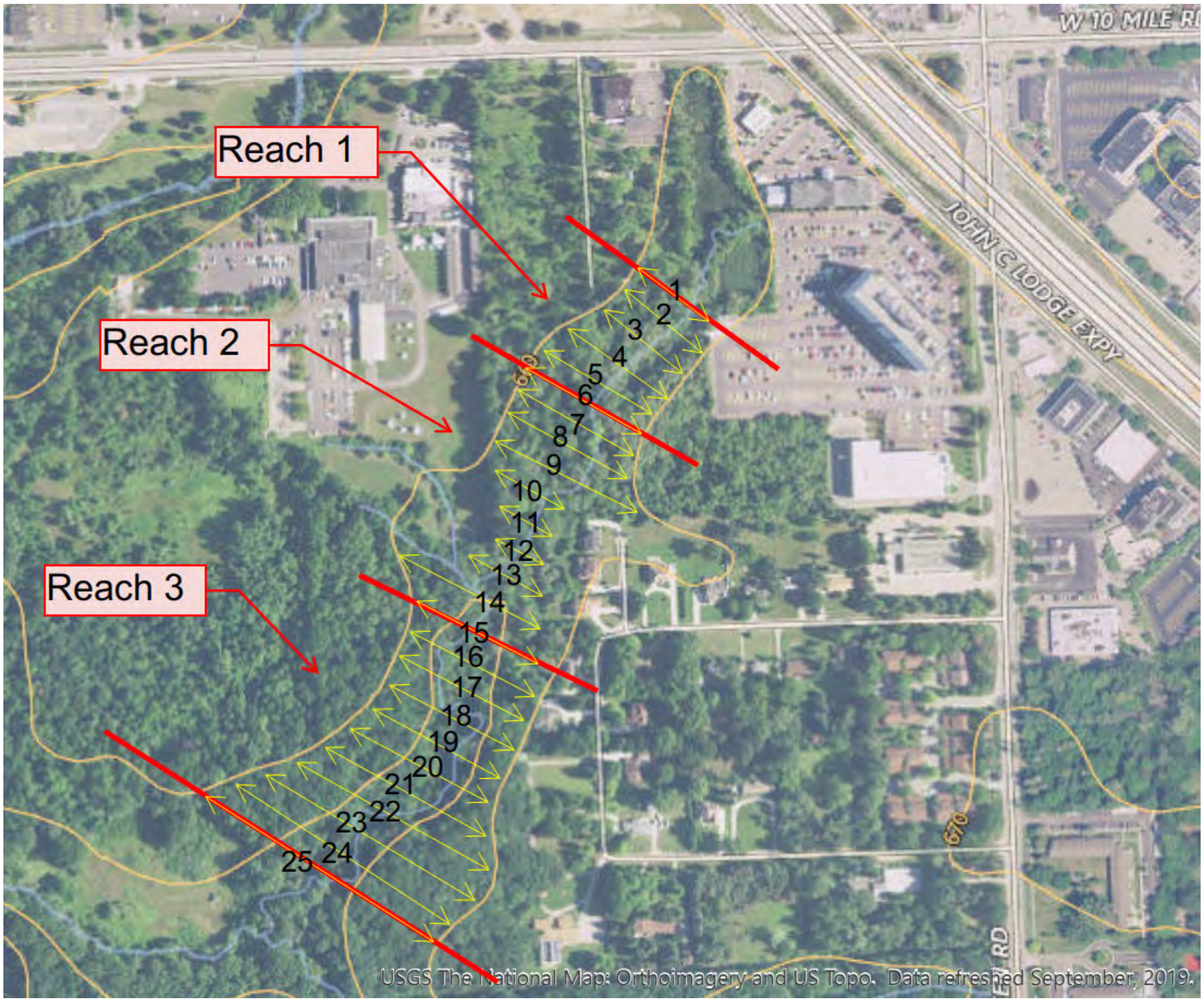
Table 10 indicates that the overall average buffer widths for Reaches 1, 2, and 3 were approximately 318, 312, and 547 feet, respectively. According to the Stream Functions Pyramid performance standards (**Appendix C**), these results indicate that all the reaches have functioning riparian buffers. For C and E stream types, an average buffer width greater than 150 feet is considered functioning (Meyer et al., 2005 (journal)).

A tree survey was performed to locate trees >3" in diameter within the project area. The results of the tree survey indicated that the existing riparian buffer is forest with predominately native species, but with a high percentage of invasive species, particularly in Reaches 1 and 2. The proposed native plant species and planting locations are included in the construction plans. The proposed channel relocation in Reaches 1 and 2 will require tree clearing along the entire beltwidth of the stream. As a result, the riparian buffer will be functioning-at-risk until the tree replacements become established, at which point it will be considered functioning.

Table 10. Riparian Buffer Widths

Reach	Transect Number Depicted in Map Figure	Total width	Total Width Minus Channel Width	West Buffer Width	East Buffer Width
1	1	270	250	220	30
1	2	306	286	171	115
1	3	320	300	165	135
1	4	360	340	185	155
1	5	380	360	209	151
1	6	393	373	208	165
Reach 1 Averages ->			**318**	**193**	**125**
2	6	393	373	208	165
2	7	406	386	253	133
2	8	420	400	262	138
2	9	467	447	277	170
2	10	218	198	153	45
2	11	172	152	104	48
2	12	150	130	90	40
2	13	248	228	115	113
2	14	463	443	249	194
2	15	386	366	184	182
Reach 2 Averages ->			**312**	**190**	**123**
3	15	386	366	184	182
3	16	418	398	99	299
3	17	428	408	133	275
3	18	437	417	292	125
3	19	445	425	279	146
3	20	485	465	337	128
3	21	580	560	358	202
3	22	706	686	352	334
3	23	771	751	337	414
3	24	783	763	422	341
3	25	798	778	435	343
Reach 3 Averages ->			**547**	**293**	**254**

Figure 2. Riparian Buffer Map with Measurement Transects Referenced in Table 10



4.0 Discharge Information and Frequencies

The bankfull flow rate (80 cfs) that was used for design purposes was estimated based on bankfull field indicators that were supported by hydrologic/hydraulic modeling and analysis. Depositional features on point bars downstream of the proposed relocation (Reach 3), and along the tops of banks in the upper portion of the relocation section (Reach 1, upstream of the existing triple-barrel culvert), were identified as primary bankfull field indicators. The flow rate in the HEC-RAS hydraulic model was adjusted until the water surface elevations matched the elevations of the observed bankfull field indicators. The flow rate required to match the bankfull field indicators (80 cfs) corresponded to a 1-year frequency flow based on the results of our TR-55/EGLE-Modified SCS hydrologic analysis. Typically, the bankfull flow rate in alluvial channels falls between a 1- and 2-year event, so these results supported the reasonableness of our bankfull flow estimate. The lower portion of the existing channel within the relocation (Reach 2, downstream of the existing triple-barrel culvert), suffered from excessive bed and bank erosion, so depositional features were absent, and bankfull field indicators were limited to secondary indicators, including scour lines and bank slope grade breaks.

Table 11 is a summary of the peak design flow data by return interval, including estimates that were not used for design purposes. The bankfull flow rate (80 cfs) was selected for design purposes because it was based on field indicators. The use of bankfull field indicators is widely accepted as the most reliable way to establish bankfull flows/elevations. The field indicators were verified by ECT's TR-55 hydrologic and hydraulic analysis. The bankfull flow rate was also in good agreement with the results of the 2006 geomorphic analysis performed by HRC (**Appendix I**).

The design flow estimates obtained by running the City of Southfield's SWMM hydrologic/hydraulic model (prepared by HRC), using Oakland County rain gauge data and design storms developed from NOAA Atlas 14 rainfall IDF estimates, were significantly higher than the estimates from the other sources described above. These higher estimates were not used for design purposes because they were not consistent with the bankfull field indicators. Using the higher estimates would likely have resulted in an oversized channel without sufficient floodplain access and at risk of excessive bed and bank erosion. It is suspected that the SWMM model over-predicted flows because stream flow/depth gauge data from actual storm events were not available for calibration of the model.

The Michigan Stream Team regional curve estimates reported in **Table 11** were included for informational purposes only. The regional curve estimates are not valid because the drainage areas of the streams used to develop the regional curve (min=16 square miles; average=146 sq. mi.; max=401 sq. mi.) were much larger than the Tamarack Creek drainage area (1 sq. mi.). As a result, the values reported for Tamarack Creek in **Table 11** were extrapolated from the regional curve, which invalidates the estimates.

Table 11. Peak Design Flow Summary

Source of Flow Estimate	Peak Design Flow Estimates by Return Interval					
	1-Year (Bankfull*)	2-Year	10-Year	25-Year	50-Year	100-Year
Bankfull field indicators and subsequent hydraulic modeling by ECT in 2019	70-80 cfs*	-	-	-	-	-
Results of TR-55 / EGLE-Modified SCS calculations performed by ECT in 2019	69-99 cfs**	81-117 cfs**	176-258 cfs**	232-345 cfs**	287-412 cfs**	333-483 cfs**
FEMA Study published in 2009	-	-	-	-	-	460 cfs
Geomorphic study prepared for the Oakland County Water Resources Commissioner (OCWRC) by HRC in 2006	52-86 cfs	-	-	-	-	-
Regional curve predictions based on the Michigan Stream Team results published in 2009 and the revised results published by Stantec in 2015	4-9 cfs***	-	-	-	-	-
Results of SWMM modeling and peak flow frequency analysis by ECT in 2019 using the City of Southfield's model (prepared by HRC) with SCS Type II design storms with NOAA Atlas 14 rainfall depths	294	345	489	-	-	650
Results of SWMM modeling and peak flow frequency analysis by ECT in 2019 using the City of Southfield's model (prepared by HRC) with 1995-2019 hourly rain data provided by OCWRC	169	227	361	-	-	553

*Bankfull flow is typically a 1- to 2-year event, and was assumed to be a 1-year event for this study because the Tamarack Creek drainage area is highly urbanized. It is not uncommon for bankfull flow events to occur multiple times each year in urban areas.

**TR-55: An extensive enclosed storm sewer system exists within the drainage area. The time of concentration (TOC) used in the flow calcs was sensitive to the assumed pipe velocities. The min and max pipe velocity design values listed in the MDOT Stormwater Drainage Manual (3 to 12 ft/s) were used to compute min and max TOC and corresponding flow estimates. This is why a range of flows are reported for each return interval.

***Regional curve predictions were not considered valid estimates because the curves had to be extraploated to generate the estimates reported here. The drainage areas of the streams used to develop the curves were orders of magnitude larger than the Tamarack Creek drainage area (approx. 1 sq. mi.).

TR-55/EGLE-Modified SCS Hydrologic Analysis

Environmental Consulting & Technology, Inc. (ECT) estimated design peak flows using methods originally developed by the United States Department of Agriculture's Natural Resources Conservation Service (NRCS), formerly known as the Soil Conservation Service (SCS). The Michigan Department of Environment, Great Lakes & Energy (EGLE)-Modified SCS Method was used, according to the procedure described in the EGLE report titled "Computing Flood Discharges for Small Ungaged Watersheds." This procedure was used to estimate the peak flow that would be expected if the watershed was gaged, using a design rainfall and a physical description of the drainage area (acreage, land use, topography, and soils data).

The steps used to generate the physical description of the drainage areas, used as inputs in the EGLE-Modified SCS Method, is summarized below:

- Drainage area boundaries established in a previous study, titled "Fluvial Geomorphic Analysis of Tamarack Drain," which was prepared for Oakland County Water Resources Commissioner (OCWRC) by HRC in 2006, were reviewed against recent digital elevation contour data obtained from the OCWRC website and storm sewer GIS data provided by the City of Southfield to verify the reasonableness of the boundaries depicted in the 2006 study.
- Land use was delineated using of aerial imagery (ESRI GIS basemap imagery) to help determine runoff curve numbers.
- Soil runoff potential was estimated through interpretation of USDA hydrologic soil group data. USDA describes most (approximately 65%) of the drainage area as "urban land," without a specific hydrologic group. This was considered an indication that topsoil fill was placed during development. Topsoil fill typically has a low runoff potential (hydrologic soil group "A"). The USDA data also indicated that a significant amount (approximately 20%) of the non-urban land contained soils with relatively high runoff potential ("C" and "D" soils); although, the non-urban land uses comprise a relatively small percentage of the overall drainage area. Based on these results, we used an average value of "B" in the in the runoff curve number calculations.

For drainage areas with times of concentration less than one hour, the NRCS's Windows TR-55 Method was used, along with the Michigan-specific hydrograph ordinates, per EGLE guidelines. The TR-55 Method requires the same inputs as the EGLE-Modified SCS Method.

Rainfall data was based on the "Rainfall Frequency Atlas of the Midwest", NOAA Midwestern Climate Center, 1992 (also known as "Bulletin 71"). We realize that more recent rainfall dataset is available (NOAA Atlas 14, published in 2013); however, EGLE issued the following warning against using Atlas 14 data as input when using the EGLE-Modified SCS Method:

> *If Bulletin 71 rainfall values are replaced with Atlas 14 rainfall values, the method will estimate unrealistically high peak discharges. We strongly recommend that the method be used only with Bulletin 71 rainfall data until such time as we have completed incorporating all the changes included in Atlas 14.*

Table 12 contains a summary of the runoff curve number (RCN) calculations and land use breakdown. Wetlands and open water accounted for a total of 1.0% of the drainage area, so the corresponding "Ponded and Swampy Adjustment Factors" listed in the EGLE report titled "Computing Flood Discharges for Small Ungaged Watersheds" were applied to generate the final flow estimates (**Table 13**).

Table 12. Summary of RCN Calculations and Land Use Breakdown

Hydrologic Soil Group	Percent of Total Drainage Area	Land Use	Percent of Soil Group	RCN	Partial RCN
B	100.00%	Commercial 85% impervious	36.00%	92	33.120
		Industrial 72% impervious		88	0.000
		Open space	6.20%	61	3.782
		Residential 1 acre		68	0.000
		Residential 1/2 acre	5.60%	70	3.920
		Residential 1/3 acre	42.90%	72	30.888
		Residential 1/4 acre		75	0.000
		Residential 1/8 acre		85	0.000
		swamp vegetated	0.60%	78	0.468
		swamp >1/3 open water		85	0.000
		Water	0.40%	100	0.400
		Woods - fair	8.30%	60	4.980
			Composite Runoff Curve Number:	**Sum**	**77.56**

Table 13. Summary of the TR-55 Peak Design Flows by Recurrence Interval

		Recurrence Interval						
		1-year*	**2-year**	**5-year**	**10-year**	**25-year**	**50-year**	**100-year**
Ponded and Swampy Adjustment factors		0.83	0.83	0.84	0.86	0.87	0.88	0.9
1.45-hour Time of Concentration**	TR55 Unadjusted flows (cfs)=>	83	98	155	205	267	326	370
	TR55 Adjusted flows(cfs)=>	**69**	**81**	**130**	**176**	**232**	**287**	**333**
0.88-hour Time of Concentration**	TR55 Unadjusted flows (cfs)=>	119	141	220	300	397	468	536
	TR55 Adjusted flows(cfs)=>	**99**	**117**	**185**	**258**	**345**	**412**	**483**

*Adjustment factor for 1-yr flow not available, so assumed same as 2-year.

**An extensive enclosed storm sewer system exists within the drainage area. The time of concentration (TOC) used in the flow calcs was sensitive to the assumed pipe velocities. The min and max pipe velocity design values listed in the MDOT Stormwater Drainage Manual (3 to 12 ft/s) were used to compute min and max TOC and corresponding flow estimates. This is why a range of flows are reported for each return interval.

5.0 Natural Channel Design

<u>Summary</u>

Natural channel design parameters for the proposed relocation/reconstruction were developed by considering conditions within the relatively stable Reach 3, which is located immediately downstream of the proposed relocation area (Reaches 1 and 2) (see Figure 1) and the performance standards listed in the Stream Functions Pyramid guidance document (**Appendix C**). **Table 14** is a summary of the proposed design parameters.

Table 14. Summary of Proposed Channel Design Parameters

Overall Summary	
Avg. Channel Slope*	0.26%
Bankfull Cross-Sectional Area [sf]*	30
Bankfull Width [ft]*	16
Bankfull mean depth [ft]*	1.9
Bottom Width [ft]*	7.2
Riffle Max Bankfull Depth [ft]*	2.5
Pool Max Depth [ft]*	4.0
Bank Angles [H:V]*	2:1
Percent Riffle**	64%
Avg. Pool-to-Pool Spacing Ratio**	5
Sinuosity*	1.25
Valley Length [ft]*	902
Stream Length (Reach 1 & 2) [ft]*	1130
Total Pool Length [ft]**	405
Total Riffle Length [ft]**	725
Avg. Riffle Length [ft]**	52

*Design value based on site conditions
**Design value based on Stream Functions Pyramid performance standards

Alignment

The proposed alignment of the reconstructed channel will convert the nearly straight existing channel into a meandering stream, which will increase energy dissipation and create pool habitat. The performance standards listed in the Stream Functions Pyramid for C and E streams were used to determine the minimum meander belt width (> 3.5 times the bankfull width) and appropriate pool-to-pool spacing (4 to 5 bankfull widths for drainage areas < 10 square miles). For comparison, Rosgen recommends pool-to-pool spacing of 5-7 bankfull widths or one-half a meander wavelength. Pools will be constructed along the outside of each meander bend. The radius of curvature of the proposed bends is approximately twice the bankfull width. Aerial imagery of reference conditions observed downstream of the project area were reviewed to ensure that the pool-to-pool spacing and radius of curvature of the proposed meander bends was within that observed range.

Bed Form

The bed of the reconstructed channel will be not be lined and riffle-pool sequences will be constructed to improve bedform diversity. The bed will not be lined with stone or any other materials to allow the stream channel to adjust, move sediment, and create or modify bed features. Pools will be constructed at meander bends within the relocated channel. The Stream Functions Pyramid performance indicate that the reconstructed channel should have a riffle-pool distribution that results in 60% to 70% riffle along its length, which is consistent with the proposed design. The performance standards also indicate that the ratio of max pool depth to bankfull depth should be > 1.5 (gravel) or >1.2 (sand), so the proposed max pool depth of 4 feet is consistent with these criteria. The proposed design results in a max pool depth 1.5 feet deeper than the riffle thalweg. The 4-foot max pool depth is measured from the bottom of the deepest part of the pool to the top of bank (bankfull elevation). Each pool will be constructed so that the max pool depth occurs at the center, or the downstream two-thirds point, along the bend.

Cross Section

The cross section of the proposed 2-stage channel in Reaches 1 and 2 was designed to limit channel depths, velocities, and shear stresses and improve habitat conditions by providing floodplain access. The first stage of the channel is relatively small, sized for the bankfull flow event (1- to 2-year frequency flow). The relatively small first stage channel, with a v-shaped bottom, will generate sufficient low-flow depths and velocities to minimize sediment deposition during normal flows. Excavating bankfull benches on either side of the first stage channel will create a second stage channel that provides floodplain access, which is needed to increase flow capacity during larger storm events and limit bankfull channel depths, velocities, and shear stresses to promote bed and bank stability.

The first stage is the bankfull channel, which was sized to flow nearly full at the bankfull flow rate (80 cfs). The banks were designed to have gradual (2H:1V) side slopes to promotes bank stability. The V-shaped channel bottom was designed to concentrate low-flows to promote sediment transport and fish passage. The width and depth were designed to be similar to the existing reference conditions that the reconstructed channel will tie into at the downstream end of the relocation.

The second stage is the floodplain channel, where the bankfull benches will be constructed to provide a meander belt width > 3.5 times the bankfull width, which is consistent with the Stream Functions Pyramid standards and NRCS guidelines. According to the NRCS Part 654 Engineering Handbook, "If the total width, when out-of-channel flow is initiated, is less than three times the top width of the bankfull channel, the benches might not fully develop, the benches are more likely to be unstable, and shear stresses on the bed and banks of the ditch will be high during large events."

High Flow Conveyance

Based on its cross-sectional dimensions, slope, and roughness, the bankfull channel can convey a maximum of approximately 80 cfs before over-topping its banks. Because a flow control device will not be used to limit the amount of flow that can enter the creek, the channel was designed with a floodway to accommodate flows in excess of its channel capacity. If a conventional over-sized trapezoidal channel were proposed, it would allow flow velocity and channel shear stress to increase with increasing discharge and water depth, increasing the risk of streambank erosion, and providing little or no floodplain access. Therefore, a two-stage channel with an adjacent floodway was proposed to convey flows in excess of channel capacity. The floodway, or two-stage channel design, allows flows in excess of channel capacity to be conveyed over a cross-sectional area that is much larger, thereby reducing channel velocity and shear stress.

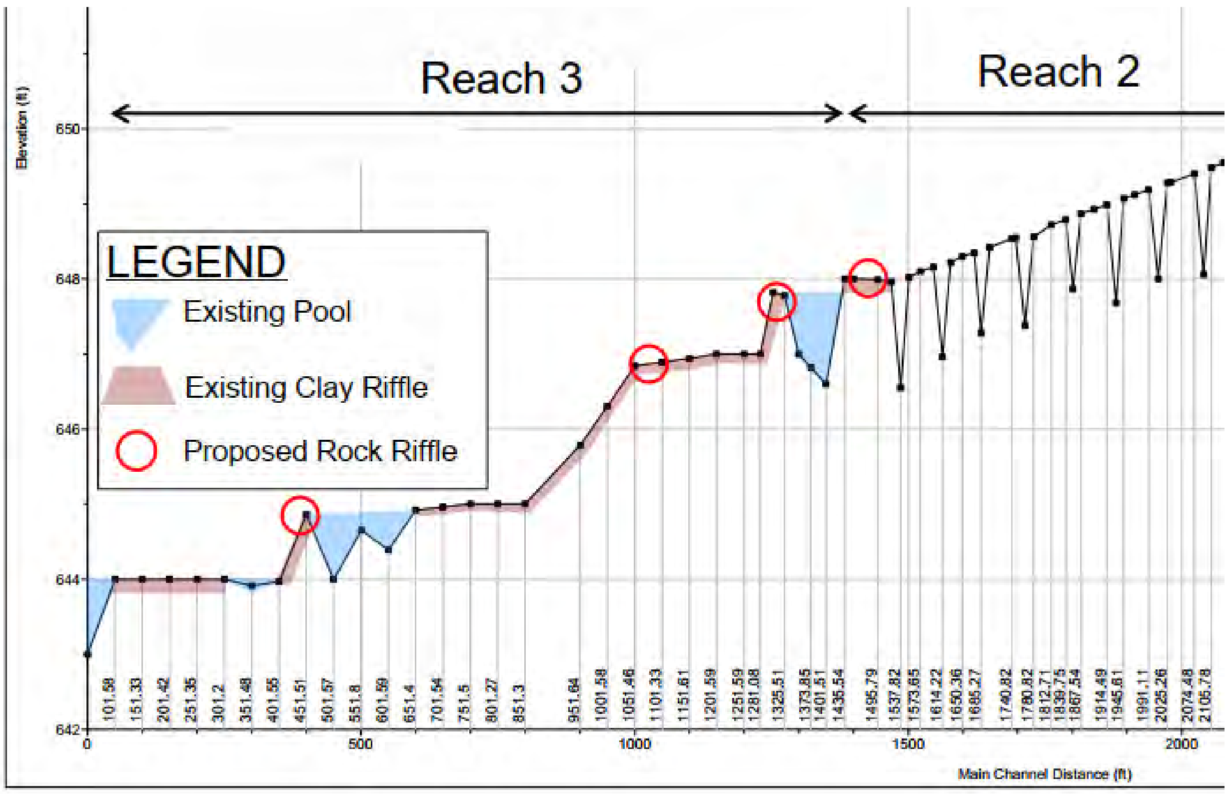
Slope

The slope of the proposed channel reconstruction in Reaches 1 and 2 was set to match the existing water surface slope downstream of the reconstruction (0.3%), which was based on the water surface profiles depicted in the FEMA study. A lower slope design was considered to minimize the amount of floodplain excavation, but the hydraulic modeling results indicated that the transition from the reconstructed channel with the lower slope to the existing channel with the higher slope would result in instabilities. For example, the model predicted supercritical flow near the transition, along with high velocities and shear stresses, which would have resulted in the need for energy dissipation measures at the transition. A drawdown effect upstream of the transition was also predicted, which would have entrenched the bankfull flow for a significant distance upstream of the transition. As a result, the slope of the reconstructed channel was designed to match the existing water surface slope downstream of the reconstructed channel to maintain uniform flow conditions at the transition and eliminate the need for energy dissipation measures at the transition.

6.0 Riffle Habitat Structures

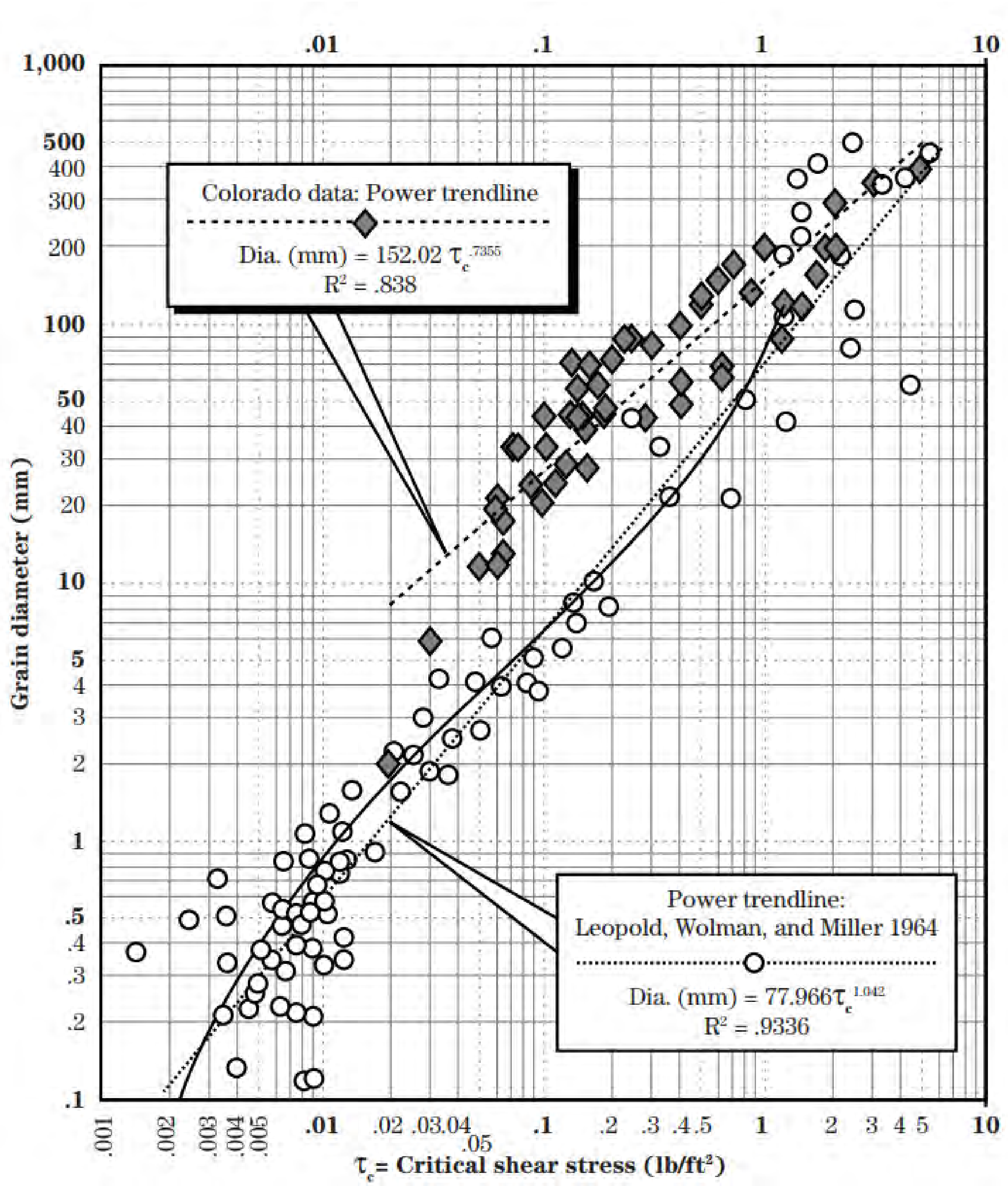
The proposed at-grade riffle habitat structures in Reach 3 were designed to provide aquatic habitat by increasing bed substrate diversity. The results of sediment sampling and analysis, previously described in this report, indicated a lack of gravel/cobble habitat. The proposed at-grade rock riffles are intended to provide coarse spawning substrate, which is lacking along the existing clay-dominated riffles. The proposed locations were selected based on existing bed high points and to maintain the existing pool-to-pool spacing. One such location was selected at the transition from the restored reach 2 to reach 3 to also provide grade control. It is important to note that the intent is to supplement the existing clay riffles with rocky substrate, not to change the existing riffle or pool spacing. The length of each of the proposed riffles will be approximately one bankfull width, based on design criteria from the ***Database of Morphologic Characteristics of Watercourses in*** *Southern Ontario,* Annable, W.K., 1996. The proposed structures will be at-grade, so they will not alter the existing cross-sectional channel dimensions or flow characteristics. **Figure 3** is a conceptual sketch of the approximate proposed locations overlaid on the longitudinal profile output from the HEC-RAS hydraulic model. Note that Reach 3 and a portion of the proposed channel reconstruction upstream of Reach 3 is depicted in the figure, not the entire project area.

Figure 3. Conceptual Sketch of the Proposed Riffle Structure Locations (Profile View)



Stone sizing for the riffle structures was performed using the Shield's Curve, along with model-predicted shear stress values for the 100-year design flow event. **Figure 4** depicts the Shield's Curve, which was developed by Leopold, Wolman, and Miller in 1964 from empirical data. The Shield's Curve is a plot of grain diameter versus critical shear stress. Critical shear stress refers to the shear stress value needed to initiate movement of a given size particle. The shear stress values at the proposed riffle locations were extracted from the model and plotted on the Shield's Curve to determine the minimum stone size (diameter of the intermediate axis) needed for the proposed riffle structures to remain stable. The intermediate axis refers to the side of the particle that would fall through a sieve opening, for example, not the longest axis. The stone size specified in the design plans represents the stone with an intermediate axis D50 greater than or equal to the minimum stone size determined from the stone sizing analysis. The provisional Colorado data provided by Rosgen (2000), which is also depicted on the Shield's Curve, was not used for the proposed stone sizing for Tamarack Creek. It likely would have produced overly conservative results (excessively large stone sizes), especially since a conservative design event (100-year event) was already used to obtain the shear stress estimates used for the stone sizing.

Figure 4. Shield's Curve used for Stone Sizing



7.0 Hydraulic Modeling

ECT developed HEC-RAS hydraulic models to replicate existing and proposed conditions of project reaches. The models were used to perform the bankfull verification, evaluate hydraulic changes due to proposed reconstruction of Reaches 1 and 2, and to show no rise in base (100-year) FEMA flood elevations as a result of the proposed improvements. The existing conditions stream profile and cross-sections were established from topographic survey data. The proposed conditions hydraulic model reflects the proposed removal of the triple-barrel culvert between Reaches 1 and 2 and the proposed floodplain excavation and channel re-alignment in Reaches 1 and 2. The proposed conditions were introduced in the model and bankfull and 100-year flow events were simulated. The model was iteratively run to determine the most effective bankfull channel dimensions that ensure appropriate shear stress for sediment transport while maintaining similarity with the reference reach channel characteristics. The calculated velocities for the range of storm events were reviewed to ensure that the proposed stream cross-section would not generate excessively erosive velocities throughout the stream reach. Shear stress and velocity estimates were also used to determine the type of erosion control blanket required in the flood plain areas, and to help size the stones for the proposed at-grade riffles and at-grade stream crossing.

Appendix J contains existing conditions model output for the bankfull and 100-year events, including a sample of cross section plots for each reach, a profile plot that includes left overbanks (LOB) and right overbanks (ROB), and floodplain inundation maps that depict the 100-year water surface elevations. Tabular output by cross-section stationing is included at the end of the appendix. The tables include water surface elevations, velocities, shear stresses, and other hydraulic parameters. Note that the river stationing used in the hydraulic modeling (Station 0+00 at the downstream end) is reversed compared to the stationing depicted in the construction plans.

The results of the proposed conditions modeling indicated that the 100-year flood plain elevation will be significantly lower as a result of the proposed culvert removal and floodplain excavation in Reaches 1 and 2, as expected. The results also show that the proposed channel reconstruction was properly sized for the bankfull event, as indicated by the water surface near the tops of the banks. **Appendix K** contains proposed conditions model output and includes the same components as described above for existing conditions (**Appendix J**). Supporting documentation for the roughness coefficients and tailwater boundary conditions are described below.

The values of the Manning's "n" roughness coefficients that were used in the HEC-RAS hydraulic model are highlighted in **Table 15**, based on information obtained from Table 4-1 of the MDOT Drainage Manual, which is a modified version of the table published by Chow, V.T., 1970. The values highlighted in **Table 15** (channel n=0.04; overbank n=0.120) were determined by matching the conditions observed at Tamarack Creek to those described in the table and selecting the "normal" value for that condition. The values were consistent with the range of values listed in the FEMA study.

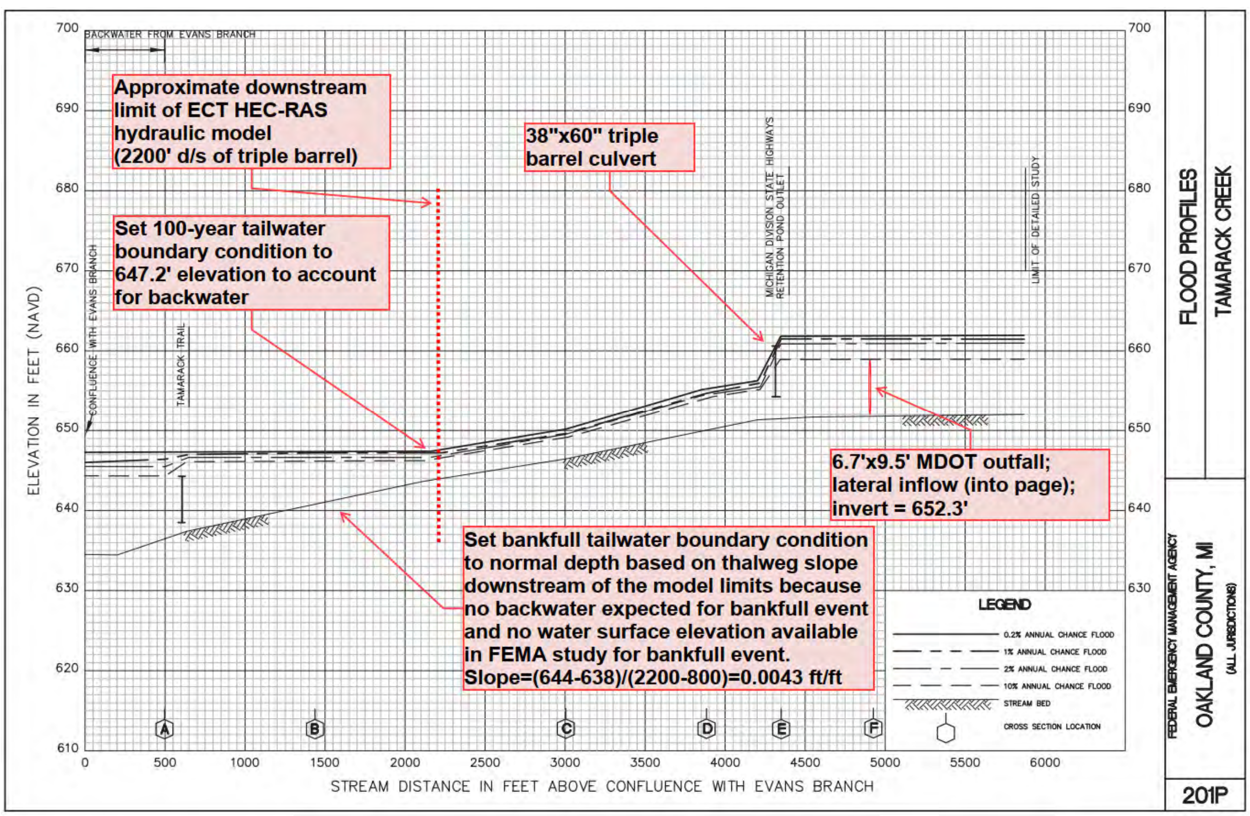
Table 15. Manning's Roughness Coefficients "n" used in HEC-RAS Hydraulic Model

Type of Channel and Description	Minimum	Normal	Maximum
NATURAL STREAMS			
1. Minor streams (top width at flood stage < 100 feet)			
a. Streams on Plain:			
1. Clean, straight, full stage, no rifts or deep pools:	0.025	0.030	0.033
2. Same as above, but more stones/weeds	0.030	0.035	0.040
3. Clean, winding, some pools/shoals	0.033	0.040	0.045
4. Same as above, but some weeds/stones	0.035	0.045	0.050
5. Same as above, lower stages, more ineffective slopes and sections:	0.040	0.048	0.055
6. Same as 4, but more stones:	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools:	0.050	0.070	0.080
8. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush:	0.075	0.100	0.150
2. Flood Plains			
a. Pasture, no brush:			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated area:			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Dense Willows, summer, straight	0.110	0.150	0.200
2. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. Same as above, but with heavy growth of spouts	0.050	0.060	0.080
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
5. Same as above, but with flood stage reaching branches	0.100	0.120	0.160
3. Major Streams (top width at flood stage > 100 feet) The n value is less than that for minor streams of similar description because banks offer less effective resistance.			
a. Regular section with no boulders or brush	0.025	--	0.060
b. Irregular and rough section	0.035	--	0.100

Source: Chow, V.T., 1970

Tailwater boundary conditions were set in the HEC-RAS based on information obtained from the FEMA study. **Figure 5**, which includes callouts that were overlain on the FEMA profile plot, indicates that during large flood events (10-year frequency flow and higher), backwater effects caused by downstream obstructions (Evans Branch and Tamarack Trail culvert) dissipate at or near the downstream limit of the HEC-RAS model that was used to simulate the proposed project improvements. To account for potential backwater effects, the 100-year tailwater boundary condition was set based on the 100-year water surface elevation from the FEMA study (647.2’ NAVD). For the relatively small bankfull event, which typically corresponds to a 1- to 2-year frequency flow, potential backwater effects from downstream obstructions would be lower (or non-existent) and would be expected to dissipate well downstream of the proposed project modeling extents. As a result, the bankfull tailwater boundary condition was set to normal depth downstream of the modeling limits, based on the thalweg slope depicted in the FEMA profile (0.43%), which is depicted in **Figure 5**.

Figure 5. Tailwater boundary conditions used in HEC-RAS Hydraulic Model



8.0 Flood Stage Impact Analysis

The proposed project lies within a FEMA-regulated floodplain (Zone AE), which is the flood insurance risk zone that corresponds to the 1-percent-annualchance (100-year) floodplain base flood elevations (BFEs) determined in the FEMA Flood Insurance Study (FIS) by detailed methods. The results of the hydraulic analysis indicated that the proposed re-alignment and 2-stage channel construction within Reaches 1 and 2 of Tamarack Creek will result in a localized decrease in the BFE and change the floodway/floodplain boundaries reported in the FEMA study.

Because the proposed project is not increasing the BFE, the City of Southfield will not be required to submit a Conditional Letter of Map Revision (CLOMR) to obtain FEMA prior to construction; however, after the project is constructed, the City of Southfield will need to submit a MT-2 FEMA revision request and a Letter of Map Revision (LOMR) with a hydraulic analysis to support the change in the mapped floodway boundaries. A LOMR-F will be required for changing floodplain boundaries with fill. The only fill in the floodway will be that needed to fill the old channel with cut from the new channel during the re-alignment of the existing channel. The proposed work will be conducted on properties not owned by the City of Southfield (applicant); therefore, the City has been working with the landowners to obtain approvals. The location of the floodplain will affect primarily one property owner, who is concerned about the potential loss of developable land as a result of the proposed project. The property owner is concerned because a portion of the property that is not currently within the 100-year floodplain, will be within the new floodplain limits as a result of the proposed project. Subsequent negotiations with this landowner have resulted in the need to fill part of the existing floodplain in one part of the landowner's property to offset the loss of developable land in another part of the property.

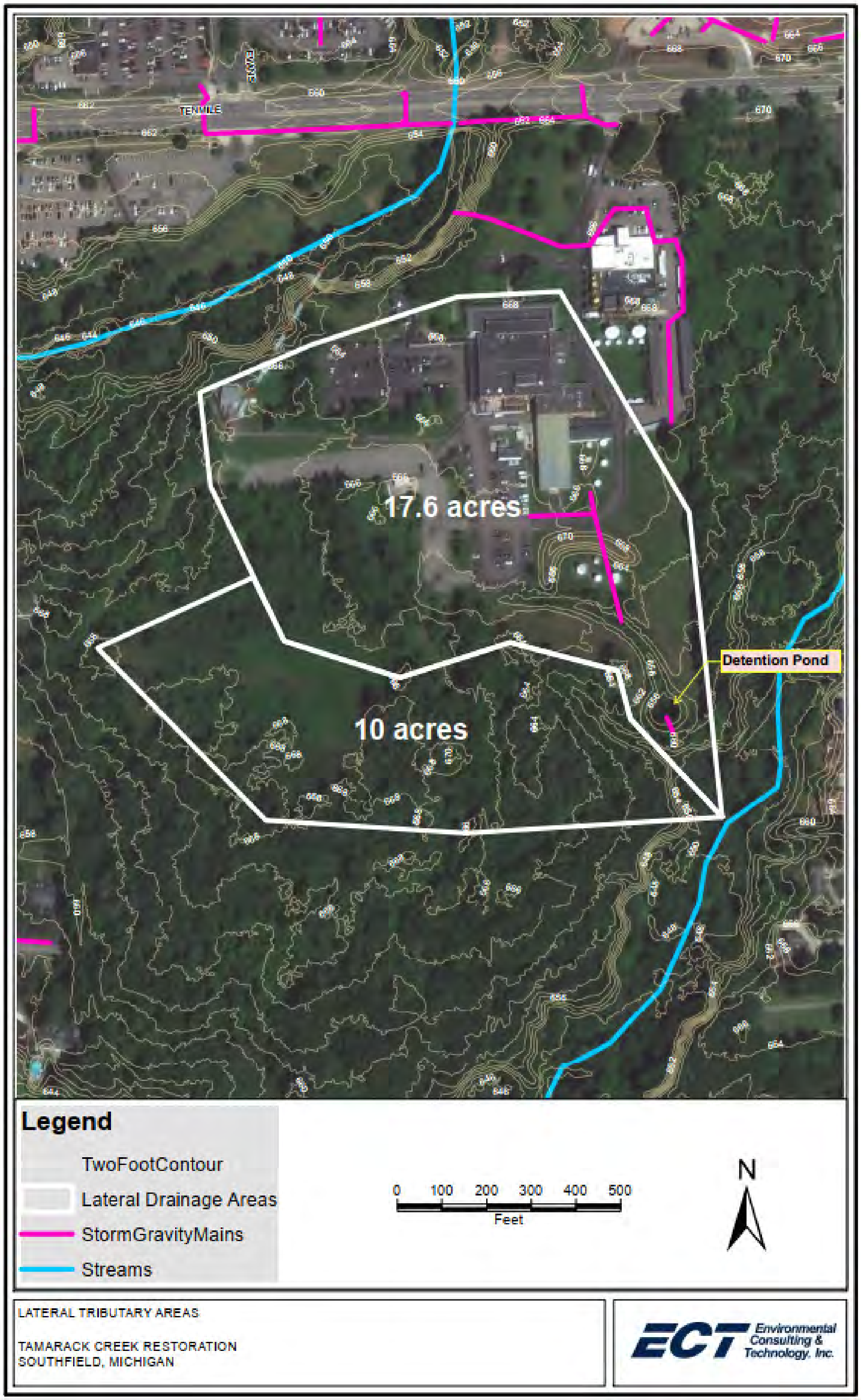
The State of Michigan's Floodplain Regulatory Authority, found in Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act (NREPA), 1994 PA 451, as amended, requires that a permit be obtained prior to any alteration or occupation of the 100-

year floodplain of a river, stream, or drain that has a drainage area that is 2 square miles or greater. The drainage area of Tamarack Creek is less than 2 square miles, so a permit is not required from EGLE, under Part 31. However, EGLE will review the proposed floodplain impacts under other State statutes found in NREPA, including Part 301-Inland Lakes and Streams and Part 303-Wetlands Protection.

9.0 Culvert Sizing

The proposed design includes a permanent maintenance road that will run parallel to Tamarack Creek. The proposed road will cross the small lateral tributary that ties into the west side of Tamarack Creek within Reach 2, which is visible on the USGS topo basemap (**Figure 1 and/or Figure 2**). Upstream of the confluence, the tributary consists of a north branch and a south branch. The north branch conveys flows from the property owned by WXYZ-TV. This approximately 17.6 acre property contains a large percentage of impervious areas (office buildings and parking lots), the flows from which are routed through a detention pond. The south branch conveys flows from an undeveloped (mostly wooded) area, approximately 10.0 acres in size, the flows from which are not routed through a detention pond. **Figure 6** depicts the tributary areas, 2-foot elevation contours obtained from Oakland County, stormwater gravity mains based on GIS data provided by the City of Southfield, and adjacent streams. These data were used to delineate the tributary area and size a culvert for the proposed maintenance road crossing, as described below.

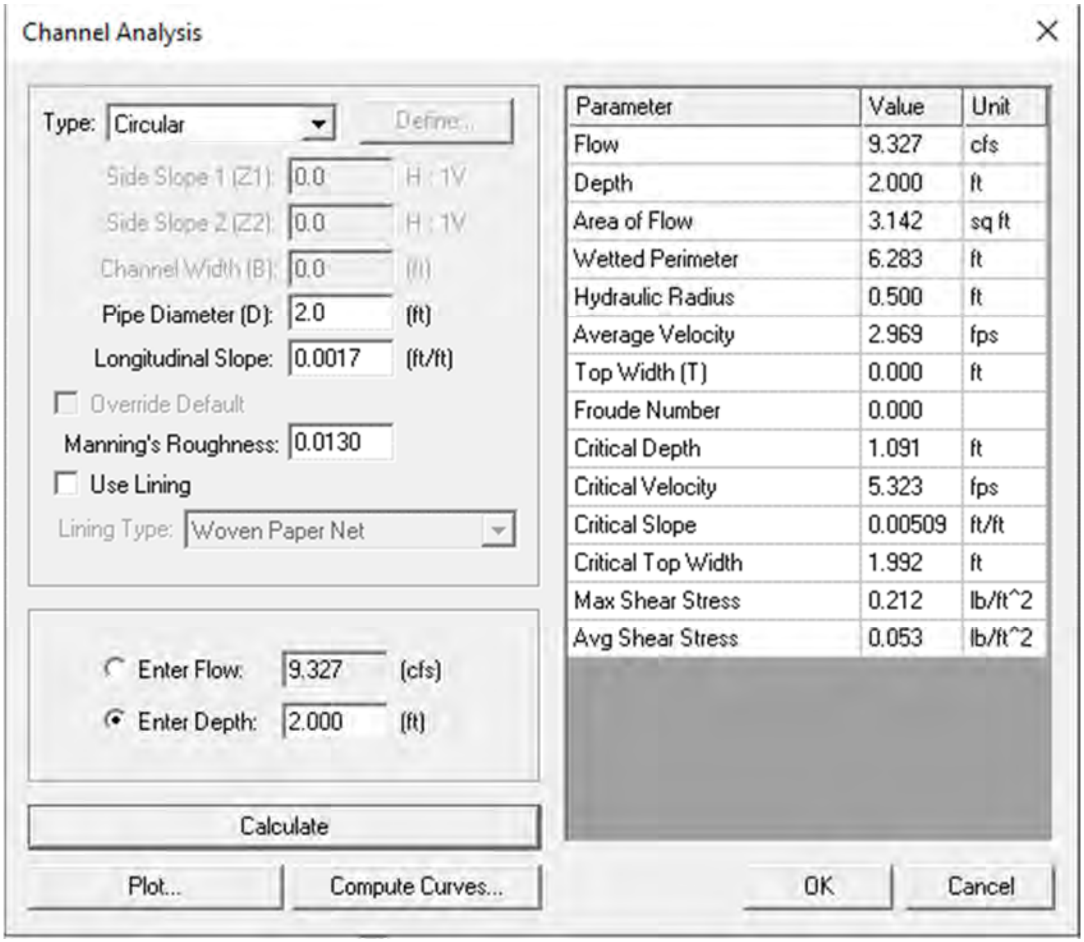
Figure 6. Lateral Tributary Areas



The culvert was sized for a 100-year frequency storm, using a peak design flow rate of 6.48 cfs. The design flow was based on the sum of flows from the north branch (17.6 acre drainage area) and south branch (10.0 acre drainage area) of the lateral tributary described above. The design flow for the 17.6 acre drainage area (3.52 cfs) was estimated using the maximum allowable detention pond design outflow of 0.2 cfs per acre, based on the Oakland County Water Resources Commissioner's Engineering Design Standards for Storm Water Facilities. The design flow for the 10.0 acre drainage area (2.96 cfs) was based on the Rational Formula (Flow=Q=CIA). For the runoff coefficient (C), the value of 0.20 was used, which is the intermediate value listed for undeveloped areas in Table 3-1 of the MDOT Drainage Manual. For the rainfall intensity (I), the value of 0.961 inches per hour was used, which is the value listed in NOAA Atlas 14 using a minimum time of concentration of 15 minutes. For the Area (A), the value of 10.0 acres was used, which is the size of the drainage area.

The results of a hydraulic analysis indicated that a 24-inch diameter culvert would be sufficient to convey the 100-year design peak flow of 6.48 cfs. This was based on a circular 24" pipe, with a 0.013 Manning's "n" roughness coefficient, set at the minimum design slope of 0.17% (self-cleansing slope listed in Table 7-6 of the MDOT Drainage Manual). A hydraulic calculator (FHWA Hydraulic Toolbox 4.4 software) was used to verify that the pipe capacity (9.33 cfs) would be sufficient to convey the 6.48 cfs design flow. An 18" pipe was also considered, but the capacity of the 18" pipe at the minimum design slope (5.44 cfs) was not sufficient to pass the design flow without surcharging. **Table 16** lists the input and output from the hydraulic calculator for the 24" pipe.

Table 16. Culvert Sizing Input/Output from the FHWA Hydraulic Toolbox Software



Appendix A

Somat Engineering, INCORPORATED

January 3, 2019
2018110B

Mr. Marty Boote, P.E.
Environmental Consulting & Technology, Inc. (ECT)
2200 Commonwealth Blvd., Suite 300
Ann Arbor, MI 48105

RE: Results of Sieve Analyses
Tamarack Creek - Habitat Restoration Design
Southfield, Michigan

Dear Mr. Boote:

Somat Engineering, Inc. (Somat) has completed the requested sieve analyses for the samples collected by ECT as part of the proposed Habitat Restoration Design at Tamarack Creek, located in Southfield, Michigan.

We received a total of seven (7) samples from ECT; they were delivered to the Somat laboratory located in Taylor, Michigan. The samples were received on December 11, 2018 and were transferred from ECT to Somat using chain-of-custody procedures. Each sample was contained in a zip-top bag labeled with the specimen identification number. Somat performed the sieve analysis tests in general accordance with ASTM D6913. The laboratory results are attached. The samples will be maintained for 30 days from the date of this letter; after which, they will be discarded.

We appreciate the opportunity to assist you with this project. Upon your review, should you have any questions or require additional information, please feel free to contact us.

Sincerely yours,
Somat Engineering, Inc.

C.Weirauch

Catherine J. Weirauch, P.E.
Project Manager

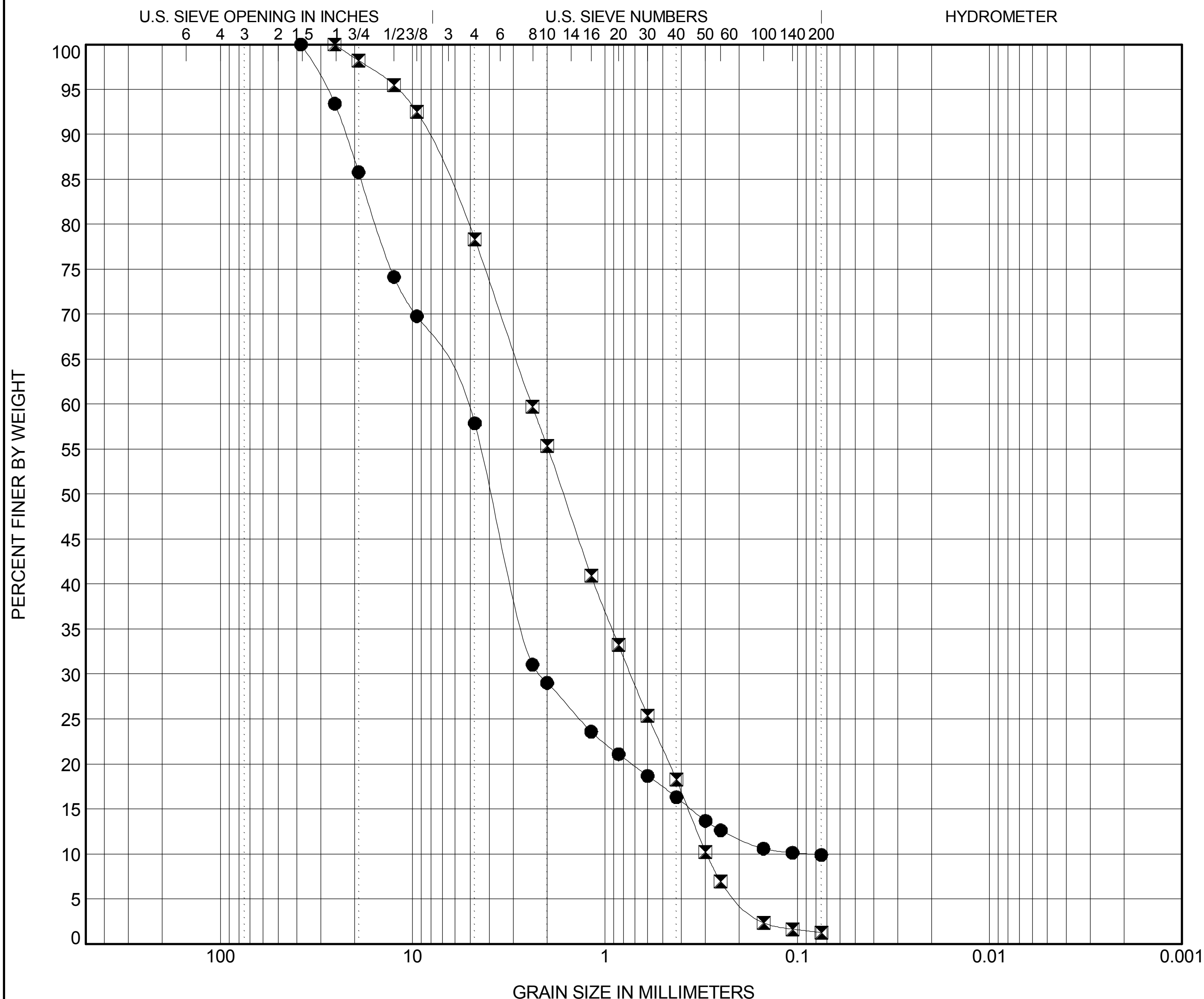
CJW/CRS

Attachment: Results of Sieve Analysis Tests

Somat Engineering, Inc.
Habitat Design at Tamarack Creek
Stream and Wetland Restoration
Southfield, Michigan

GRAIN SIZE DISTRIBUTION

PROJECT NO. 2018110B



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification	Depth ft.	Remarks	LL	PL	PI	Cc	Cu
●	**R151**	**0.2**	1-inch sieve retained an aggregation				**9.96**	**60.74**
⧗	**R152**	**0.2**	3/4-inch sieve retained one stone; No.4 sieve contained plastic debris and wood pieces				**0.76**	**8.13**

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**R151**	**0.2**	**38.1**	**5.374**	**2.176**	**0.088**	**42.1**	**48.0**	**9.9**	
⧗	**R152**	**0.2**	**25.4**	**2.407**	**0.737**	**0.296**	**21.7**	**77.1**	**1.2**	

GRAIN SIZE TAMARACK CREEK HABITAT RESTORATION.GPJ SOMAT.GDT 12/19/18

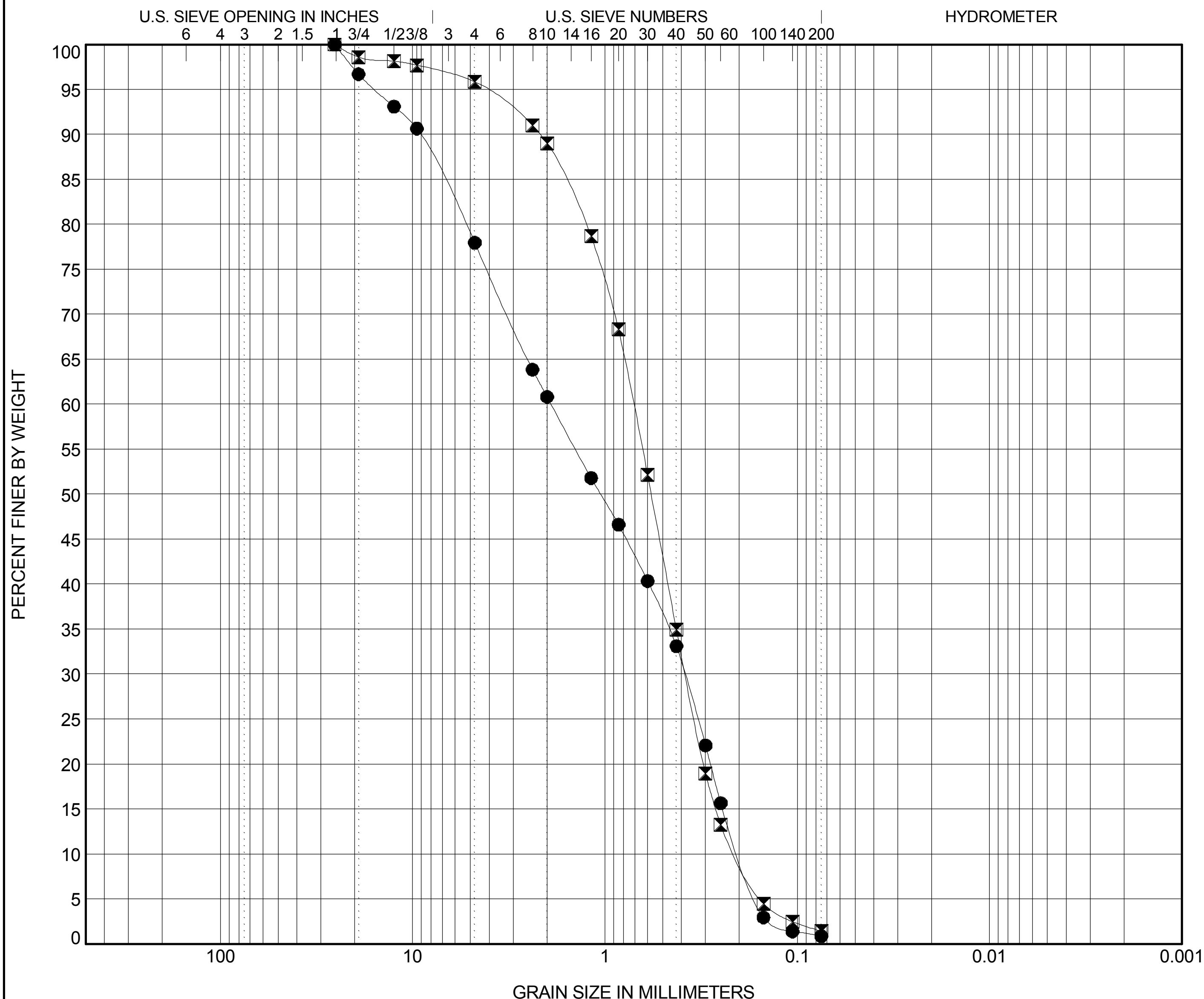
01/03/19

Somat Engineering, Inc.

Habitat Design at Tamarack Creek
Stream and Wetland Restoration
Southfield, Michigan

GRAIN SIZE DISTRIBUTION

PROJECT NO. 2018110B



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification	Depth ft.	Remarks	LL	PL	PI	Cc	Cu
●	**R153**	**0.2**	No.8 sieve contained glass debris; No.8 sieve contained wood pieces				**0.39**	**9.57**
⧗	**R251**	**0.2**	3/4-inch and 3/8-inch sieves retained one stone each				**0.99**	**3.44**

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**R153**	**0.2**	**25.4**	**1.907**	**0.385**	**0.199**	**22.0**	**77.1**	**0.9**	
⧗	**R251**	**0.2**	**25.4**	**0.711**	**0.382**	**0.207**	**4.2**	**94.4**	**1.4**	

GRAIN SIZE TAMARACK CREEK HABITAT RESTORATION.GPJ SOMAT.GDT 12/19/18

01/03/19

Somat Engineering, Inc.
Habitat Design at Tamarack Creek
Stream and Wetland Restoration
Southfield, Michigan

GRAIN SIZE DISTRIBUTION

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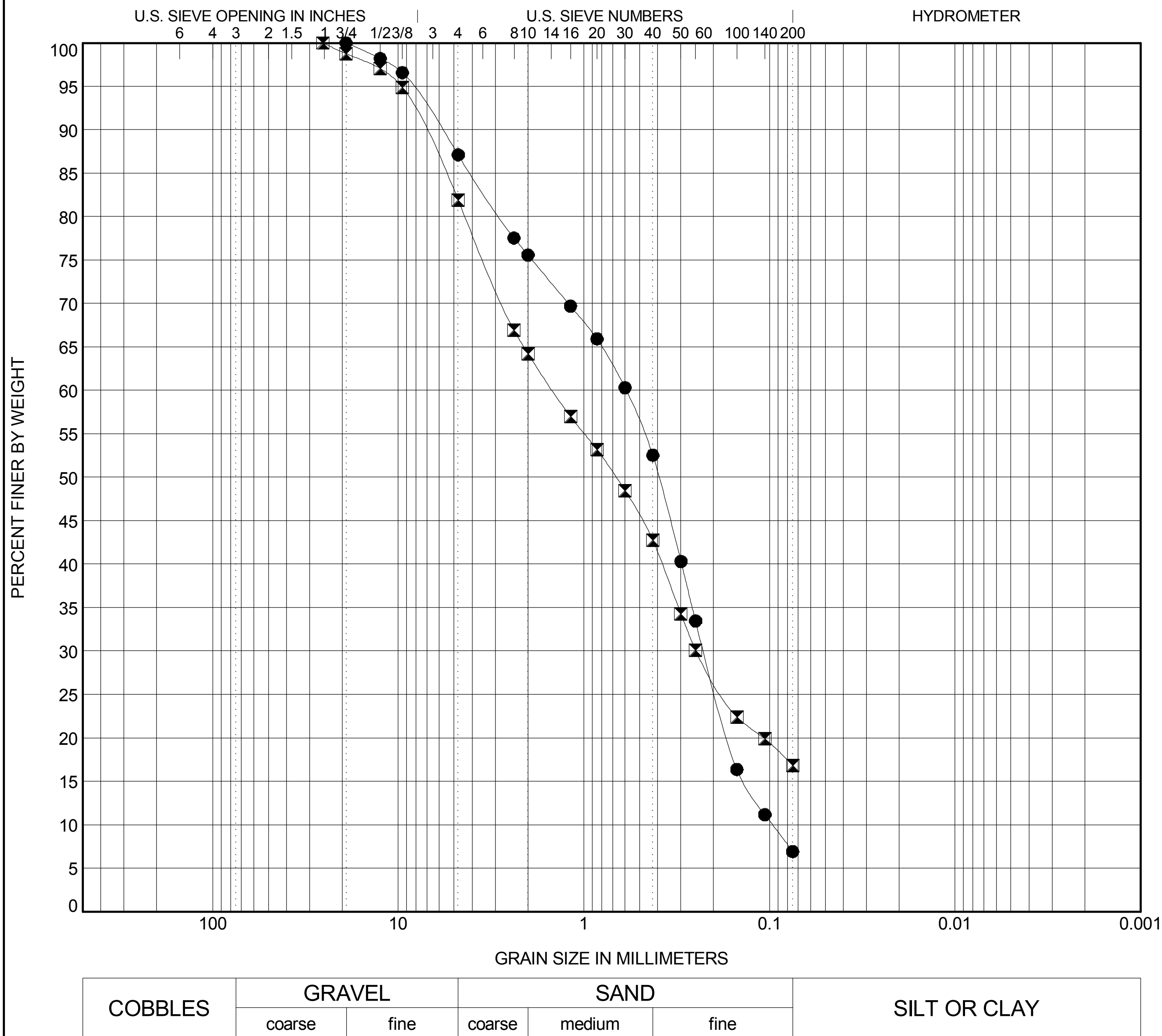


Specimen Identification		Depth ft.	Remarks	LL	PL	PI	Cc	Cu
●	**R351**	**0.2**	No.4 sieve contained wood pieces				**0.89**	**6.13**
⧗	**R352**	**0.2**	3/4-inch sieve retained one stone					

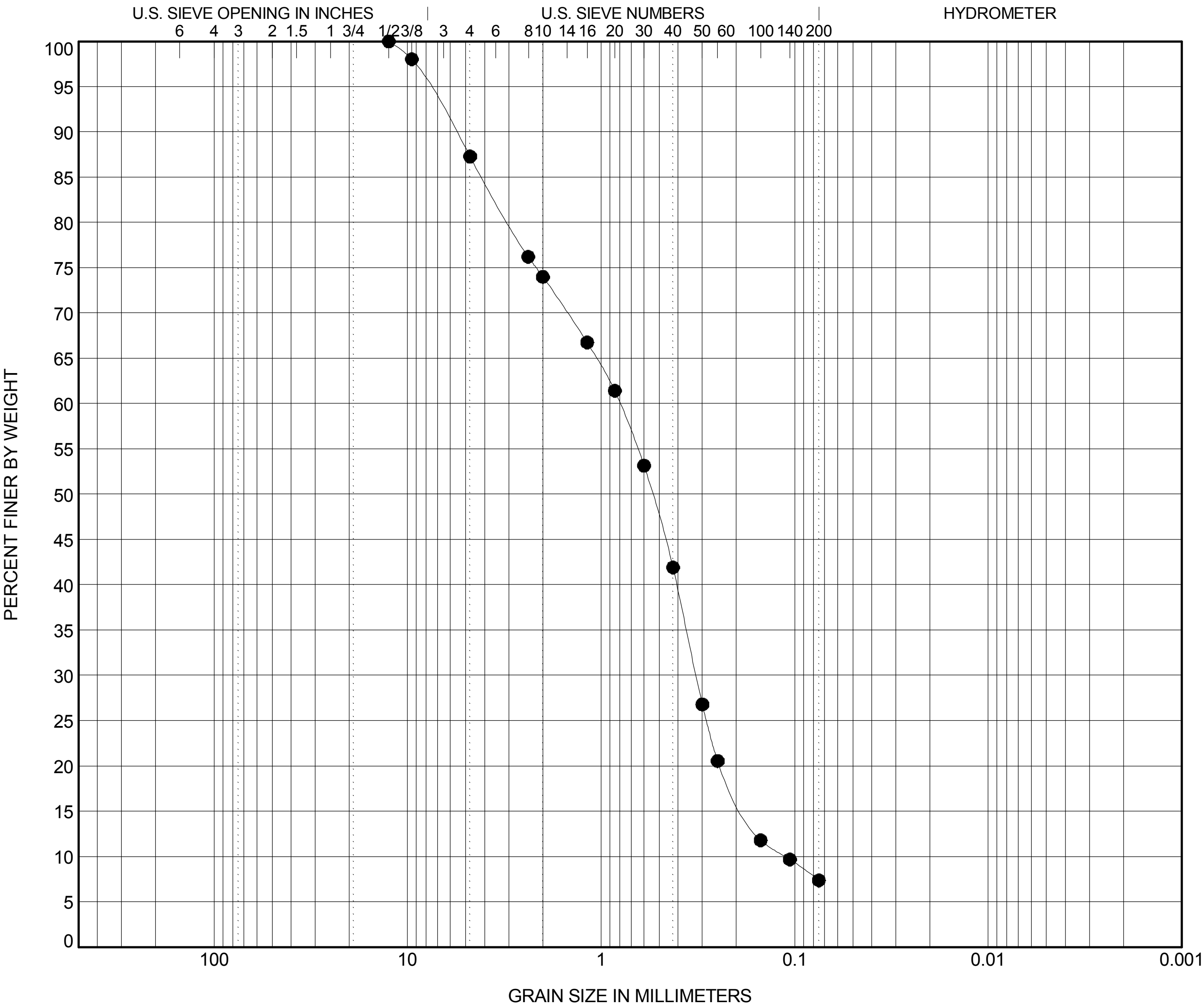
Specimen Identification			D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**R351**	**0.2**	**19.1**	**0.592**	**0.225**	**0.097**	**12.9**	**80.2**	**6.9**	
⧗	**R352**	**0.2**	**25.4**	**1.47**	**0.248**		**18.1**	**65.1**	**16.8**	

Somat Engineering, Inc.

Habitat Design at Tamarack Creek
Stream and Wetland Restoration
Southfield, Michigan

GRAIN SIZE DISTRIBUTION

PROJECT NO. 2018110B



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

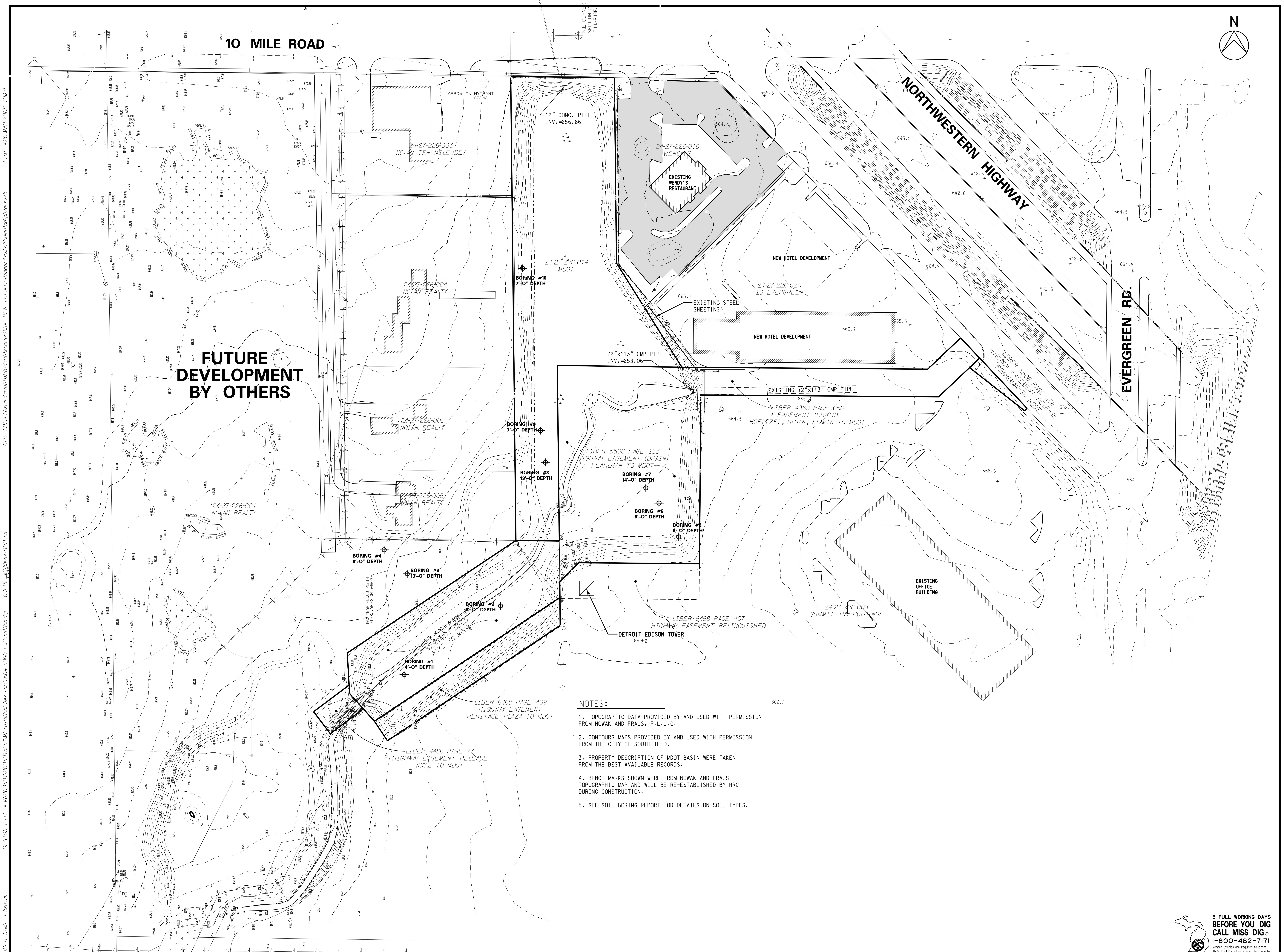
	Specimen Identification	Depth ft.	Remarks	LL	PL	PI	Cc	Cu
●	**R353**	**0.2**					**1.17**	**7.15**

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**R353**	**0.2**	**12.5**	**0.8**	**0.323**	**0.112**	**12.7**	**79.9**	**7.4**	

GRAIN SIZE TAMARACK CREEK HABITAT RESTORATION.GPJ SOMAT.GDT 12/19/18

01/03/19

Appendix B



NOTES:

1. TOPOGRAPHIC DATA PROVIDED BY AND USED WITH PERMISSION FROM NOWAK AND FRAUS, P.L.L.C.
2. CONTOURS MAPS PROVIDED BY AND USED WITH PERMISSION FROM THE CITY OF SOUTHFIELD.
3. PROPERTY DESCRIPTION OF MDOT BASIN WERE TAKEN FROM THE BEST AVAILABLE RECORDS.
4. BENCH MARKS SHOWN WERE FROM NOWAK AND FRAUS TOPOGRAPHIC MAP AND WILL BE RE-ESTABLISHED BY HRC DURING CONSTRUCTION.
5. SEE SOIL BORING REPORT FOR DETAILS ON SOIL TYPES.

OCDC
OAKLAND COUNTY DRAIN COMMISSIONER
John P. McCulloch

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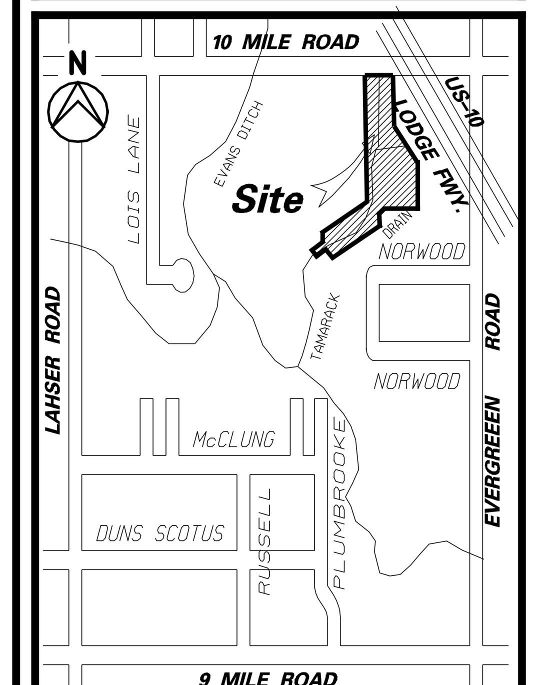
WEB SITE: http://www.hrc-engr.com

DATE	ADDITIONS AND/OR REVISIONS
07-26-2007	ISSUED FOR OWNER'S REVIEW
01-29-2007	ISSUED FOR OWNER'S REVIEW
12-20-2006	ISSUED FOR OWNER'S REVIEW

DESIGNED	J.F.B./D.E.B.
DRAWN	A.D.A./R.C.S.
CHECKED	G.J.T.
APPROVED	G.E.H.



OAKLAND COUNTY
DRAIN COMMISSION
TAMARACK DRAIN
BASIN RETROFIT

EXISTING
CONDITIONS

HRC JOB NO. 20050156	SCALE 1" = 60'
DATE DECEMBER 11, 2006	SHEET NO. 4 OF 18

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26000 Evergreen Road
P.O. Box 2055
Southfield MI 48037-2055

Date: 9-2-04

File: 20000588

Attention of: Karen Mondora

Project: MDOT Detention Basin

We are forwarding by Mail, the following: One (1) copy of Schleede-Hampton Soil Boring Repor.

Issued:

HUBBELL, ROTH & CLARK, INC.

BY: Nicole Fortino

/ / Recipient above please acknowledge receipt by signing the enclosed duplicate copy of this Form and return to us. Thank you.

Copy To:

File

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By:

Date:

Corporate Office: 555 Hulet Drive • P.O. Box 824 • Bloomfield Hills, MI 48303-0824 (Mailing – P.O. Box) – 48302-0360 (UPS Zip)
Telephone: (248) 454-6300 • FAX: (248) 338-2592 or (248) 454-6312 • www.hrc-engr.com

SCHLEEDE
HAMPTON
ASSOCIATES INC

CONSULTING ENGINEERS

• CIVIL • GEOTECHNICAL • CONSTRUCTION MATERIALS • CONSULTANTS •

SCHLEEDE HAMPTON ASSOCIATES INC
CONSULTING ENGINEERS

August 26, 2004

Hubbell, Roth & Clark, Inc.
555 Hulet Drive
Bloomfield Hills, Michigan 48303-0824

Attention: Mr. Stephen H. Pyc

Regarding: Soil Test Boring Report
Detention Basin Expansion Study
Northwestern Highway (M-10) at 10 Mile Road
Section 27, City of Southfield, Michigan
SHA Project Number 64322

Dear Mr. Pyc:

Schleede-Hampton Associates, Inc. has performed 10 soil test borings within the limits of the proposed detention basin expansion project in Southfield. The basin is located within the MDOT Easement, south of 10 Mile Road and east of Northwestern Highway (M-10) in the northeast quarter of Section 27. This brief report presents the boring results together with the results of basic geotechnical soils laboratory tests and analytical tests conducted on samples recovered during the drilling and sampling work. Our general comments regarding the potential for environmentally contaminated soils at the site based upon the borings and test results are included, as well.

Scope of Work

Ten soil borings were drilled within the limits of the basin area at locations selected and marked in the field by HRC. The borings were drilled through the surficial sediment and / or topsoil layers of the soil profile and into the deeper native soils. Boring depths ranged from 4 Ft. to 13 Ft. below the surface.

Borings were drilled using an all terrain type (ATV) drill rig and continuous flight augers. Soil samples collected during the drilling and sampling work were packed in glass jars and shipped to the SHA soils lab for visual classification and basic index testing. After classification testing, the samples were shipped to Environmental Quality Laboratories, Inc. (EQL) for analytical analyses. Composite samples were created from each boring, and each composite sample was tested for a list of parameters selected by HRC. Samples were extracted using TCLP methods (EPA Method 1311) and tested for Michigan metals (EPA various methods 6000 / 7000 series), PCBs (EPA Method 8081), and PNAs (EPA Method 8310).

2254 COLE STREET
BIRMINGHAM, MICHIGAN 48009
248-540-3044 • FAX: 248-540-3282

Observations and Test Results

The Oakland County soil map reports the surface soils at the detention basin site are fine grained sediments, typically loams or clay loams by textural classification. Geological survey records show the underlying soils are water-laid moraines that extend to shale or sandstone bedrock at approximately elevation 550 Ft.

The borings performed for this study generally confirm the upper soil profile at the site as described by published records. In general, the surface of the basin area is covered with a topsoil layer, nominally 3 inches to 12 inches thick. The topsoil layer was heavy, resembling peat, at boring 9. Underlying soils were either fine grained sediments, ranging from fine sand at boring 1 to variegated (discolored) clay soils at other locations. Apparent fill soils were noted below the topsoil extending to a depth of 3 Ft. at boring 2. The sediment / fill materials extended to depths of 1 Ft. to 3 Ft. below the surface at the boring locations. Brown or brown mottled (mixed) grey silty clay soils, typically of the moraine deposits in the area, were noted below these upper sediment or fill soils at all of the boring locations. These deeper soils were judge to be undisturbed and in their natural state.

Significant groundwater seepage was noted within the surficial soil deposits at borings 1 and 2. These observations appear to represent a perched condition typical of the poorly drained clay type soils in the area. The transition from partially saturated to fully saturated soil is expected to occur at a depth near the change in soil color from brown to grey clay soils. This color change was noted at a depth of 7 Ft. below existing site grade at borings 7 and 8.

In general, a composite sample was obtained from each boring that represented the upper topsoil, sediment, and / or fill type materials. Of the 10 composite samples tested, all showed trace concentration or metals compounds above method detection limits, and 5 showed trace levels of the PNA compounds above method detection limits. None of the samples produced any indication of PCB compounds above the method detection limits. Results of analytical testing program as reported by EQL are contained in the Appendix.

Closure

Schleede-Hampton Associates, Inc. appreciates the opportunity to provide these services to Hubbell, Roth & Clark, Inc. and the City of Southfield. If you have any questions or comments regarding this submittal, please contact us at your convenience.

Very truly yours,
Schleede-Hampton Associates, Inc.

James Berry, P.E.
Project Manager

APPENDIX

Contains Soil Test Boring Logs (Records of Subsurface Exploration), Analytical Laboratory Test Results, and General Notes

SCHLEEDE HAMPTON ASSOCIATES INC
CONSULTING ENGINEERS

RECORD OF SUBSURFACE EXPLORATION

BORING 1 PAGE 1 OF 1

PROJECT NAME: Detention Basin Expansion Study
SHA PROJECT NO. 64322
SITE LOCATION Northwestern Highway (M-10)
at 10 Mile Road
NE Quarter Section 27
City of Southfield, Michigan

DATE STARTED August 14, 2004
DATE COMPLETED August 14, 2004
DRILLER MD BORING METHOD CFA
GW ENCOUNTERED WHILE DRILLING 1-1/2 Ft.
GROUNDWATER, AT COMPLETION 2 Ft.
GROUNDWATER, AFTER - DAYS -
HOLE CAVED, 2 Ft. AT After Completion

ELEV.	DESCRIPTION	DEPTH	SAMPLE	N	Qu	Qp	Wc	REMARKS
-	Surface							
	3 in. ± Moist Brown Sandy Topsoil							
	9 in. ± Moist to Wet Brown Silty Fine SAND		Au-1	-	-	-	30.8	
	Moist Variegated Dark Brown Sandy CLAY							
	Moist Stiff Brown Mottled Grey Silty CLAY, Little Sand, Trace Gravel	2.5	Au-2	-	-	-	21.3	
	End of Boring @ 4 Ft.	5						

SYMBOLS

N: STANDARD PENETRATION, BLOWS/FT.
Qu: UNCONFINED COMPRESSISVE STRENGTH, TONS/SQ. FT.
Wc: WATER CONTENT, %
LL: LIQUID LIMIT, %
PI: PLASTICITY INDEX
Dd: NATURAL DRY DENSITY, LBS./CU. FT.
Qp: HAND PENETROMETER, TONS/SQ. FT.

SAMPLE DESIGNATION
SS- DRIVEN SPLIT SPOON 1 3/8" I.D., 2" O.D.
OS- DRIVEN OVER SIZED SPLIT SPOON 3" I.D.
ST- PRESSED SHELBY TUBE
AU- AUGER SAMPLE
RC- ROCK CORE - NXM

BORING METHOD
HSA- HOLLOW STEM AUGERS
CFA- CONTINUOUS FLIGHT AUGERS
C- CASING
MD- MUD DRILLING

NOTE: The stratification lines represent the approximate boundary between soil types and the transition may be gradual.

SCHLEEDE HAMPTON ASSOCIATES INC
CONSULTING ENGINEERS

RECORD OF SUBSURFACE EXPLORATION

BORING 2 PAGE 1 OF 1

PROJECT NAME: Detention Basin Expansion Study

SHA PROJECT NO. 64322

SITE LOCATION Northwestern Highway (M-10)
at 10 Mile Road
NE Quarter Section 27
City of Southfield, Michigan

DATE STARTED August 14, 2004
DATE COMPLETED August 14, 2004
DRILLER MD BORING METHOD CFA
GW ENCOUNTERED WHILE DRILLING 1-1/2 Ft.
GROUNDWATER, AT COMPLETION None
GROUNDWATER, AFTER - DAYS -
HOLE CAVED, N/A AT -

ELEV.	DESCRIPTION	DEPTH	SAMPLE	N	Qu	Qp	Wc	REMARKS
-	Surface							
	6 in. ± Moist Brown Sandy Topsoil							
	Moist Brown Sandy CLAY Little Gravel, Trace Construction Debris, Occasional Wet Sand Seams (Fill)		Au-1	-	-	-	40.4	
		2.5	Au-2	-	-	-	10.8	
	Moist Stiff Brown Silty CLAY, Little Sand, Trace Gravel							
	End of Boring @ 5 Ft.	5						

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SAMPLE DESIGNATION
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OS- DRIVEN OVER SIZED SPLIT SPOON 3" I.D.
ST- PRESSED SHELBY TUBE
AU- AUGER SAMPLE
RC- ROCK CORE - NXM

BORING METHOD
HSA- HOLLOW STEM AUGERS
CFA- CONTINUOUS FLIGHT AUGERS
C- CASING
MD- MUD DRILLING

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SCHLEEDE HAMPTON ASSOCIATES INC
CONSULTING ENGINEERS

RECORD OF SUBSURFACE EXPLORATION

BORING 3 PAGE 1 OF 1

PROJECT NAME: Detention Basin Expansion Study
SHA PROJECT NO. 64322
SITE LOCATION Northwestern Highway (M-10)
at 10 Mile Road
NE Quarter Section 27
City of Southfield, Michigan

DATE STARTED August 14, 2004
DATE COMPLETED August 14, 2004
DRILLER MD BORING METHOD CFA
GW ENCOUNTERED WHILE DRILLING None
GROUNDWATER, AT COMPLETION None
GROUNDWATER, AFTER - DAYS -
HOLE CAVED, N/A AT -

ELEV.	DESCRIPTION	DEPTH	SAMPLE	N	Qu	Qp	Wc	REMARKS
-	Surface							
	8 in. ± Moist Brown Clayey Topsoil		Au-1	-	-	-	19.9	
	Moist Stiff Brown Silty CLAY, Little Sand, Trace Gravel	2.5	Au-2	-	-	-	19.1	
	End of Boring @ 5 Ft.	5						

SYMBOLS

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BORING METHOD

HSA- HOLLOW STEM AUGERS
CFA- CONTINUOUS FLIGHT AUGERS
C- CASING
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SCHLEEDE HAMPTON ASSOCIATES INC
CONSULTING ENGINEERS

RECORD OF SUBSURFACE EXPLORATION

BORING 4 PAGE 1 OF 1

PROJECT NAME: Detention Basin Expansion Study

SHA PROJECT NO. 64322

SITE LOCATION: Northwestern Highway (M-10)
at 10 Mile Road
NE Quarter Section 27
City of Southfield, Michigan

DATE STARTED: August 14, 2004
DATE COMPLETED: August 14, 2004
DRILLER: MD BORING METHOD: CFA
GW ENCOUNTERED WHILE DRILLING: None
GROUNDWATER, AT COMPLETION: None
GROUNDWATER, AFTER - DAYS -
HOLE CAVED, N/A AT -

ELEV.	DESCRIPTION	DEPTH	SAMPLE	N	Qu	Qp	Wc	REMARKS
-	Surface							
	4 in. ± Moist Brown Clayey Topsoil		Au-1	-	-	-	18.2	
	Moist Stiff Brown Mottled Grey Silty CLAY, Little Sand Trace Gravel	2.5						
	End of Boring @ 5 Ft.	5						

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AU- AUGER SAMPLE
RC- ROCK CORE - NXM

BORING METHOD
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CFA- CONTINUOUS FLIGHT AUGERS
C- CASING
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SCHLEEDE HAMPTON ASSOCIATES INC
CONSULTING ENGINEERS

RECORD OF SUBSURFACE EXPLORATION

BORING 5 PAGE 1 OF 1

PROJECT NAME: Detention Basin Expansion Study

SHA PROJECT NO. 64322

SITE LOCATION: Northwestern Highway (M-10)
at 10 Mile Road
NE Quarter Section 27
City of Southfield, Michigan

DATE STARTED: August 14, 2004
DATE COMPLETED: August 14, 2004
DRILLER: MD BORING METHOD: CFA
GW ENCOUNTERED WHILE DRILLING: None
GROUNDWATER, AT COMPLETION: None
GROUNDWATER, AFTER - DAYS -
HOLE CAVED, N/A AT -

ELEV.	DESCRIPTION	DEPTH	SAMPLE	N	Qu	Qp	Wc	REMARKS
-	Surface							
	1 in. ± Moist Brown Clayey Topsoil							
	Moist Firm Variegated Brown Silty CLAY, Little to Some Sand, Trace Gravel		Au-1	-	-	-	18.2	
	Moist Stiff Brown Silty CLAY, Little Sand, Tracel Gravel	2.5						
	End of Boring @ 5 Ft.	5						

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RECORD OF SUBSURFACE EXPLORATION

BORING 6 PAGE 1 OF 1

PROJECT NAME: Detention Basin Expansion Study

SHA PROJECT NO. 64322
SITE LOCATION Northwestern Highway (M-10)
at 10 Mile Road
NE Quarter Section 27
City of Southfield, Michigan

DATE STARTED August 14, 2004
DATE COMPLETED August 14, 2004
DRILLER MD BORING METHOD CFA
GW ENCOUNTERED WHILE DRILLING None
GROUNDWATER, AT COMPLETION None
GROUNDWATER, AFTER - DAYS -
HOLE CAVED, N/A AT -

ELEV.	DESCRIPTION	DEPTH	SAMPLE	N	Qu	Qp	Wc	REMARKS
-	Surface							
	4 in. ± Moist Brown Clayey Topsoil							
	Moist Stiff Brown Mottled Grey Silty CLAY, Little Sand, Trace Gravel		Au-1	-	-	-	34.4	
		2.5	Au-2	-	-	-	25.4	
	End of Boring @ 5 Ft.	5						

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RECORD OF SUBSURFACE EXPLORATION

BORING 7 PAGE 1 OF 1

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City of Southfield, Michigan

DATE STARTED August 14, 2004
DATE COMPLETED August 14, 2004
DRILLER MD BORING METHOD CFA
GW ENCOUNTERED WHILE DRILLING None
GROUNDWATER, AT COMPLETION None
GROUNDWATER, AFTER - DAYS -
HOLE CAVED, N/A AT -

ELEV.	DESCRIPTION	DEPTH	SAMPLE	N	Qu	Qp	Wc	REMARKS
-	Surface							
	4 in. ± Moist Black Clayey Topsoil							
	Moist Stiff Brown Mottled Grey Silty CLAY, Little Sand, Trace Gravel		Au-1	-	-	-	22.7	
	Moist Very Stiff Brown Silty CLAY, Little Sand, Trace Gravel	5						
	Moist Very Stiff Grey Silty CLAY, Trace Sand, Trace Gravel							
	End of Boring @ 10 Ft.	10						

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RECORD OF SUBSURFACE EXPLORATION

BORING 8 PAGE 1 OF 1

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City of Southfield, Michigan

DATE STARTED August 14, 2004
DATE COMPLETED August 14, 2004
DRILLER MD BORING METHOD CFA
GW ENCOUNTERED WHILE DRILLING None
GROUNDWATER, AT COMPLETION None
GROUNDWATER, AFTER - DAYS -
HOLE CAVED, N/A AT -

ELEV.	DESCRIPTION	DEPTH	SAMPLE	N	Qu	Qp	Wc	REMARKS
-	Surface							
	10 in. ± Moist Black Clayey Topsoil		Au-1	15	-	-	36.8	
	Moist Stiff to Very Stiff Brown Silty CLAY, Little Sand, Trace Gravel,	5						
	Moist Stiff Grey Silty CLAY, Trace to Little Sand, Trace Gravel	10	Au-2	-	-	-	18.3	
	End of Boring @ 13 Ft.							

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BORING METHOD
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CONSULTING ENGINEERS

RECORD OF SUBSURFACE EXPLORATION

BORING 9 PAGE 1 OF 1

PROJECT NAME: Detention Basin Expansion Study

SHA PROJECT NO. 64322
SITE LOCATION Northwestern Highway (M-10)
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NE Quarter Section 27
City of Southfield, Michigan

DATE STARTED August 14, 2004
DATE COMPLETED August 14, 2004
DRILLER MD BORING METHOD CFA
GW ENCOUNTERED WHILE DRILLING None
GROUNDWATER, AT COMPLETION None
GROUNDWATER, AFTER - DAYS -
HOLE CAVED, N/A AT -

ELEV.	DESCRIPTION	DEPTH	SAMPLE	N	Qu	Qp	Wc	REMARKS
-	Surface							
	9 in. ± Moist Black Clayey Topsoil Trace Peat		Au-1	-	-	-	43.5	
	Moist Stiff Brown Silty CLAY, Little Sand, Trace Gravel	2.5						
	End of Boring @ 5 Ft.	5						

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CONSULTING ENGINEERS

RECORD OF SUBSURFACE EXPLORATION

BORING 10 PAGE 1 OF 1

PROJECT NAME:	Detention Basin Expansion Study	DATE STARTED	August 14, 2004
SHA PROJECT NO.	64322	DATE COMPLETED	August 14, 2004
SITE LOCATION	Northwestern Highway (M-10)	DRILLER MD	BORING METHOD CFA
	at 10 Mile Road	GW ENCOUNTERED WHILE DRILLING	None
	NE Quarter Section 27	GROUNDWATER, AT COMPLETION	None
	City of Southfield, Michigan	GROUNDWATER, AFTER - DAYS	-
		HOLE CAVED, N/A	AT -

ELEV.	DESCRIPTION	DEPTH	SAMPLE	N	Qu	Qp	Wc	REMARKS
-	Surface							
	4 in. ± Moist Black Clayey Topsoil, Little Peat							
	Moist Firm Variegated Brown Silty CLAY, Little Sand, Trace Gravel		Au-1	-	-	-	110.4	
	Moist Stiff Brown Mottled Grey Silty CLAY, Little Sand, Trace Gravel	2.5	Au-2	-	-	-	23.1	
	End of Boring @ 5 Ft.	5						

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BORING METHOD

- HSA- HOLLOW STEM AUGERS
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44075 Phoenix Drive
Sterling Heights, Michigan 48314-1420
586-731-1818
Outside Michigan Dial 1-800-368-5227
Fax Line 586-731-2590
www.EQualityLabs.com

CLIENT NAME: SCHLEEDE HAMPTON
33101 SCHOOLCRAFT RD.
LIVONIA, MI 48150

PROJECT NAME/NO.: SOUTHFIELD BASIN

DATE RECEIVED	**SAMPLE TEMP**	**DATE TCLP EXTRACTED**	**DATE ANALYZED**	**DATE REPORTED**
08/17/04	4°C	08/18/04 EXTRACTION FLUID 1	08/20/04	08/25/04

ANALYZED BY: JD **METALS REFERENCED METHOD:** 6000/7000/1311 ALL SOIL RESULTS REPORTED IN ppMillion DRY WEIGHT CORRECTED (SOILS ONLY)

LAB NO. **COMPOUND NAME**	**RDL TCLP ppM**	**3359 SOIL B-1 0-4'**	**3360 SOIL B-2 0-3'**	**3361 SOIL B-3 0-3.5'**	**3362 SOIL B-4 0-1.5'**	**3363 SOIL B-5 0-1.5'**	**3364 SOIL B-6 0-3.5'**
ARSENIC 6010	0.010	ND	ND	ND	ND	ND	ND
BARIUM 6010	0.100	0.511	0.534	0.665	0.442	0.931	0.803
CADMIUM 6010	0.001	ND	0.001	0.001	ND	ND	ND
CHROME, TOTAL 6010	0.005	ND	ND	ND	ND	ND	ND
COPPER 6010	0.004	ND	ND	ND	ND	ND	ND
LEAD 7421	0.003	0.009	ND	ND	ND	ND	ND
SILVER 6010	0.0002	ND	ND	ND	ND	ND	ND
ZINC 6010	0.050	0.091	0.256	0.190	0.092	0.421	0.175
SELENIUM 7740	0.005	ND	ND	ND	ND	ND	ND
MERCURY 7470	0.0002	ND	ND	ND	ND	ND	ND

NOTE: "ND" DENOTES THAT ANALYTE RESULT IS BELOW THE REPORTED REGULATORY DERIVED TARGET LIMIT OF DETECTION.

THOMAS S. MEGNA, PRESIDENT ____________ ALA GADJA, LAB SUPERVISOR ____________

REFERENCES: 40 CFR PART 136. CURRENT EDITION. las

44075 Phoenix Drive
Sterling Heights, Michigan 48314-1420
586-731-1818
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CLIENT NAME: SCHLEEDE HAMPTON
33101 SCHOOLCRAFT RD.
LIVONIA, MI 48150

PROJECT NAME/NO.: SOUTHFIELD BASIN

DATE RECEIVED	**SAMPLE TEMP**	**DATE TCLP EXTRACTED**	**DATE ANALYZED**	**DATE REPORTED**
08/17/04	4^0C	08/18/04 EXTRACTION FLUID 1	08/20/04	08/25/04

ANALYZED BY: JD **METALS REFERENCED METHOD:** 6000/7000/1311 ALL SOIL RESULTS REPORTED IN ppMillion
DRY WEIGHT CORRECTED (SOILS ONLY)

LAB NO. **COMPOUND NAME**	**RDL TCLP ppM**	**3365 SOIL B-7 0-1.5'**	**3366 SOIL B-8 0-13'**	**3367 SOIL B-9 0-1'**	**3368 SOIL B-10 0-3.5'**
ARSENIC 6010	0.010	ND	ND	ND	ND
BARIUM 6010	0.100	1.1	0.783	0.553	0.698
CADMIUM 6010	0.001	ND	ND	ND	ND
CHROME, TOTAL 6010	0.005	ND	ND	ND	ND
COPPER 6010	0.004	ND	ND	ND	ND
LEAD 7421	0.003	ND	ND	ND	ND
SILVER 6010	0.0002	ND	ND	ND	ND
ZINC 6010	0.050	0.381	0.295	0.265	0.420
SELENIUM 7740	0.005	ND	ND	ND	ND
MERCURY 7470	0.0002	ND	ND	ND	ND

NOTE: "ND" DENOTES THAT ANALYTE RESULT IS BELOW THE REPORTED REGULATORY DERIVED TARGET LIMIT OF DETECTION.

THOMAS S. MEGNA, PRESIDENT ____________ ALA GADJA, LAB SUPERVISOR ____________

REFERENCES: 40 CFR PART 136. CURRENT EDITION. las

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33101 SCHOOLCRAFT RD.
LIVONIA, MI 48150

PROJECT NAME/NO.: SOUTHFIELD BASIN

DATE REPORTED	**DATE RECEIVED**	**SAMPLE TEMP**	**DATE EXTRACTED**	**DATE ANALYZED**
08/25/04	08/17/04	4^0C	08/19/04	08/19/04

ANALYZED BY: GN **REFERENCED METHOD:** 8310 SCAN DRY WEIGHT CORRECTED (SOILS ONLY)
RESULTS REPORTED IN ppBillion

LAB NO. / **COMPOUND NAME**	**RDL SOIL ppB**	**RDL WATER ppB**	**3359 SOIL B-1 0-4'**	**3360 SOIL B-2 0-3'**	**3361 SOIL B-3 0-3.5'**	**3362 SOIL B-4 0-1.5'**	**3363 SOIL B-5 0-1.5'**	**3364 SOIL B-6 0-3.5'**	**3365 SOIL B-7 0-1.5'**	**3366 SOIL B-8 0-13'**
Naphthalene	330	5.0	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthylene	330	5.0	ND	880	ND	ND	ND	ND	ND	ND
Acenaphthene	330	5.0	ND	6400	900	390	ND	ND	ND	820
Fluorene	330	5.0	ND	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	330	2.0	ND	1900	330	ND	ND	ND	ND	ND
Anthracene	330	5.0	ND	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	330	1.0	ND	5400	1200	380	ND	ND	ND	770
Pyrene	330	5.0	ND	3400	850	ND	ND	ND	ND	480
Benzo(a)anthracene	330	1.0	ND	1600	ND	ND	ND	ND	ND	ND
Chrysene	330	1.0	ND	2500	540	ND	ND	ND	ND	430
Benzo(b)fluoranthene	330	1.0	ND	2500	650	ND	ND	ND	ND	460
Benzo(k)fluoranthene	330	0.8	ND	1500	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	330	1.0	ND	3100	620	ND	ND	ND	ND	540
Dibenzo(ah)anthracene	330	0.2	ND	360	ND	ND	ND	ND	ND	ND
Benzo(ghi)perylene	330	0.4	ND	1500	350	ND	ND	ND	ND	ND
Indeno(123-cd)pyrene	330	0.4	ND	2000	480	ND	ND	ND	ND	390
2-Methylnaphthalene	330	5.0	ND	2200	340	ND	ND	ND	ND	340

NOTE: "ND" DENOTES THAT ANALYTE RESULT IS BELOW THE REPORTED REGULATORY DERIVED TARGET LIMIT OF DETECTION.

THOMAS S. MEGNA, PRESIDENT ____________ ALA GAJDA, LAB SUPERVISOR ____________

REFERENCES: 40 CFR PART 136. CURRENT EDITION. las

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CLIENT NAME: SCHLEEDE HAMPTON
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LIVONIA, MI 48150

PROJECT NAME/NO.: SOUTHFIELD BASIN

DATE REPORTED	**DATE RECEIVED**	**SAMPLE TEMP**	**DATE EXTRACTED**	**DATE ANALYZED**
08/25/04	08/17/04	4^0C	08/19/04	08/19/04

ANALYZED BY: GN **REFERENCED METHOD:** 8310 SCAN DRY WEIGHT CORRECTED (SOILS ONLY)
RESULTS REPORTED IN ppBillion

LAB NO.			**3367**	**3368**
COMPOUND NAME	**RDL SOIL ppB**	**RDL WATER ppB**	**SOIL B-9 0-1'**	**SOIL B-10 0-3.5'**
Naphthalene	330	5.0	ND	ND
Acenaphthylene	330	5.0	ND	ND
Acenaphthene	330	5.0	570	1500
Fluorene	330	5.0	ND	ND
Phenanthrene	330	2.0	ND	400
Anthracene	330	5.0	ND	ND
Fluoranthene	330	1.0	530	1700
Pyrene	330	5.0	570	1300
Benzo(a)anthracene	330	1.0	ND	360
Chrysene	330	1.0	ND	780
Benzo(b)fluoranthene	330	1.0	ND	1000
Benzo(k)fluoranthene	330	0.8	ND	470
Benzo(a)pyrene	330	1.0	ND	1000
Dibenzo(ah)anthracene	330	0.2	ND	ND
Benzo(ghi)perylene	330	0.4	ND	510
Indeno(123-cd)pyrene	330	0.4	ND	690
2-Methylnaphthalene	330	5.0	ND	530

NOTE: "ND" DENOTES THAT ANALYTE RESULT IS BELOW THE REPORTED REGULATORY DERIVED TARGET LIMIT OF DETECTION.

THOMAS S. MEGNA, PRESIDENT ______ ALA GAJDA, LAB SUPERVISOR ______

REFERENCES: 40 CFR PART 136. CURRENT EDITION. las

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CLIENT NAME: SCHLEEDE HAMPTON
33101 SCHOOLCRAFT RD.
LIVONIA, MI 48150

PROJECT NAME/NO.: SOUTHFIELD BASIN

DATE REPORTED 08/25/04

DATE RECEIVED 08/17/04

SAMPLE TEMP 4°C

DATE EXTRACTED 08/23/04

DATE ANALYZED 08/24/04

ANALYZED BY: GN

REFERENCED METHOD: 8082 PCB's

DRY WEIGHT CORRECTED (SOILS ONLY)
RESULTS REPORTED IN ppBillion

LAB NO. / COMPOUND NAME	RDL SOIL ppB	RDL WATER ppB	3359 SOIL B-1 0-4'	3360 SOIL B-2 0-3'	3361 SOIL B-3 0-3.5'	3362 SOIL B-4 0-1.5'	3363 SOIL B-5 0-1.5'	3364 SOIL B-6 0-3.5'	3365 SOIL B-7 0-1.5'	3366 SOIL B-8 0-13'
Aroclor 1016	330	0.2	ND	ND	ND	ND	ND	ND	ND	ND
Aroclor 1221	330	0.2	ND	ND	ND	ND	ND	ND	ND	ND
Aroclor 1232	330	0.4	ND	ND	ND	ND	ND	ND	ND	ND
Aroclor 1242	330	0.2	ND	ND	ND	ND	ND	ND	ND	ND
Aroclor 1248	330	0.2	ND	ND	ND	ND	ND	ND	ND	ND
Aroclor 1254	330	0.2	ND	ND	ND	ND	ND	ND	ND	ND
Aroclor 1260	330	0.2	ND	ND	ND	ND	ND	ND	ND	ND

NOTE: "ND" DENOTES THAT ANALYTE RESULT IS BELOW THE REPORTED REGULATORY DERIVED TARGET LIMIT OF DETECTION.

THOMAS S. MEGNA, PRESIDENT ______________ ALA GAJDA, LAB SUPERVISOR ______________

REFERENCES: 40 CFR PART 136. CURRENT EDITION. las

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CLIENT NAME: SCHLEEDE HAMPTON
33101 SCHOOLCRAFT RD.
LIVONIA, MI 48150

PROJECT NAME/NO.: SOUTHFIELD BASIN

DATE REPORTED	DATE RECEIVED	SAMPLE TEMP	DATE EXTRACTED	DATE ANALYZED
08/25/04	08/17/04	4^0C	08/23/04	08/24/04

ANALYZED BY: GN **REFERENCED METHOD:** 8082 PCB's DRY WEIGHT CORRECTED (SOILS ONLY)
RESULTS REPORTED IN ppBillion

LAB NO.			3367	3368
COMPOUND NAME	RDL SOIL ppB	RDL WATER ppB	SOIL B-9 0-1'	SOIL B-10 0-3.5'
Aroclor 1016	330	0.2	ND	ND
Aroclor 1221	330	0.2	ND	ND
Aroclor 1232	330	0.4	ND	ND
Aroclor 1242	330	0.2	ND	ND
Aroclor 1248	330	0.2	ND	ND
Aroclor 1254	330	0.2	ND	ND
Aroclor 1260	330	0.2	ND	ND

NOTE: "ND" DENOTES THAT ANALYTE RESULT IS BELOW THE REPORTED REGULATORY DERIVED TARGET LIMIT OF DETECTION.

THOMAS S. MEGNA, PRESIDENT ________ ALA GAJDA, LAB SUPERVISOR ________

REFERENCES: 40 CFR PART 136. CURRENT EDITION. las

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№ 01955

Chain of Custody
Analysis Request

1 Consultant: SCHLEEDE-HAMPTON ASSOC.
Sampler: NG Phone: 248.540.3044
Project: SOUTHFIELD BASIN EXPANSION PROJ NO. 64322
248 540 3044 VOICE Fax: 248 540 3282

2 **4** Matrix **5** Analysis Requested

	Sample Identification	Collection Date	Collection Time	Grab	Composite	Soil	Water	Other	Total # of Containers	TCLP EXTRACTION	HIGH METALS	PCBS - 8081	PNAS - 8310				Remarks (6)
3359	BORING 1 0FT TO 4FT								3	X	X	X	X				
3360	BORING 2 0FT TO 3FT								4	X	X	X	X				
3361	BORING 3 0FT TO 3 1/2FT								3	X	X	X	X				
3362	BORING 4 0FT TO 1 1/2FT								1	X	X	X	X				
3363	BORING 5 0FT TO 1 1/2FT								1	X	X	X	X				
3364	BORING 6 0FT TO 3 1/2FT								2	X	X	X	X				
3365	BORING 7 0FT TO 1 1/2FT.								1	X	X	X	X				
3366	BORING 8 0FT TO 1 3FT.								3	X	X	X	X				
3367	BORING 9 0FT TO 1FT								2	X	X	X	X				
3368	BORING 10 0FT TO 3 1/2FT								3	X	X	X	X				

COMBINE ALL CONTAINERS FOR EACH SAMPLE & TEST COMPOSITE

7
Turnaround time requested, (please circle): Emergency (Routine)
(Call to confirm Emergency turnaround time).
Rush analysis results via:
Fax#: ______ -or- Phone #: ______

8 • This section MUST be signed each time the sample changes hands! •

Relinquished by	Date	Time	Received by	Date	Time
[signature]	8/17/04	1:40	[signature]	8/17/04	1:40
[signature]	8/17/04	2:20			

9
CONDITION OF SAMPLES UPON RECEIPT AT EQL.
Sample Temp: ______ Preserve? ______ Damaged? ______
Comments: ______

In case we have questions when the samples arrive, call:
Name: ______ Phone: ______
Send report to: ______

GENERAL NOTES

PARTICLE SIZE DESCRIPTION & TERMINOLOGY

Coarse Grained or Granular Soils have more than 50% of their dry weight retained on a #200 sieve; they are described as: boulders, cobbles, gravel or sand. Fine Grained soils have less than 50% of their dry weight retained on a #200 sieve; they are described as: clays or clayey silts if they are cohesive and silts if they are non-cohesive. In addition to gradation, granular soils are defined on the basis of their relative in-place density and the fine grained soils on the basis of their strength or consistency and their plasticity.

Major Component of Sample	Size Range
Boulders	Over 8 in. (200 mm)
Cobbles	8 inches to 3 inches (200 mm to 75mm)
Gravel	3 inches to #4 sieve (75mm to 4.75mm)
Sand	#4 to #200 sieve (4.75mm to 75µm)
Silt	Passing #200 sieve (75µm to 2µm)
Clay	Smaller than 2µm

Descriptive Term of Components Also Present in Sample	Approximate Quantity (Percent)
Trace	1 - 9
Little	10 - 19
Some	20 - 34
And	35 - 50

RELATIVE DENSITY AND CONSISTENCY CLASSIFICATION

GRANULAR SOILS

DENSITY CLASSIFICATION	APPROXIMATE RANGE OF N *
Very Loose	0 - 3
Slightly Dense	4 - 9
Medium Dense	10 - 29
Dense	30 - 49
Very Dense	50 - 80
Extremely Dense	80 +

COHESIVE SOILS

CONSISTENCY	UNCONFINED COMPRESSIVE STRENGTH, Qu - TSF	APPROXIMATE RANGE OF N *
Very Soft	0.25	0 - 2
Soft	0.25 - 0.49	3 - 4
Firm	0.50 - 0.99	5 - 8
Stiff	1.00 - 1.99	9 - 15
Very Stiff	2.00 - 3.99	16 - 30
Hard	4.00 - 8.00	31 - 50
Very Hard	8.00 +	Over 50

* STANDARD PENETRATION TEST (ASTM D1586) - A 2.0" outside-diameter, split barrel sampler is driven into undisturbed soil by means of a 140 pound weight falling freely through a vertical distance of 30 inches. The sampler is normally driven 3 successive 6 inch increments. The total number of blows required for the final 12 inches of penetration is the Standard Penetration Resistance (N).

Appendix C

APPENDIX A: STREAM FUNCTIONS PYRAMID

d. PERFORMANCE STANDARDS TABLE

Notes:

1. Since there are no Hydrology Performance Standards, there is not a Hydology Summary Table
2. Many of the performance standard values, especially the dimensionless ratios, should be considered as examples that can be modified based on regional differences in reference conditions.
3. Great care should be taken when selecting measurement methods and performance standards. Refer to Chapters 6-10 and the associated references before selecting measurement methods and performance standards.

HYDRAULIC

PARAMETER	MEASUREMENT METHOD	PERFORMANCE STANDARD			SOURCE
		FUNCTIONING	FUNCTIONING-AT-RISK	NOT FUNCTIONING	
Floodplain Connectivity	Bank Height Ratio (BHR)	1.0 to 1.2	1.3 to 1.5	> 1.5	Rosgen, 2001 (proceedings) and 1994 (book)
	Entrenchment Ratio (ER) for C and E Stream Types	> 2.2	2.0 to 2.2	< 2.0	
	Entrenchment Ratio (ER) for B and Bc Stream Types	> 1.4	1.2 to 1.4	< 1.2	
	Dimensionless rating curve	Project site Q/Q_{bkf} plots on the curve	Project site Q/Q_{bkf} plots above the curve	Project site Q/Qbkf of 2.0 plots above 1.6 for $d/_{dbkf}$	Dunne and Leopold 1978 (book)
Flow Dynamics	Bankfull Velocity for C and E stream types (ft/s)	3 to 6	6 to 7	> 7	Dunne and Leopold 1978 (book)
	Bankfull Velocity for Cc (ft/s)	< 3	3 to 4	> 5	
	Bankfull Velocity for B stream types (ft/s)	4 to 6	6 to 7	> 7	

APPENDIX A: STREAM FUNCTIONS PYRAMID (CONT.)

d. PERFORMANCE STANDARDS TABLE

GEOMORPHOLOGY					
PARAMETER	MEASUREMENT METHOD	PERFORMANCE STANDARD			SOURCE
		FUNCTIONING	FUNCTIONING-AT-RISK	NOT FUNCTIONING	
Large Woody Debris	Large Woody Debris Index (LWDI)	LWDI of project reach equals LWDI of reference reach.	LWDI of project reach does not equal LWDI of reference reach, but is trending in that direction.	LWDI of project reach does not equal LWDI of reference reach and is not trending in that direction.	Davis et al., 2001 (USFS Technical Report)
Channel Evolution	**Rosgen's Stream Type Succession Scenarios**				
	1. E→C→Gc→F→C→E	E, C	C→Gc and F→C	Gc, F	Rosgen 2010 (conference workshop)
	2. C→D→C	C	C→D and D→C	D	
	3. C→D→Gc→F→C	C	C→D and F→C	D, Gc, F	
	4. C→G→F→Bc	C, Bc	C→G and F→Bc	G, F	
	5. E→Gc→F→C→E	E, C	E→Gc and F→C	Gc, F	
	6. B→G→Fb→B	B	B→G and Fb→B	G, Fb	
	7. Eb→G→B	Eb, B	Eb→G and G→B	G	
	8. C→G→F→D→C	C	C→G and D→C	G, F, D	
	9. C→G→F→C	C	C→G and F→C	G, F	
	10. E→A→G→F→C→E	E	E→A and F→C	A,G, F	
	11. C→F→C→F→C	First and last C	C→F	F	
	12. C→G→F→C→C→C	First and last C	C→G and C→C	G,F, Fourth C	
	Simon Channel Evolution Model Stages				
	1. Sinuous, pre-modified	✓			Simon 1989 (journal)
	2. Channelized			✓	
	3. Degradation			✓	

APPENDIX A: STREAM FUNCTIONS PYRAMID (CONT.)

d. PERFORMANCE STANDARDS TABLE

GEOMORPHOLOGY					
PARAMETER	MEASUREMENT METHOD	PERFORMANCE STANDARD			SOURCE
		FUNCTIONING	FUNCTIONING-AT-RISK	NOT FUNCTIONING	
Channel Evolution	4. Degradation and widening			✓	Simon 1989 (journal)
	5. Aggradation and widening		✓ *	✓	
	6. Quasi-equilibrium	✓			
	* *Only late Stage 5 of the Simon model, where the stream has begun to construct a new floodplain at a lower elevation, is considered to be Functioning-at-Risk.*				
Bank Migration/ Lateral Stability	Meander Width Ratio for C and E stream types	≥ 3.5 (based on reference reach surveys)	3.0 to 3.5 as long as sinuosity is ≥ 1.2	< than 3.0	Rosgen, 2001 (proceedings) and 2006 (book)
	Lateral Erosion rate – Low BEHI Curve	Very low to Moderate NBS	Moderate to Very High NBS	Extreme NBS	
	Lateral Erosion rate – Moderate BEHI Curve	Very low to Low NBS	Low to High NBS	High to Extreme NBS	
	Lateral Erosion rate – High and Very High BEHI Curve	N/A	Low to Moderate NBS	Moderate to Extreme NBS	
	Lateral Erosion rate – Extreme BEHI Curve	N/A	Low NBS	Low to Extreme NBS	
	Lateral Erosion Rate (Bank Pins and Bank Profiles)	Erosion rate is similar to reference reach values, generally < 0.1 ft/yr	0.1 to 0.5 ft/yr	> 0.5 ft/yr	

APPENDIX A: STREAM FUNCTIONS PYRAMID (CONT.)

d. PERFORMANCE STANDARDS TABLE

GEOMORPHOLOGY					
PARAMETER	MEASUREMENT METHOD	PERFORMANCE STANDARD			SOURCE
		FUNCTIONING	FUNCTIONING-AT-RISK	NOT FUNCTIONING	
Bank Migration/ Lateral Stability	Lateral Erosion Rate for C4 streams (Cross Sections)	$\frac{w/Dproj}{w/Dref}$ = 1.0 to 1.2	$\frac{w/Dproj}{w/Dref}$ = 1.2 to 1.4	$\frac{w/Dproj}{w/Dref}$ = > 1.4	Simon and Langendoen 2006 (proceedings)
	Bank Stability and Toe Erosion Model	$Fs > 1.3$	$1.0 < Fs > 1.3$	$Fs < 1.0$	
Riparian Vegetation	Average Buffer Width (Ft) C and E Stream Types	> 150	30 to 150	< 30	Meyer et al., 2005 (journal)
	Buffer Width (Ft) from Meander Belt Width for C and E Stream Types	Meander belt width at least 3.5 times the bankfull width plus ≥ 15 feet from outside of meander bend	Meander belt width at least 3.5 times the bankfull width plus 10 to 15 feet from outside of meander bend	Meander belt width ≤ 3.5 times the bankfull width and/or ≤ 10 feet from outside of meander bend	Proposed as an option in this document
	Buffer Density (Stems/ac) Buffer Age Buffer Composition Buffer Growth Canopy Density	Parameter is similar to reference reach condition, with no additional maintenance required.	Parameter deviates from reference reach condition, limiting function, but the potential exists for full functionality over time or with moderate additional maintenance.	Significantly less functional than reference condition; little or no potential to improve without significant restoration effort.	
	Proper Functioning Condition (PFC)	Proper Functioning Condition	Functional At-Risk	Nonfunctional	Prichard et al., 1998 (USFS Technical Report)

APPENDIX A: STREAM FUNCTIONS PYRAMID (CONT.)

d. PERFORMANCE STANDARDS TABLE

GEOMORPHOLOGY					
PARAMETER	MEASUREMENT METHOD	PERFORMANCE STANDARD			SOURCE
		FUNCTIONING	FUNCTIONING-AT-RISK	NOT FUNCTIONING	
Riparian Vegetation	NRCS Rapid Visual Assessment Protocol	Natural vegetation extends at least one to two active channel widths on each side, or if less than one width, covers entire floodplain. (8-10)	Natural vegetation extends at least one-half to one-third active channel widths on each side, or filtering function moderately compromised. (3-5)	Natural vegetation less than one-third active channel widths on each side, or lack of regeneration, or filtering function severly compromised. (1)	NRCS Technical Report
	The EPA Rapid Bioassessment Protocol (RBP)	Width of riparian zone > 18 meters; humans have not impacted zone. (Optimal, 9-10)	Width of riparian zone 12-18 meters; human activities have minimally impacted zone. (Sub-Optimal, 6-8) Width of riparian zone 6-12 meters; human activities have impacted zone a great deal. (Marginal, 3-5)	Width of riparian zone < 6 meters; little or no riparian vegetation due to human activity. (Poor, 0-2)	Barbour et al., 1999 (EPA Technical Report)

APPENDIX A: STREAM FUNCTIONS PYRAMID (CONT.)

d. PERFORMANCE STANDARDS TABLE

GEOMORPHOLOGY					
PARAMETER	MEASUREMENT METHOD	PERFORMANCE STANDARD			SOURCE
		FUNCTIONING	FUNCTIONING-AT-RISK	NOT FUNCTIONING	
Riparian Vegetation	USFWS Stream Assessment Ranking (SAR)	All three zones of vegetation exist; runoff is primarly sheet flow; hillslopes < 10%; hillslopes > 200 ft from stream; ponding or wetland areas and litter or debris jams are well represented.	Only Zone 2 of vegetation is well represented; runoff is equally sheet and concentrated flow (moderate gully and rill erosion); hillslopes 20-40%; hillslopes 50-100 ft from stream; ponding or wetland areas and litter or debris jams are minimally represented.	No zones of vegetation well represented; runoff is primarily concentrated flow (extensive gully and rill erosion); hillslopes > 40%; hillslopes < 50 ft from stream; ponding or wetland areas and litter or debris jams are not well represented or completely absent.	Allen et al., 1999

APPENDIX A: STREAM FUNCTIONS PYRAMID (CONT.)

d. PERFORMANCE STANDARDS TABLE

GEOMORPHOLOGY					
PARAMETER	MEASUREMENT METHOD	PERFORMANCE STANDARD			SOURCE
		FUNCTIONING	FUNCTIONING-AT-RISK	NOT FUNCTIONING	
	Perennial Streams in Alluvial Valleys (C, E)				
	Percent Riffle	60 to 70	70 to 80	> 80	Professional Judgement
			40 to 60	< 40	
	Pool-to-Pool Spacing Ratio (Watersheds < 10 mi²)	4 to 5	3 to 4 and 5 to 7	< 3.0 and > 7	Leopold 1994, Gregory et al., 1994 journal), Whittake 1987 (book), Chin 1989 (journal), and Grant 1990 (journal)
Bed Form Diversity	Pool-to-Pool Spacing Ratio (Watersheds > 10 mi²)	5 to 7	3.5 to 5 and 7 to 8	< 3.5 and > 8	Leopold 1994, Gregory et al., 1994 journal), Whittake 1987 (book), Chin 1989 (journal), and Grant 1990 (journal)
	Depth Variability – Gravel Bed Streams (Pool Max Depth Ratio)	> 1.5	1.2 to 1.5	< 1.2	Rosgen 2006 (book)
	Depth Variability – Sand Bed Streams (Pool Max Depth Ratio)	> 1.2	1.1 to 1.2	< 1.1	

APPENDIX A: STREAM FUNCTIONS PYRAMID (CONT.)

d. PERFORMANCE STANDARDS TABLE

GEOMORPHOLOGY					
PARAMETER	MEASUREMENT METHOD	PERFORMANCE STANDARD			SOURCE
		FUNCTIONING	FUNCTIONING-AT-RISK	NOT FUNCTIONING	
Bed Material Characterization	Bed material composition	Project Reach is not statistically different than reference reach.	N/A	Project Reach is statistically different (finer) than reference reach.	Bevenger and King, 2005 (USFS Technical Report)
Bed Form Diversity	**Moderate Gradient Perennial Streams in Colluvial Valleys**				
	Pool-to-Pool Spacing Ratio (Slope between 3 and 5%)	2 to 4	4 to 6	>6	Leopold 1994, Gregory et al., 1994 journal), Whittake 1987 (book), Chin 1989 (journal), and Grant 1990 (journal)
	Depth Variability (Pool Max Depth Ratio)	> 1.5	1.2 to 1.5	< 1.2	Leopold 1994, Gregory et al., 1994 journal), Whittake 1987 (book), Chin 1989 (journal), and Grant 1990 (journal)

APPENDIX A: STREAM FUNCTIONS PYRAMID (CONT.)

d. PERFORMANCE STANDARDS TABLE

<table>
<tr><th colspan="6">PHYSICOCHEMICAL</th></tr>
<tr><th rowspan="2">PARAMETER</th><th rowspan="2">MEASUREMENT METHOD</th><th colspan="3">PERFORMANCE STANDARD</th><th rowspan="2">SOURCE</th></tr>
<tr><th>FUNCTIONING</th><th>FUNCTIONING-AT-RISK</th><th>NOT FUNCTIONING</th></tr>
<tr><td rowspan="5">Water Quality</td><td rowspan="3">DO
Temperature
Turbidity</td><td>Meets water quality standards for designated use</td><td>Meets water quality standards for designated use</td><td>Does not meet water quality standards</td><td rowspan="5">Performance standards have not been developed for these parameters and are therefore based on reference reach comparisons and state water quality databases.</td></tr>
<tr><td rowspan="2">Representative of reference reach and meets species requirements</td><td rowspan="2">Is not representative of reference reach and does not support species requirements</td><td>Is not representative of the reference reach</td></tr>
<tr><td>Does not support species requirements</td></tr>
<tr><td rowspan="2">pH
Conductivity
Turbidity</td><td rowspan="2">Representative of values measured in reference reach</td><td>Does not have representative reference reach values or</td><td rowspan="2">Statistically different than reference reach and does not support aquatic life</td></tr>
<tr><td>Does not support designated use or species requirements</td></tr>
</table>

APPENDIX A: STREAM FUNCTIONS PYRAMID (CONT.)

d. PERFORMANCE STANDARDS TABLE

PHYSICOCHEMICAL					
PARAMETER	MEASUREMENT METHOD	PERFORMANCE STANDARD			SOURCE
		FUNCTIONING	FUNCTIONING-AT-RISK	NOT FUNCTIONING	
Nutrients	Field test kits using reagents reactions	Meets water quality standards for designated use	Meets water quality standards for designated use, but is not representative of reference reach	Does not meet water quality standards	Performance standards have not been developed for these parameters and are therefore based on reference reach comparisons and state water quality databases.
	Laboratory analysis	Representative of reference reach	Does not cause eutrophication	Is not representative of the reference reach	
		Does not cause eutrophication		Causes eutrophication	
Organic Carbon	Laboratory analysis	Meet reference reach OC concentrations	Do not meet reference reach OC concentrations	Do not meet reference reach OC concentrations and are below a predetermined threshold determined for adequate organic processing	Performance standards have not been developed for these parameters and are therefore based on reference reach comparisons and state water quality databases.

APPENDIX A: STREAM FUNCTIONS PYRAMID (CONT.)

d. PERFORMANCE STANDARDS TABLE

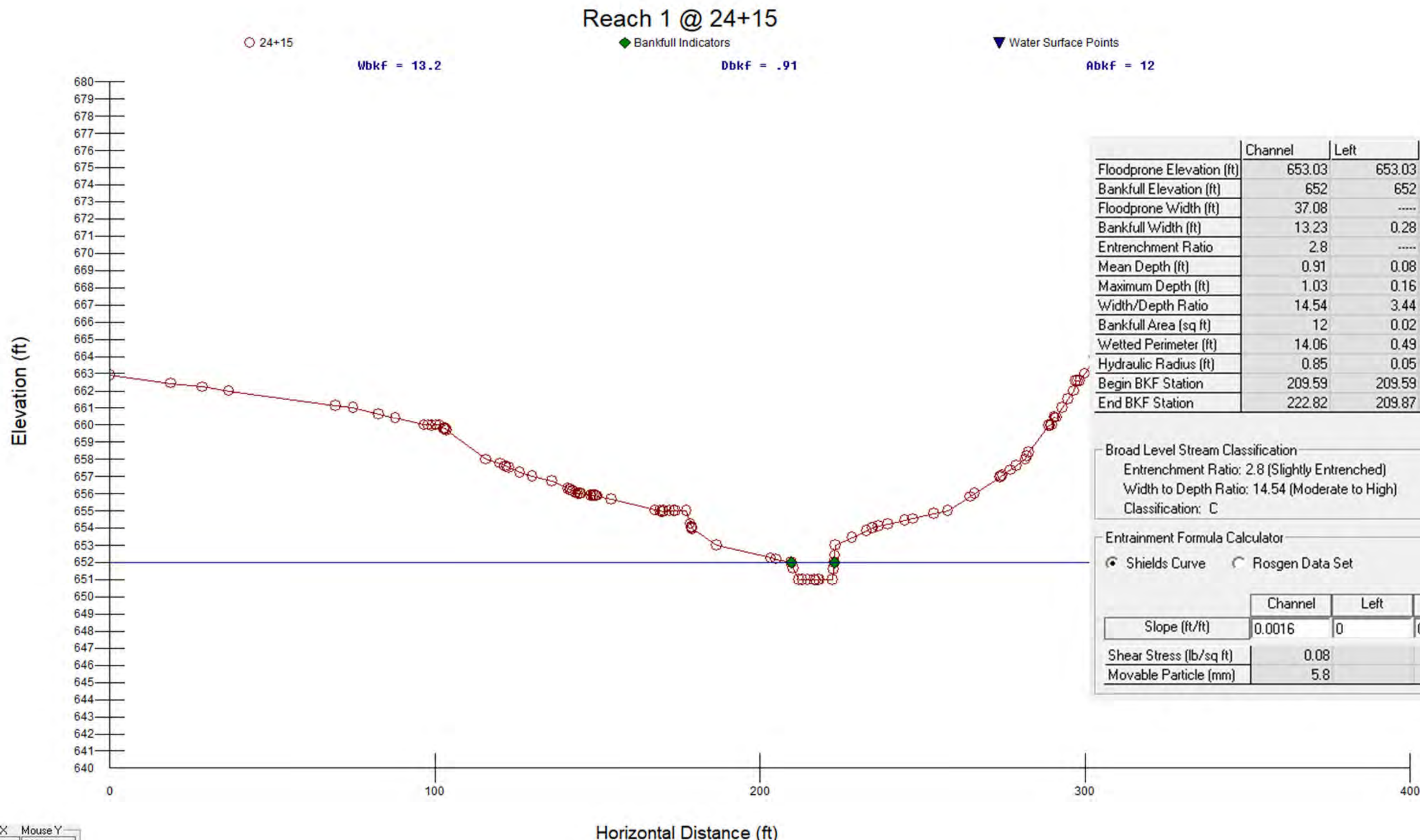
BIOLOGY					
PARAMETER	MEASUREMENT METHOD	PERFORMANCE STANDARD			SOURCE
		FUNCTIONING	FUNCTIONING-AT-RISK	NOT FUNCTIONING	
Microbial Communities	Periphyton Index of Biological Integrity (PIBI)	≥ 72	61-71	≤ 60	Hill et al., 2000 (Journal)
Macrophytes	**Biological Indices**				
	Mean Trophic Rank (MTR)	> 65	25-65	< 25	Holmes et al., 1999 (Technical Report)
	Reference Index (RI)	-50 to 100	-70 to -50	< -70	Meilenger, 2005 (Journal)
Macroinvertebrate Communities	**Biological Indices**				
	Family-Level Biotic Index (FBI) Ranges	0.00-4.25	4.26-5.75	5.76-10.00	Hilsenhoff, 1988 (Journal)
		Excellent to Very Good	Good to Fair	Fairly Poor to Very Poor	
	WVSCI Ranges	68-100	45-61	0-45	Gerritsen et al., 2000; WVDEP
		Very Good to Good	Gray Area to Fair	Poor to Very Poor	
	Virginia Stream Condition Index	61-100	40-60	0-40	Burton J. and J. Gerritsen, 2003
		Exceptional to Similar to Ref.	Impaired Tier 1	Impaired Tier1 & 2	
	SOS Multimetric Index	7-12	N/A	0-6	Engel and Voshell, 2002
		Acceptable		Unacceptable	

APPENDIX A: STREAM FUNCTIONS PYRAMID (CONT.)

d. PERFORMANCE STANDARDS TABLE

BIOLOGY					
PARAMETER	MEASUREMENT METHOD	PERFORMANCE STANDARD			SOURCE
		FUNCTIONING	FUNCTIONING-AT-RISK	NOT FUNCTIONING	
Fish Communities	**Biological Indices**				
	Mid-Atlantic Highlands IBI	IBI > 72	IBI = 56 to 71	IBI < 56	McCormick et al., 2001
		Good to Excellent	Fair	Poor	
	Mid-Western Fish Community IBI	48-60	40-44	0-34	Karr et al., 1986
		Good to Excellent	Fair	Poor to No Fish	

Appendix D



	Channel	Left	Right
Floodprone Elevation (ft)	653.03	653.03	653.03
Bankfull Elevation (ft)	652	652	652
Floodprone Width (ft)	37.08	-----	-----
Bankfull Width (ft)	13.23	0.28	12.95
Entrenchment Ratio	2.8	-----	-----
Mean Depth (ft)	0.91	0.08	0.93
Maximum Depth (ft)	1.03	0.16	1.03
Width/Depth Ratio	14.54	3.44	13.92
Bankfull Area (sq ft)	12	0.02	11.98
Wetted Perimeter (ft)	14.06	0.49	13.89
Hydraulic Radius (ft)	0.85	0.05	0.86
Begin BKF Station	209.59	209.59	209.87
End BKF Station	222.82	209.87	222.82

Broad Level Stream Classification

Entrenchment Ratio: 2.8 (Slightly Entrenched)

Width to Depth Ratio: 14.54 (Moderate to High)

Classification: C

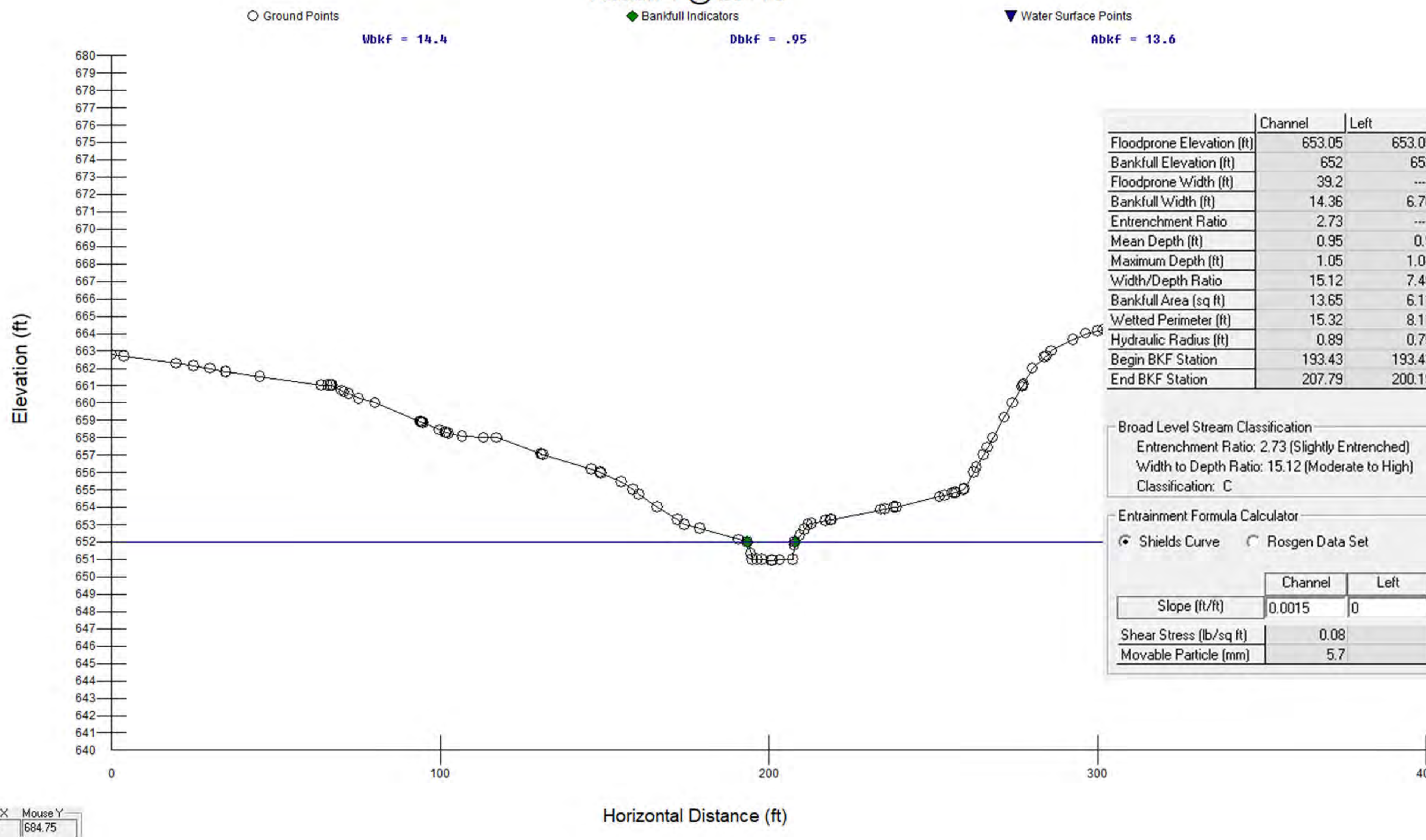
Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0016	0	0
Shear Stress (lb/sq ft)	0.08		
Movable Particle (mm)	5.8		

Mouse X	Mouse Y
-30.50	685.58

Reach 1 @ 23+79



	Channel	Left	Right
Floodprone Elevation (ft)	653.05	653.05	653.05
Bankfull Elevation (ft)	652	652	652
Floodprone Width (ft)	39.2	-----	-----
Bankfull Width (ft)	14.36	6.76	7.6
Entrenchment Ratio	2.73	-----	-----
Mean Depth (ft)	0.95	0.9	0.99
Maximum Depth (ft)	1.05	1.04	1.05
Width/Depth Ratio	15.12	7.48	7.68
Bankfull Area (sq ft)	13.65	6.11	7.54
Wetted Perimeter (ft)	15.32	8.11	9.28
Hydraulic Radius (ft)	0.89	0.75	0.81
Begin BKF Station	193.43	193.43	200.19
End BKF Station	207.79	200.19	207.79

Broad Level Stream Classification

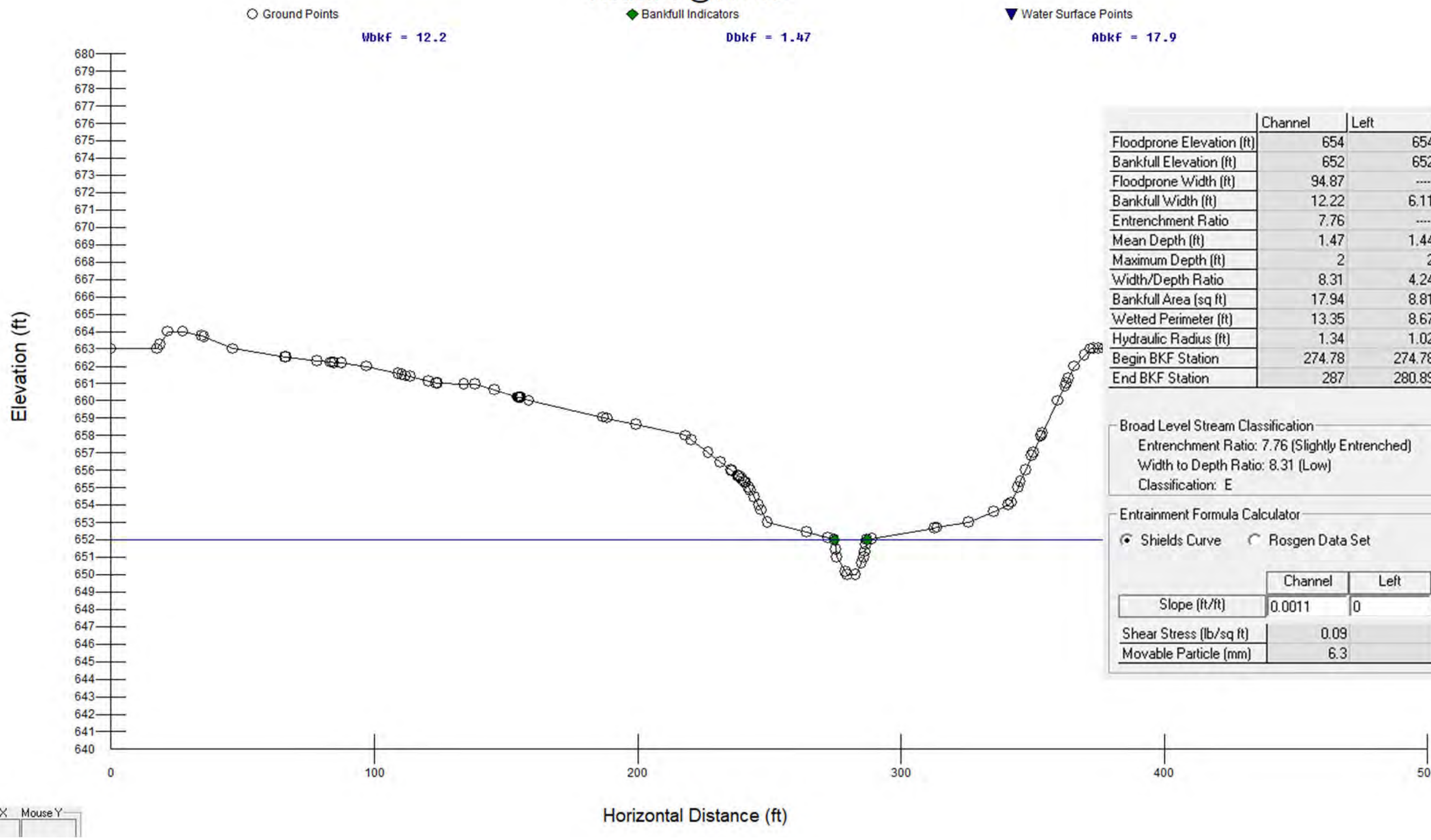
Entrenchment Ratio: 2.73 (Slightly Entrenched)
Width to Depth Ratio: 15.12 (Moderate to High)
Classification: C

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0015	0	0
Shear Stress (lb/sq ft)	0.08		
Movable Particle (mm)	5.7		

Reach 1 @ 22+82



	Channel	Left	Right
Floodprone Elevation (ft)	654	654	654
Bankfull Elevation (ft)	652	652	652
Floodprone Width (ft)	94.87	-----	-----
Bankfull Width (ft)	12.22	6.11	6.11
Entrenchment Ratio	7.76	-----	-----
Mean Depth (ft)	1.47	1.44	1.49
Maximum Depth (ft)	2	2	2
Width/Depth Ratio	8.31	4.24	4.1
Bankfull Area (sq ft)	17.94	8.81	9.13
Wetted Perimeter (ft)	13.35	8.67	8.68
Hydraulic Radius (ft)	1.34	1.02	1.05
Begin BKF Station	274.78	274.78	280.89
End BKF Station	287	280.89	287

Broad Level Stream Classification

Entrenchment Ratio: 7.76 (Slightly Entrenched)

Width to Depth Ratio: 8.31 (Low)

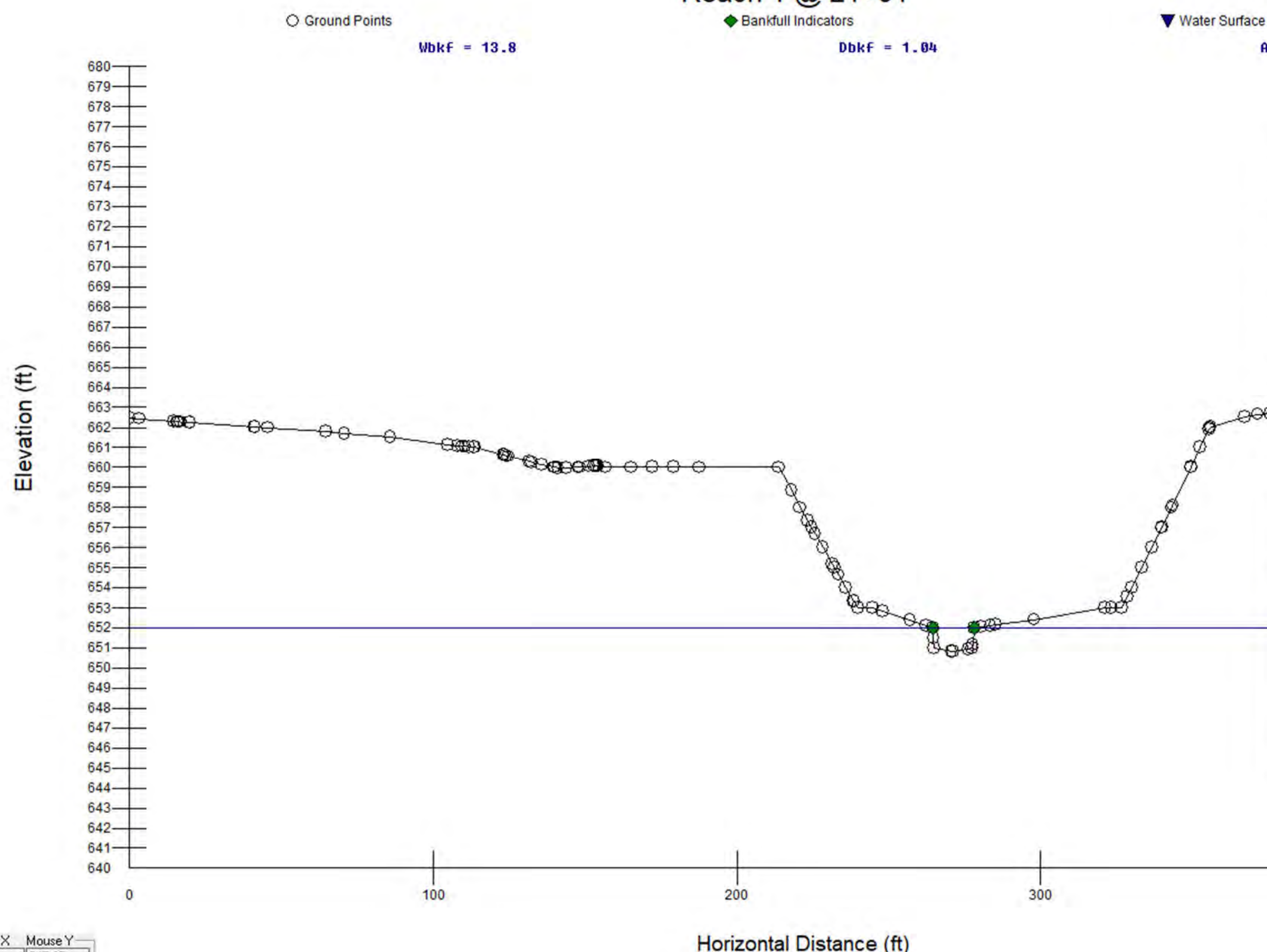
Classification: E

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0011	0	0
Shear Stress (lb/sq ft)	0.09		
Movable Particle (mm)	6.3		

Reach 1 @ 21+91



	Channel	Left	Right
Floodprone Elevation (ft)	653.18	653.18	653.18
Bankfull Elevation (ft)	652	652	652
Floodprone Width (ft)	88.21	-----	-----
Bankfull Width (ft)	13.77	6.88	6.89
Entrenchment Ratio	6.41	-----	-----
Mean Depth (ft)	1.04	1.04	1.04
Maximum Depth (ft)	1.18	1.18	1.18
Width/Depth Ratio	13.24	6.59	6.62
Bankfull Area (sq ft)	14.32	7.19	7.14
Wetted Perimeter (ft)	14.93	8.68	8.61
Hydraulic Radius (ft)	0.96	0.83	0.83
Begin BKF Station	264.51	264.51	271.39
End BKF Station	278.28	271.39	278.28

Broad Level Stream Classification

Entrenchment Ratio: 6.41 (Slightly Entrenched)
Width to Depth Ratio: 13.24 (Moderate to High)
Classification: C

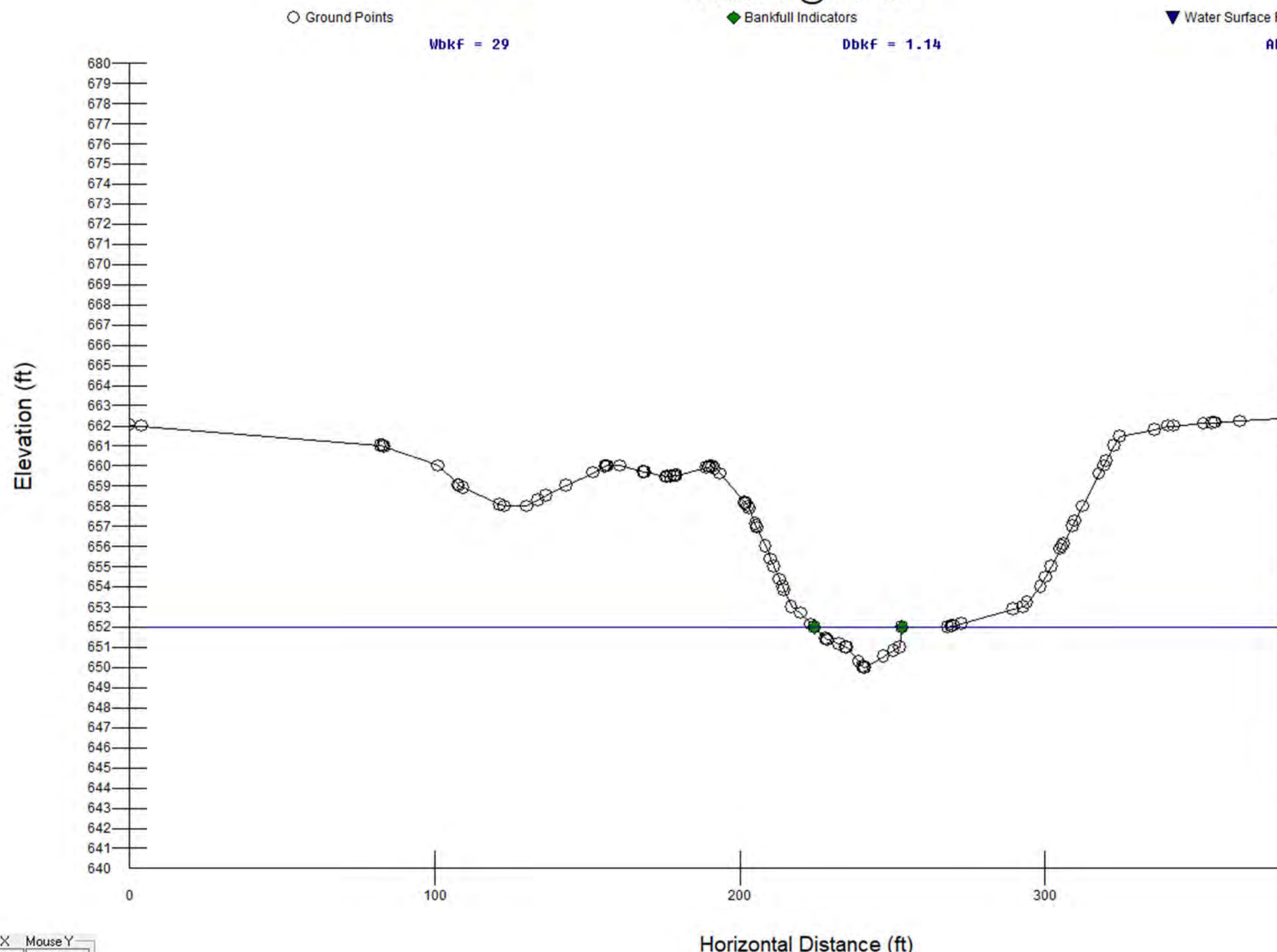
Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0021	0	0
Shear Stress (lb/sq ft)	0.13		
Movable Particle (mm)	8.0		

Mouse X	Mouse Y
-40.70	647.65

Reach 1 @ 21+52



	Channel	Left	Right
Floodprone Elevation (ft)	654	654	654
Bankfull Elevation (ft)	652	652	652
Floodprone Width (ft)	84.51	-----	-----
Bankfull Width (ft)	28.97	14.48	14.49
Entrenchment Ratio	2.92	-----	-----
Mean Depth (ft)	1.14	0.8	1.49
Maximum Depth (ft)	2	1.67	2
Width/Depth Ratio	25.41	18.16	9.72
Bankfull Area (sq ft)	33.14	11.54	21.6
Wetted Perimeter (ft)	29.59	16.26	16.66
Hydraulic Radius (ft)	1.12	0.71	1.3
Begin BKF Station	224.35	224.35	238.83
End BKF Station	253.32	238.83	253.32

Broad Level Stream Classification

Entrenchment Ratio: 2.92 (Slightly Entrenched)

Width to Depth Ratio: 25.41 (Moderate to High)

Classification: C

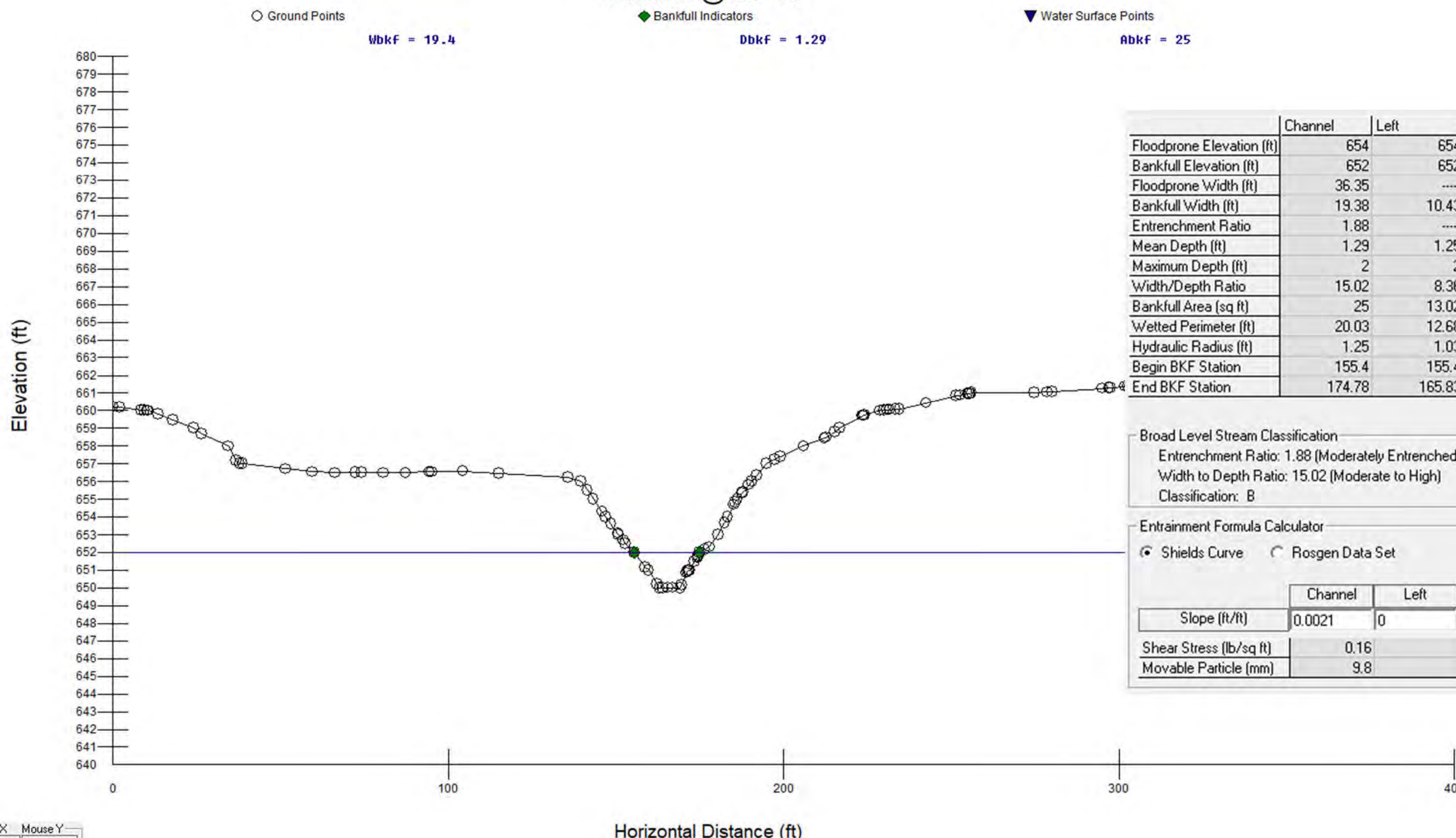
Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.00043	0	0
Shear Stress (lb/sq ft)	0.03		
Movable Particle (mm)	2.2		

Mouse X	Mouse Y
111.77	635.29

Reach 2 @ 20+56



	Channel	Left	Right
Floodprone Elevation (ft)	654	654	654
Bankfull Elevation (ft)	652	652	652
Floodprone Width (ft)	36.35	-----	-----
Bankfull Width (ft)	19.38	10.43	8.95
Entrenchment Ratio	1.88	-----	-----
Mean Depth (ft)	1.29	1.25	1.34
Maximum Depth (ft)	2	2	2
Width/Depth Ratio	15.02	8.36	6.68
Bankfull Area (sq ft)	25	13.02	11.98
Wetted Perimeter (ft)	20.03	12.68	11.31
Hydraulic Radius (ft)	1.25	1.03	1.06
Begin BKF Station	155.4	155.4	165.83
End BKF Station	174.78	165.83	174.78

Broad Level Stream Classification

Entrenchment Ratio: 1.88 (Moderately Entrenched)

Width to Depth Ratio: 15.02 (Moderate to High)

Classification: B

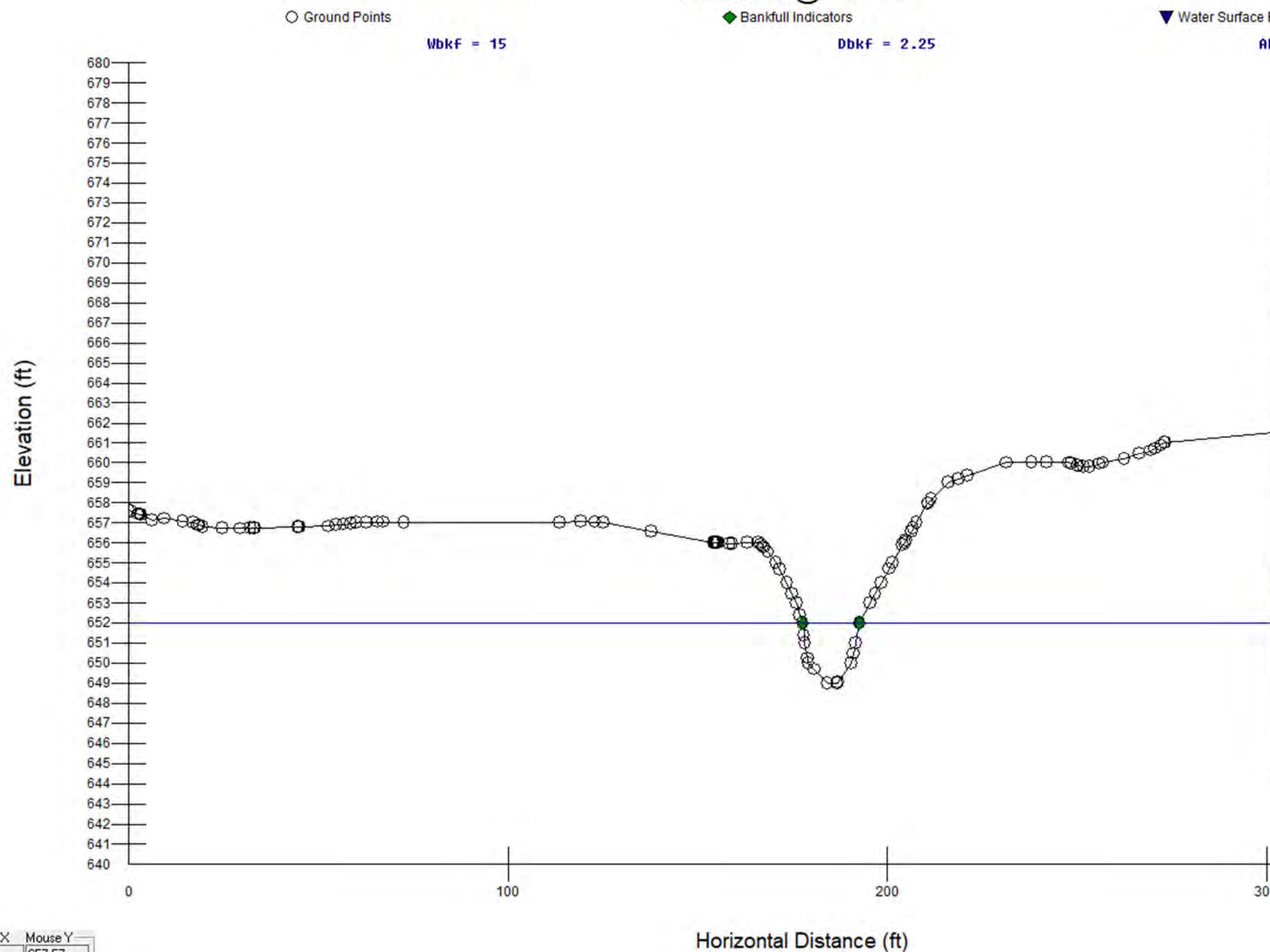
Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0021	0	0
Shear Stress (lb/sq ft)	0.16		
Movable Particle (mm)	9.8		

Mouse X	Mouse Y
131.87	662.52

Reach 2 @ 19+89



	Channel	Left	Right
Floodprone Elevation (ft)	655	655	655
Bankfull Elevation (ft)	652	652	652
Floodprone Width (ft)	30.78	-----	-----
Bankfull Width (ft)	14.97	7.59	7.38
Entrenchment Ratio	2.06	-----	-----
Mean Depth (ft)	2.25	2.32	2.18
Maximum Depth (ft)	3	3	3
Width/Depth Ratio	6.65	3.27	3.39
Bankfull Area (sq ft)	33.7	17.6	16.1
Wetted Perimeter (ft)	17.05	11.74	11.31
Hydraulic Radius (ft)	1.98	1.5	1.42
Begin BKF Station	177.68	177.68	185.27
End BKF Station	192.65	185.27	192.65

Broad Level Stream Classification

Entrenchment Ratio: 2.06 (Moderately Entrenched)
Width to Depth Ratio: 6.65 (Low)
Classification: B

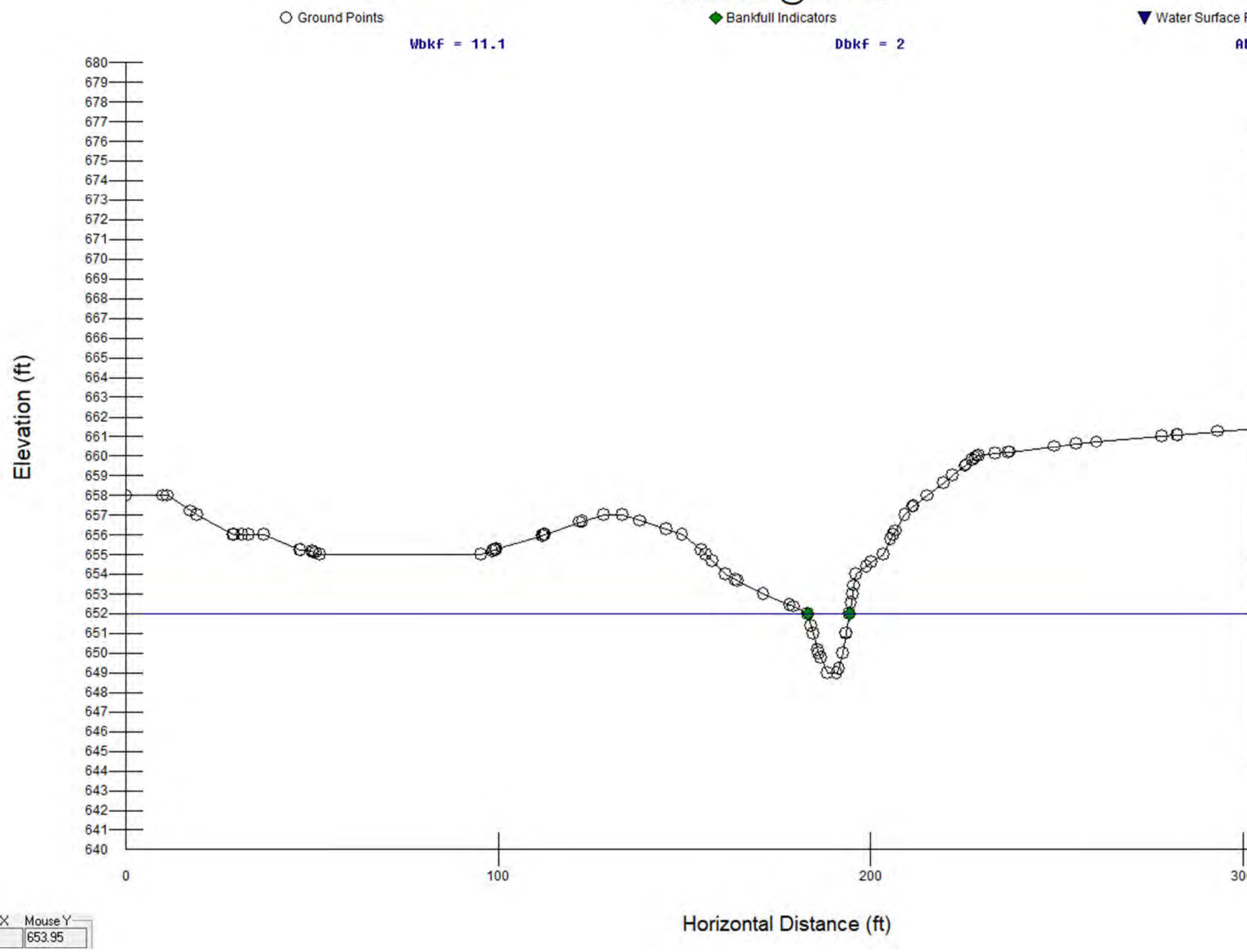
Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.001	0	0
Shear Stress (lb/sq ft)	0.12		
Movable Particle (mm)	7.9		

Mouse X	Mouse Y
39.96	657.57

Reach 2 @ 18+79



	Channel	Left	Right
Floodprone Elevation (ft)	655	655	655
Bankfull Elevation (ft)	652	652	652
Floodprone Width (ft)	47.7	-----	-----
Bankfull Width (ft)	11.14	5.57	5.57
Entrenchment Ratio	4.28	-----	-----
Mean Depth (ft)	2	1.76	2.24
Maximum Depth (ft)	3	3	3
Width/Depth Ratio	5.57	3.16	2.49
Bankfull Area (sq ft)	22.28	9.81	12.47
Wetted Perimeter (ft)	13.18	9.4	9.78
Hydraulic Radius (ft)	1.69	1.04	1.27
Begin BKF Station	183.14	183.14	188.71
End BKF Station	194.28	188.71	194.28

Broad Level Stream Classification

Entrenchment Ratio: 4.28 (Slightly Entrenched)

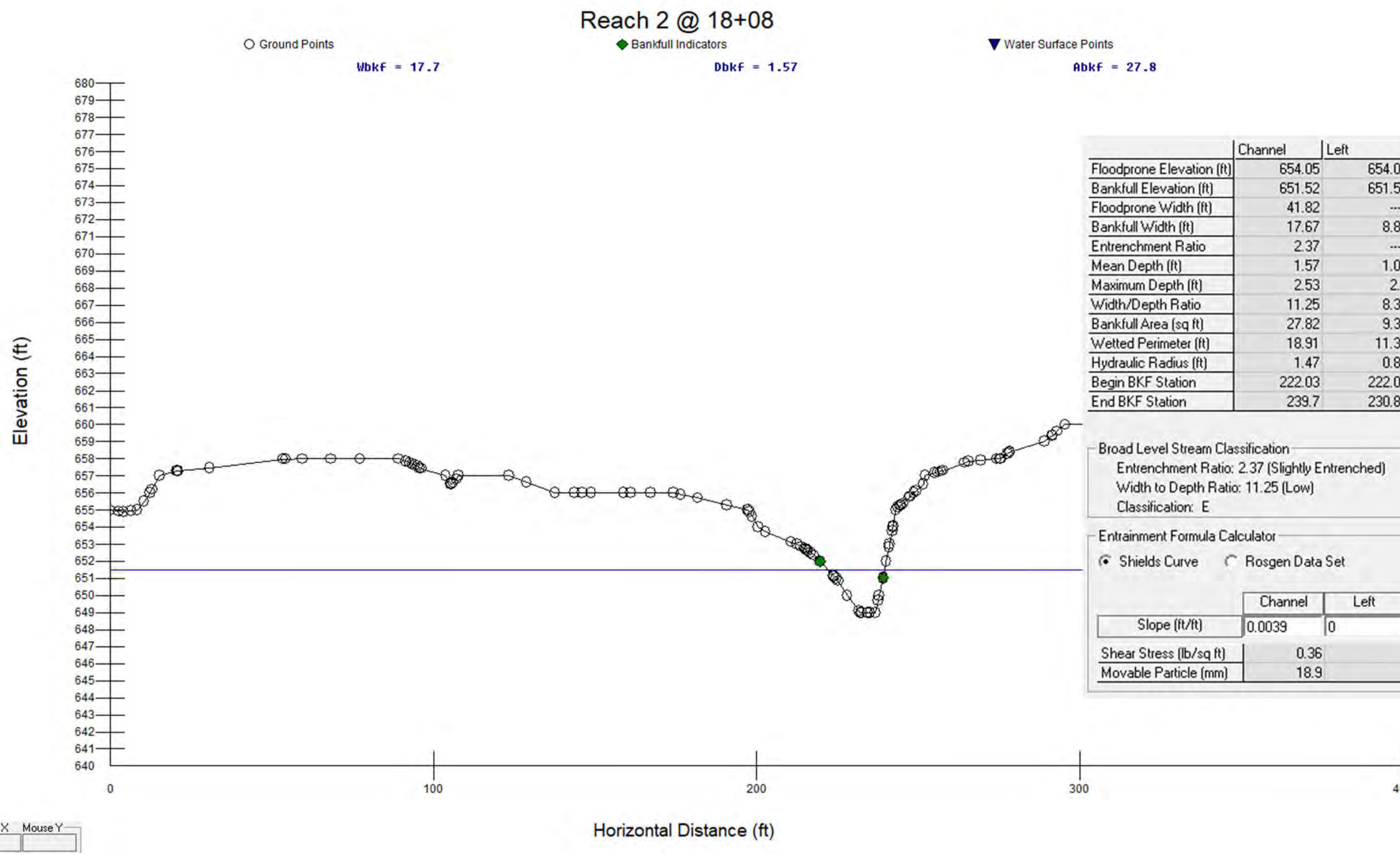
Width to Depth Ratio: 5.57 (Low)

Classification: E

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0053	0	0
Shear Stress (lb/sq ft)	0.56		
Movable Particle (mm)	33.0		



	Channel	Left	Right
Floodprone Elevation (ft)	654.05	654.05	654.05
Bankfull Elevation (ft)	651.52	651.52	651.52
Floodprone Width (ft)	41.82	-----	-----
Bankfull Width (ft)	17.67	8.84	8.83
Entrenchment Ratio	2.37	-----	-----
Mean Depth (ft)	1.57	1.06	2.09
Maximum Depth (ft)	2.53	2.2	2.53
Width/Depth Ratio	11.25	8.35	4.22
Bankfull Area (sq ft)	27.82	9.36	18.46
Wetted Perimeter (ft)	18.91	11.32	11.99
Hydraulic Radius (ft)	1.47	0.83	1.54
Begin BKF Station	222.03	222.03	230.87
End BKF Station	239.7	230.87	239.7

Broad Level Stream Classification

Entrenchment Ratio: 2.37 (Slightly Entrenched)

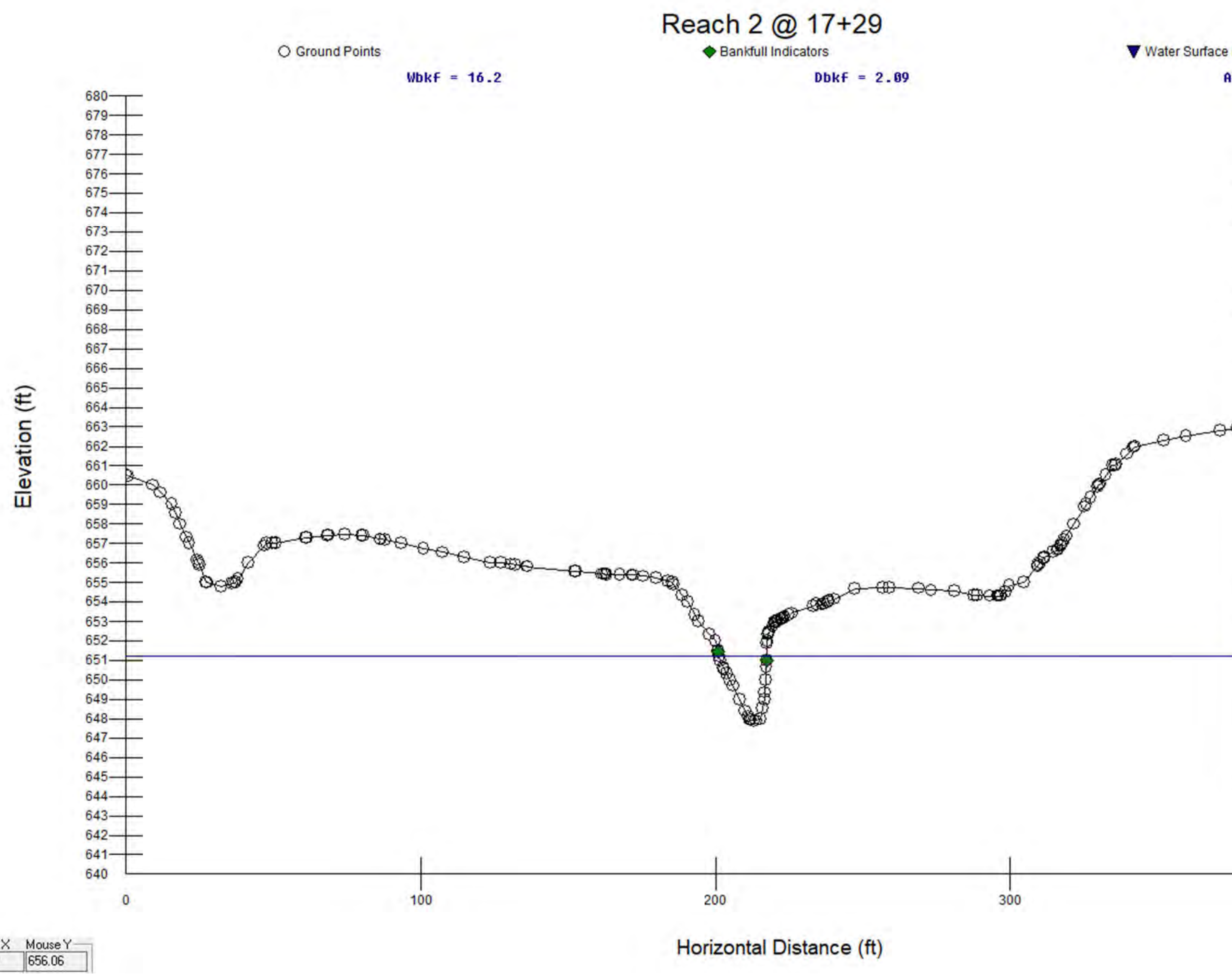
Width to Depth Ratio: 11.25 (Low)

Classification: E

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0039	0	0
Shear Stress (lb/sq ft)	0.36		
Movable Particle (mm)	18.9		



	Channel	Left	Right
Floodprone Elevation (ft)	654.54	654.54	654.54
Bankfull Elevation (ft)	651.21	651.21	651.21
Floodprone Width (ft)	74.41	-----	-----
Bankfull Width (ft)	16.18	8.09	8.09
Entrenchment Ratio	4.6	-----	-----
Mean Depth (ft)	2.09	1.33	2.86
Maximum Depth (ft)	3.33	2.53	3.33
Width/Depth Ratio	7.74	6.09	2.83
Bankfull Area (sq ft)	33.87	10.75	23.12
Wetted Perimeter (ft)	18.57	11.02	12.61
Hydraulic Radius (ft)	1.82	0.98	1.83
Begin BKF Station	201.25	201.25	209.34
End BKF Station	217.43	209.34	217.43

Broad Level Stream Classification

Entrenchment Ratio: 4.6 (Slightly Entrenched)

Width to Depth Ratio: 7.74 (Low)

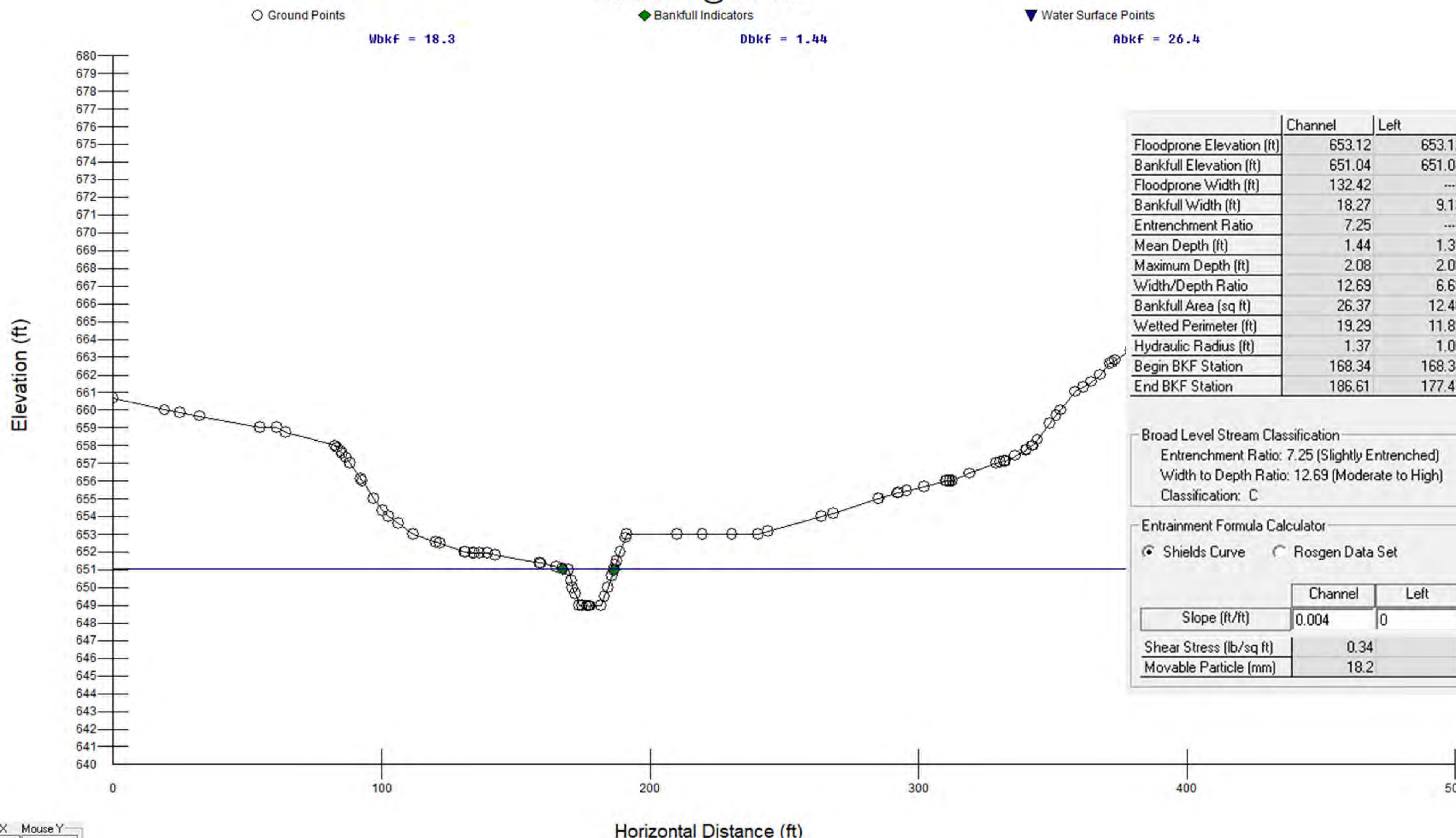
Classification: E

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0015	0	0
Shear Stress (lb/sq ft)	0.17		
Movable Particle (mm)	10.1		

Reach 2 @ 16+27



	Channel	Left	Right
Floodprone Elevation (ft)	653.12	653.12	653.12
Bankfull Elevation (ft)	651.04	651.04	651.04
Floodprone Width (ft)	132.42	-----	-----
Bankfull Width (ft)	18.27	9.13	9.14
Entrenchment Ratio	7.25	-----	-----
Mean Depth (ft)	1.44	1.37	1.52
Maximum Depth (ft)	2.08	2.08	2.08
Width/Depth Ratio	12.69	6.69	6.01
Bankfull Area (sq ft)	26.37	12.46	13.91
Wetted Perimeter (ft)	19.29	11.81	11.63
Hydraulic Radius (ft)	1.37	1.06	1.2
Begin BKF Station	168.34	168.34	177.47
End BKF Station	186.61	177.47	186.61

Broad Level Stream Classification

Entrenchment Ratio: 7.25 (Slightly Entrenched)

Width to Depth Ratio: 12.69 (Moderate to High)

Classification: C

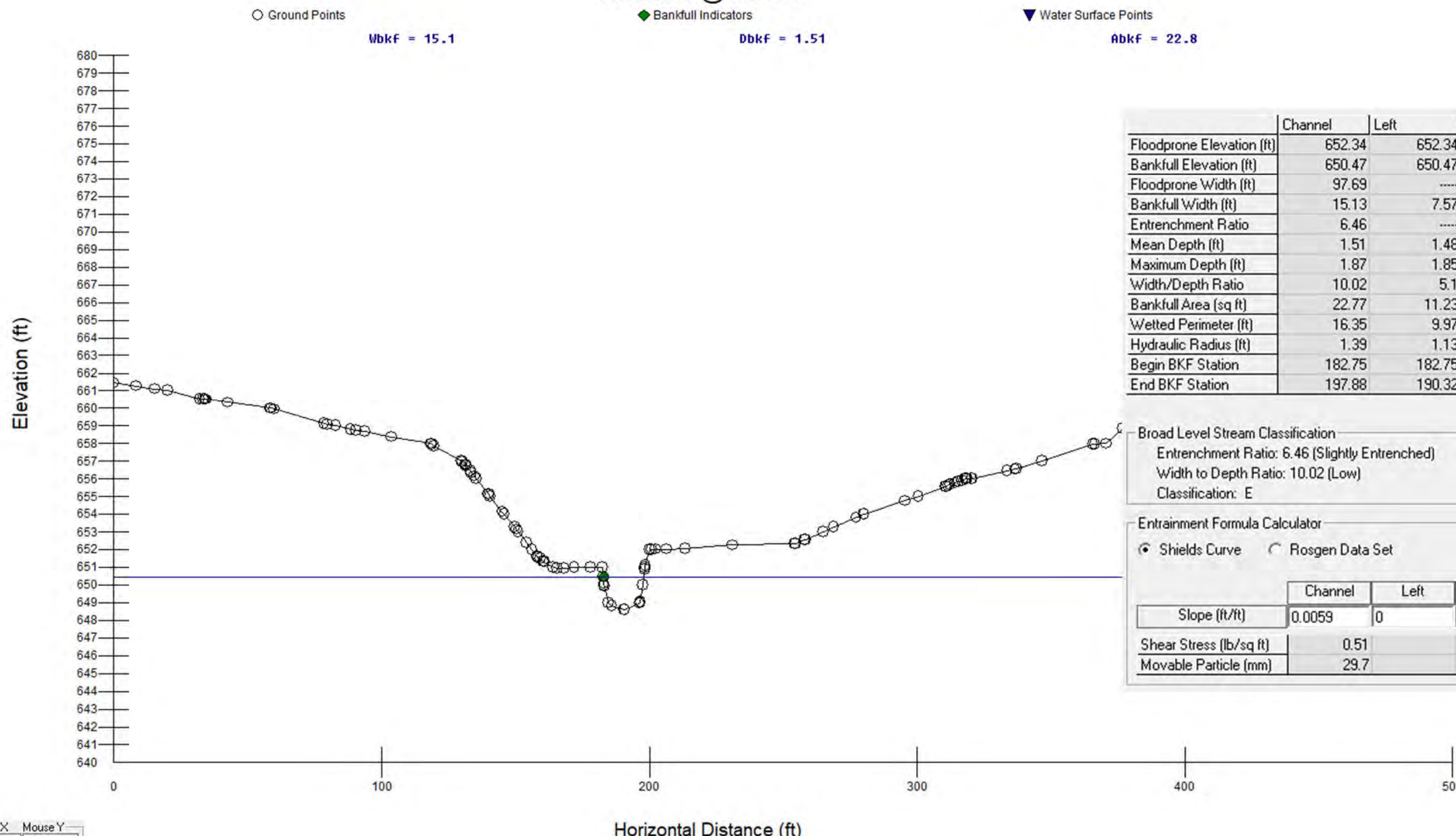
Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.004	0	0
Shear Stress (lb/sq ft)	0.34		
Movable Particle (mm)	18.2		

Mouse X Mouse Y

Reach 2 @ 15+56



	Channel	Left	Right
Floodprone Elevation (ft)	652.34	652.34	652.34
Bankfull Elevation (ft)	650.47	650.47	650.47
Floodprone Width (ft)	97.69	-----	-----
Bankfull Width (ft)	15.13	7.57	7.56
Entrenchment Ratio	6.46	-----	-----
Mean Depth (ft)	1.51	1.48	1.53
Maximum Depth (ft)	1.87	1.85	1.87
Width/Depth Ratio	10.02	5.1	4.94
Bankfull Area (sq ft)	22.77	11.23	11.54
Wetted Perimeter (ft)	16.35	9.97	10.09
Hydraulic Radius (ft)	1.39	1.13	1.14
Begin BKF Station	182.75	182.75	190.32
End BKF Station	197.88	190.32	197.88

Broad Level Stream Classification

Entrenchment Ratio: 6.46 (Slightly Entrenched)

Width to Depth Ratio: 10.02 (Low)

Classification: E

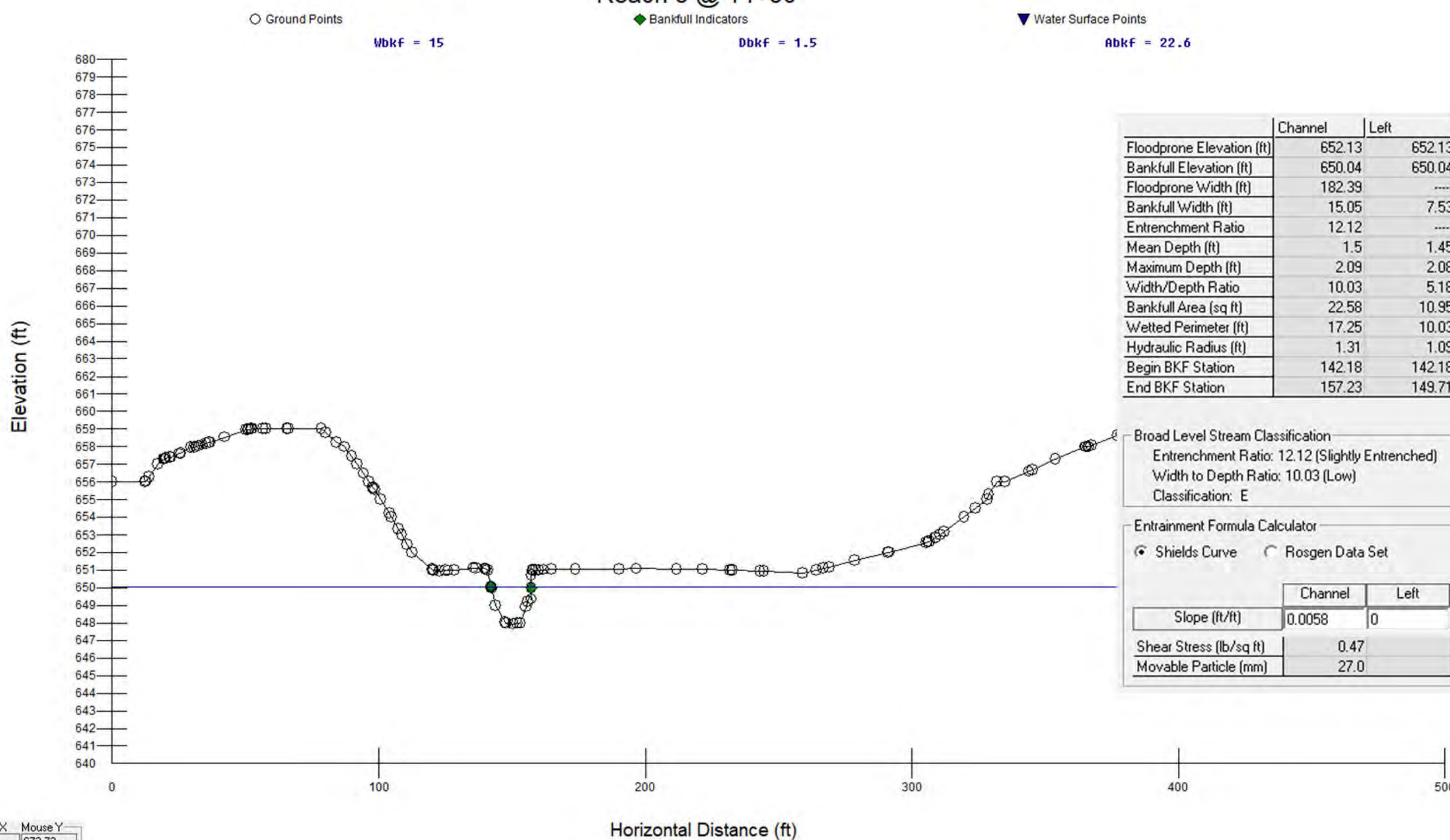
Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0059	0	0
Shear Stress (lb/sq ft)	0.51		
Movable Particle (mm)	29.7		

Mouse X	Mouse Y
-8.27	659.35

Reach 3 @ 14+50



	Channel	Left	Right
Floodprone Elevation (ft)	652.13	652.13	652.13
Bankfull Elevation (ft)	650.04	650.04	650.04
Floodprone Width (ft)	182.39	-----	-----
Bankfull Width (ft)	15.05	7.53	7.52
Entrenchment Ratio	12.12	-----	-----
Mean Depth (ft)	1.5	1.45	1.55
Maximum Depth (ft)	2.09	2.08	2.09
Width/Depth Ratio	10.03	5.18	4.85
Bankfull Area (sq ft)	22.58	10.95	11.63
Wetted Perimeter (ft)	17.25	10.03	11.38
Hydraulic Radius (ft)	1.31	1.09	1.02
Begin BKF Station	142.18	142.18	149.71
End BKF Station	157.23	149.71	157.23

Broad Level Stream Classification

Entrenchment Ratio: 12.12 (Slightly Entrenched)

Width to Depth Ratio: 10.03 (Low)

Classification: E

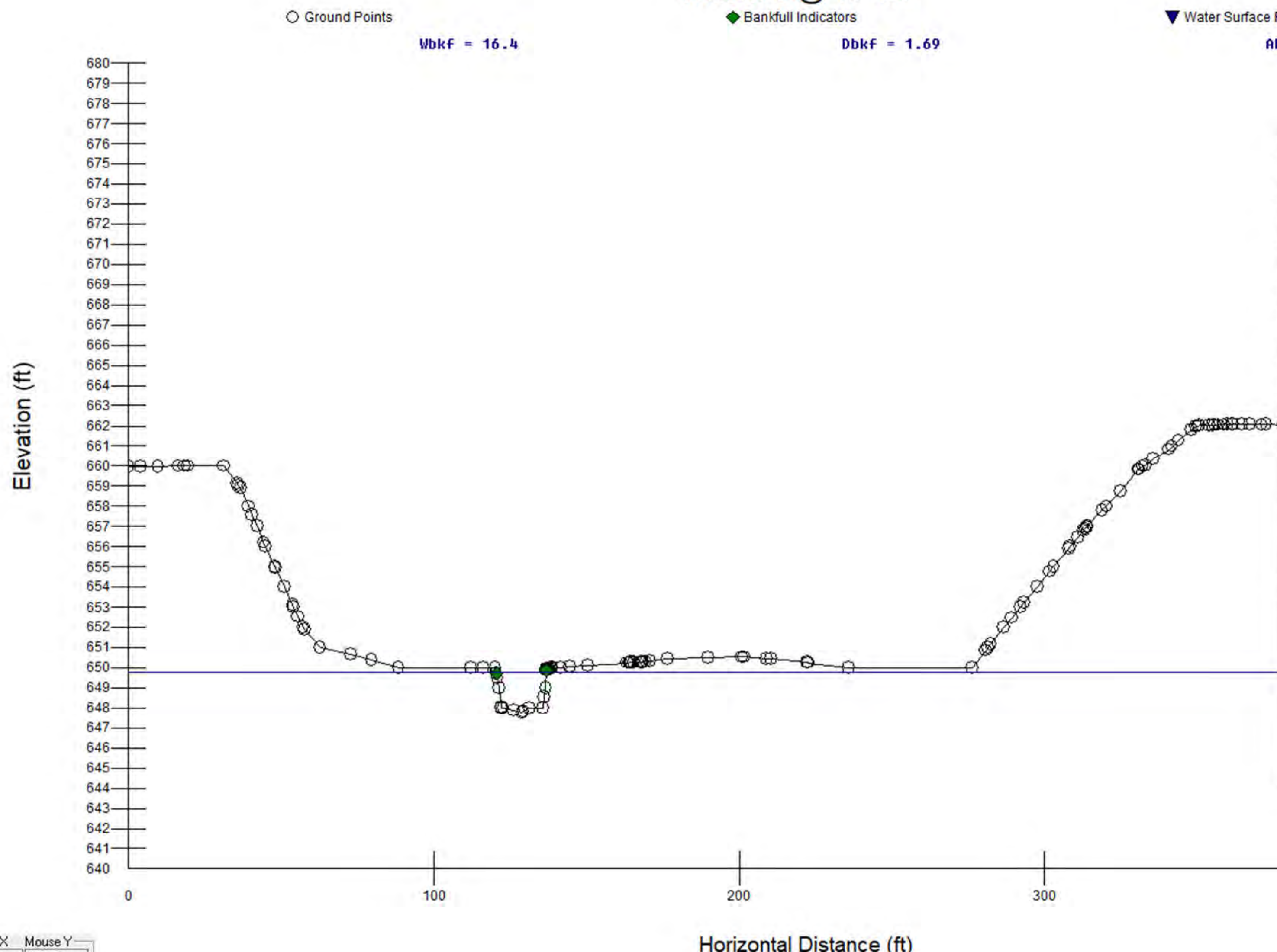
Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0058	0	0
Shear Stress (lb/sq ft)	0.47		
Movable Particle (mm)	27.0		

Mouse X	Mouse Y
-13.76	673.72

Reach 3 @ 13+25



	Channel	Left	Right
Floodprone Elevation (ft)	651.78	651.78	651.78
Bankfull Elevation (ft)	649.78	649.78	649.78
Floodprone Width (ft)	227.45	-----	-----
Bankfull Width (ft)	16.43	8.22	8.21
Entrenchment Ratio	13.85	-----	-----
Mean Depth (ft)	1.69	1.64	1.74
Maximum Depth (ft)	2	1.99	2
Width/Depth Ratio	9.72	5	4.72
Bankfull Area (sq ft)	27.75	13.5	14.25
Wetted Perimeter (ft)	18.32	11.01	11.29
Hydraulic Radius (ft)	1.51	1.23	1.26
Begin BKF Station	120.37	120.37	128.59
End BKF Station	136.8	128.59	136.8

Broad Level Stream Classification

Entrenchment Ratio: 13.85 (Slightly Entrenched)

Width to Depth Ratio: 9.72 (Low)

Classification: E

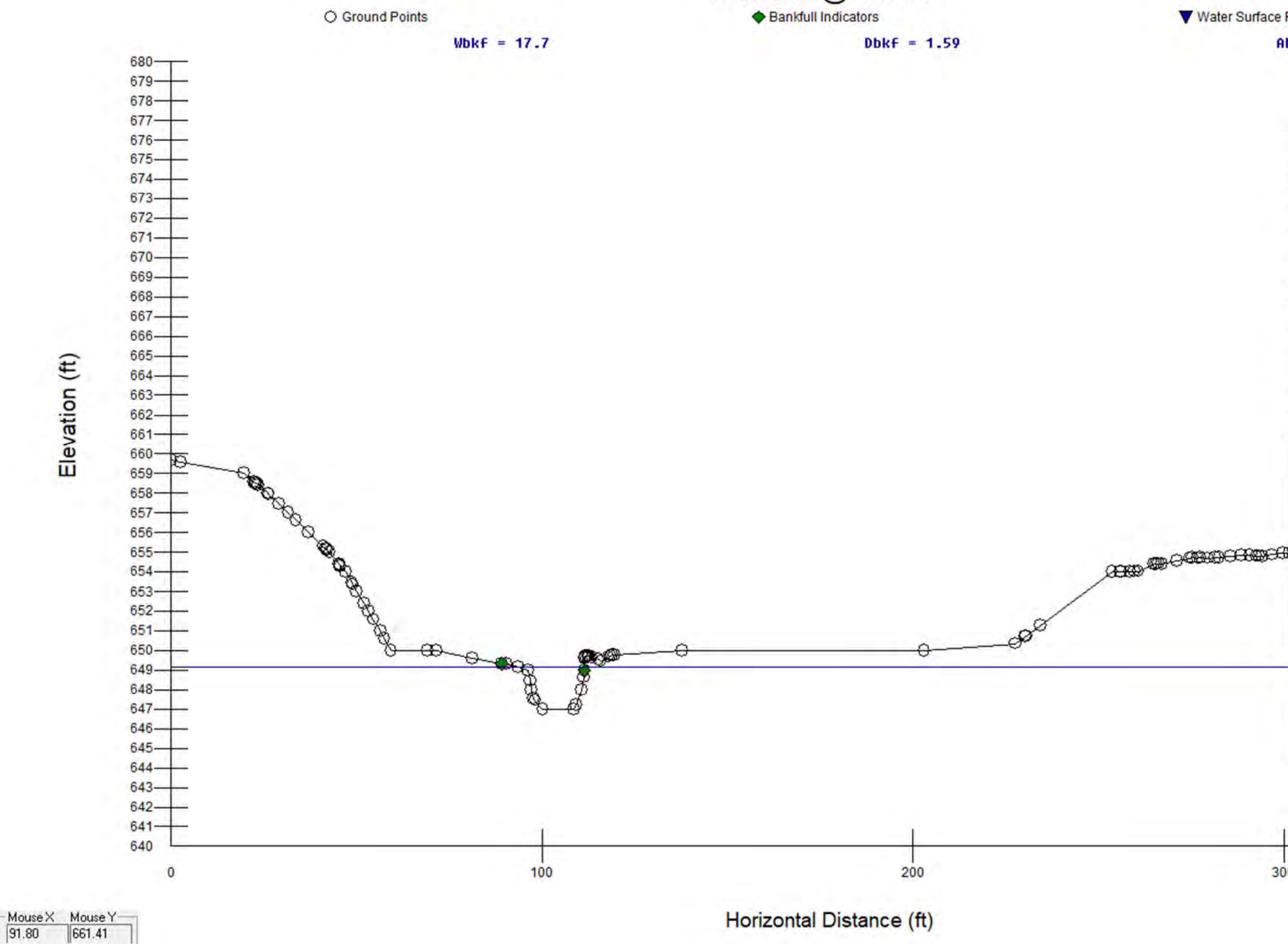
Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0055	0	0
Shear Stress (lb/sq ft)	0.52		
Movable Particle (mm)	30.2		

Mouse X	Mouse Y
-39.55	677.61

Reach 3 @ 12+51



	Channel	Left	Right
Floodprone Elevation (ft)	651.3	651.3	651.3
Bankfull Elevation (ft)	649.15	649.15	649.15
Floodprone Width (ft)	179.2	-----	-----
Bankfull Width (ft)	17.73	4.16	13.56
Entrenchment Ratio	10.11	-----	-----
Mean Depth (ft)	1.59	0.43	1.95
Maximum Depth (ft)	2.15	1.64	2.15
Width/Depth Ratio	11.15	9.59	6.95
Bankfull Area (sq ft)	28.27	1.81	26.46
Wetted Perimeter (ft)	19.25	6.4	16.12
Hydraulic Radius (ft)	1.47	0.28	1.64
Begin BKF Station	93.68	93.68	97.84
End BKF Station	111.4	97.84	111.4

Broad Level Stream Classification

Entrenchment Ratio: 10.11 (Slightly Entrenched)

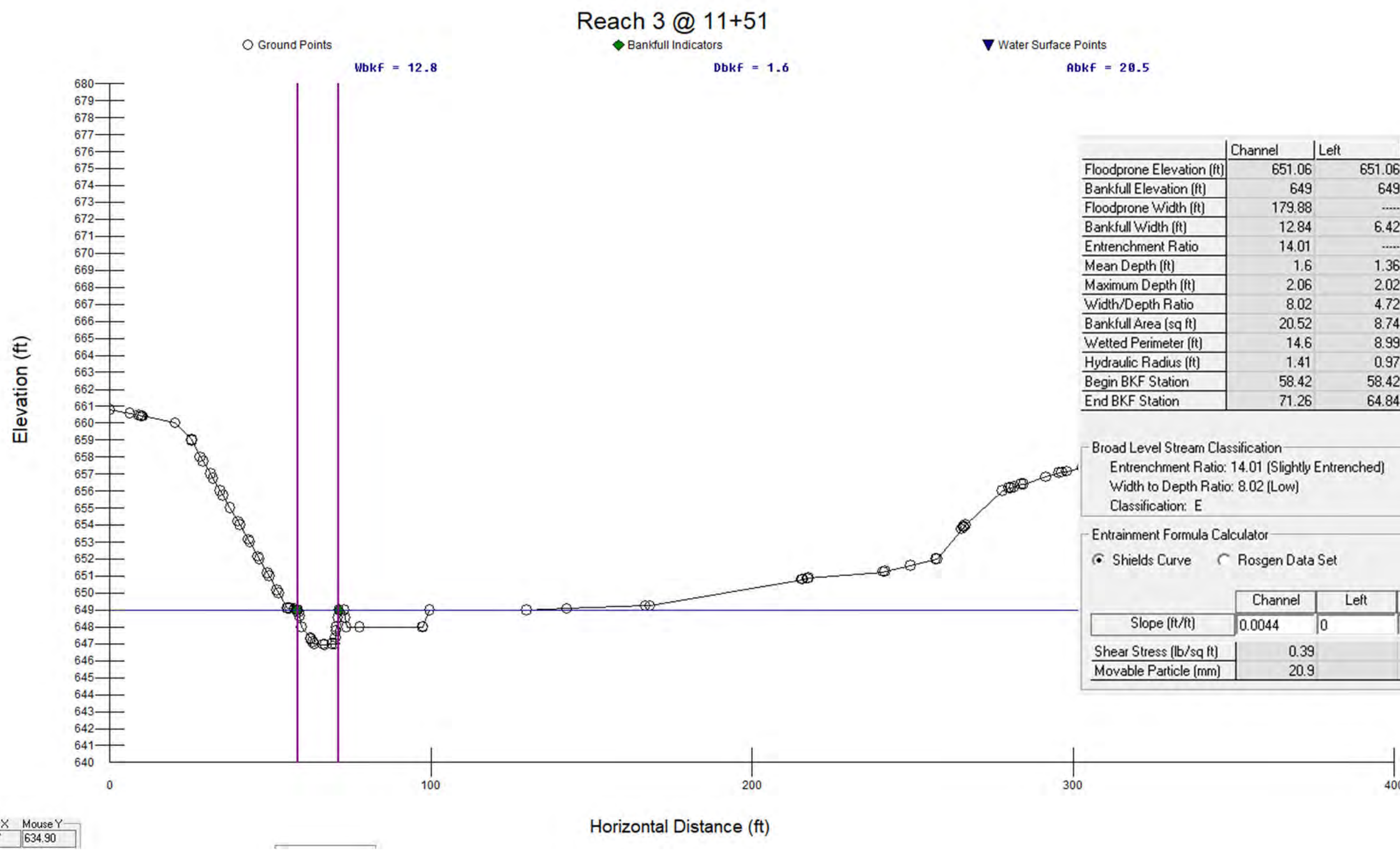
Width to Depth Ratio: 11.15 (Low)

Classification: E

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0028	0	0
Shear Stress (lb/sq ft)	0.26		
Movable Particle (mm)	14.2		



	Channel	Left	Right
Floodprone Elevation (ft)	651.06	651.06	651.06
Bankfull Elevation (ft)	649	649	649
Floodprone Width (ft)	179.88	-----	-----
Bankfull Width (ft)	12.84	6.42	6.42
Entrenchment Ratio	14.01	-----	-----
Mean Depth (ft)	1.6	1.36	1.84
Maximum Depth (ft)	2.06	2.02	2.06
Width/Depth Ratio	8.02	4.72	3.49
Bankfull Area (sq ft)	20.52	8.74	11.78
Wetted Perimeter (ft)	14.6	8.99	9.66
Hydraulic Radius (ft)	1.41	0.97	1.22
Begin BKF Station	58.42	58.42	64.84
End BKF Station	71.26	64.84	71.26

Broad Level Stream Classification

Entrenchment Ratio: 14.01 (Slightly Entrenched)

Width to Depth Ratio: 8.02 (Low)

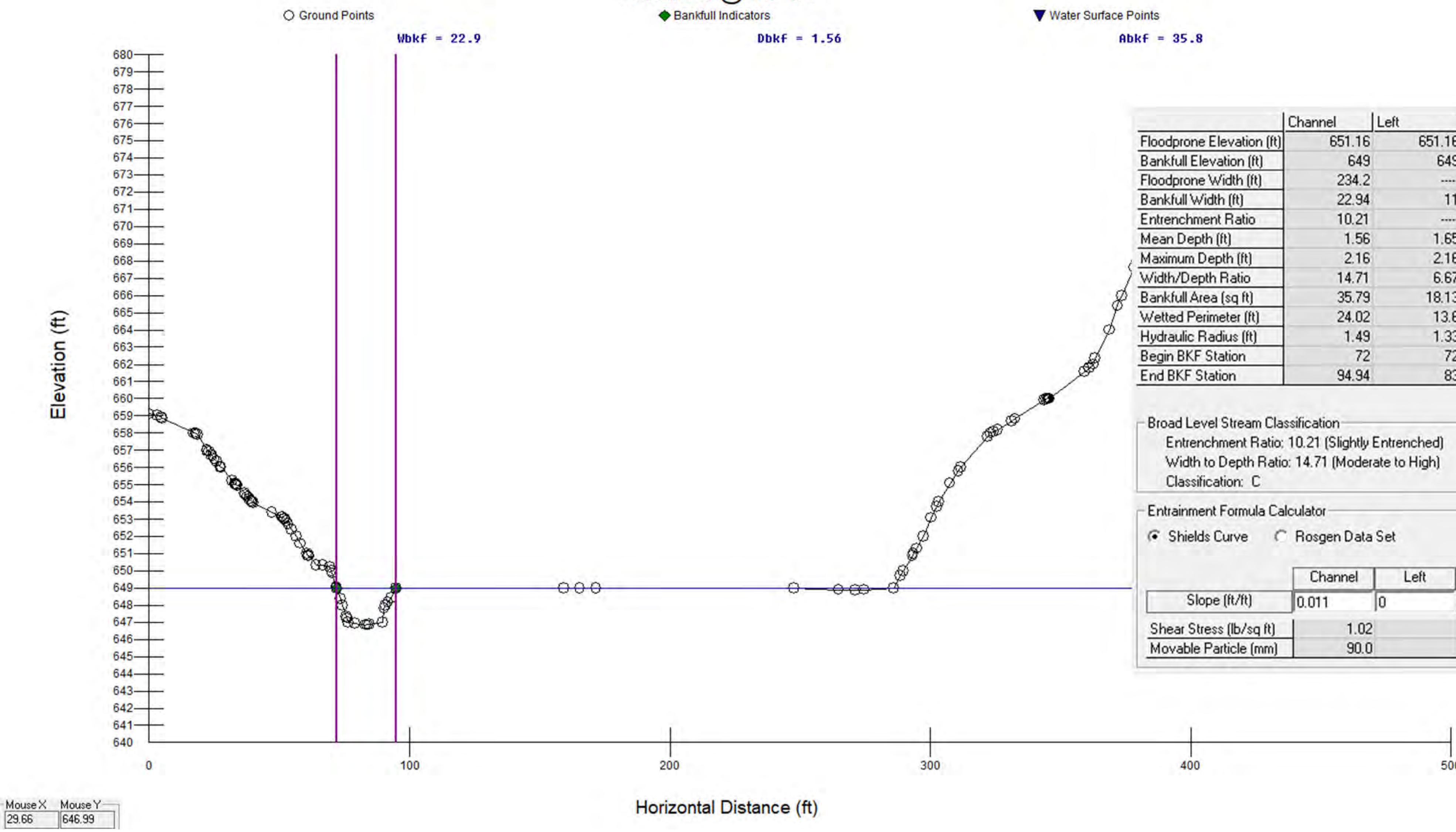
Classification: E

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0044	0	0
Shear Stress (lb/sq ft)	0.39		
Movable Particle (mm)	20.9		

Reach 3 @ 10+51



	Channel	Left	Right
Floodprone Elevation (ft)	651.16	651.16	651.16
Bankfull Elevation (ft)	649	649	649
Floodprone Width (ft)	234.2	-----	-----
Bankfull Width (ft)	22.94	11	11.94
Entrenchment Ratio	10.21	-----	-----
Mean Depth (ft)	1.56	1.65	1.48
Maximum Depth (ft)	2.16	2.16	2.16
Width/Depth Ratio	14.71	6.67	8.07
Bankfull Area (sq ft)	35.79	18.13	17.66
Wetted Perimeter (ft)	24.02	13.6	14.74
Hydraulic Radius (ft)	1.49	1.33	1.2
Begin BKF Station	72	72	83
End BKF Station	94.94	83	94.94

Broad Level Stream Classification

Entrenchment Ratio: 10.21 (Slightly Entrenched)

Width to Depth Ratio: 14.71 (Moderate to High)

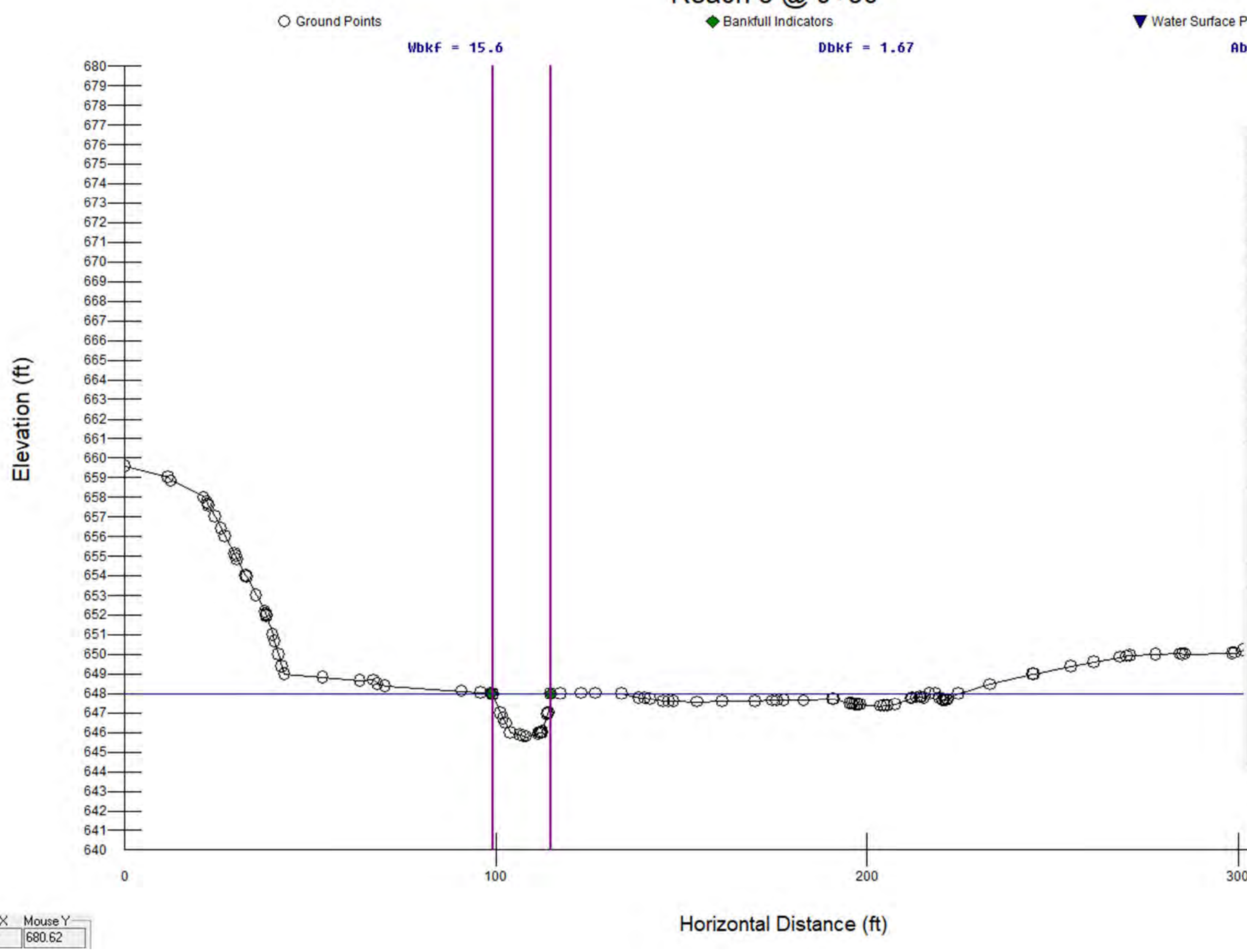
Classification: C

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.011	0	0
Shear Stress (lb/sq ft)	1.02		
Movable Particle (mm)	90.0		

Reach 3 @ 9+50



	Channel	Left	Right
Floodprone Elevation (ft)	650.24	650.24	650.24
Bankfull Elevation (ft)	648.01	648.01	648.01
Floodprone Width (ft)	268.4	-----	-----
Bankfull Width (ft)	15.62	7.81	7.81
Entrenchment Ratio	17.18	-----	-----
Mean Depth (ft)	1.67	1.48	1.85
Maximum Depth (ft)	2.23	2.18	2.23
Width/Depth Ratio	9.35	5.27	4.22
Bankfull Area (sq ft)	26.05	11.58	14.47
Wetted Perimeter (ft)	16.86	10.42	10.79
Hydraulic Radius (ft)	1.54	1.11	1.34
Begin BKF Station	99.16	99.16	106.97
End BKF Station	114.78	106.97	114.78

Broad Level Stream Classification

Entrenchment Ratio: 17.18 (Slightly Entrenched)

Width to Depth Ratio: 9.35 (Low)

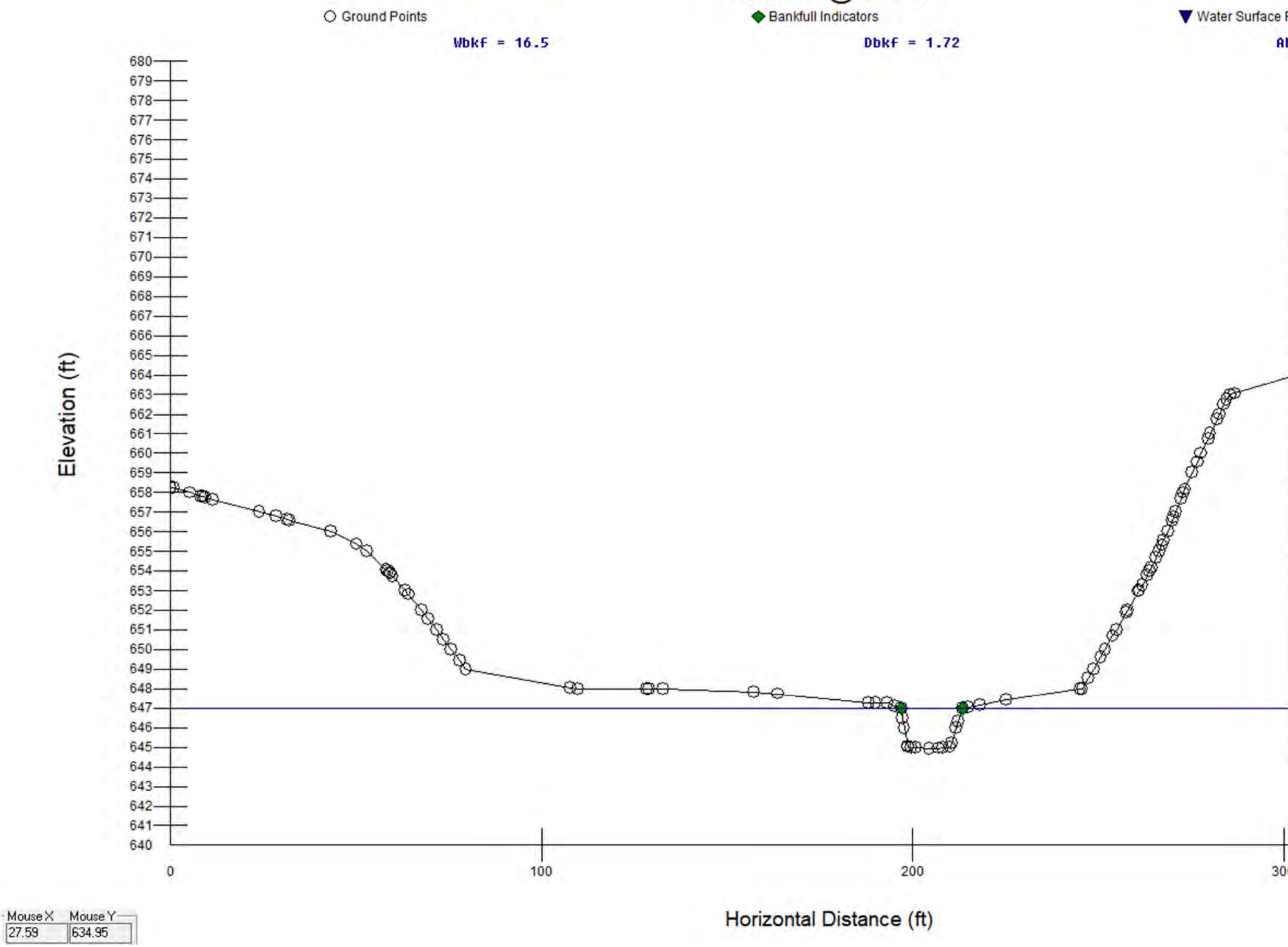
Classification: E

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0044	0	0
Shear Stress (lb/sq ft)	0.42		
Movable Particle (mm)	23.4		

Reach 3 @ 6+50



	Channel	Left	Right
Floodprone Elevation (ft)	649.08	649.08	649.08
Bankfull Elevation (ft)	647	647	647
Floodprone Width (ft)	169.82	-----	-----
Bankfull Width (ft)	16.51	8.26	8.25
Entrenchment Ratio	10.29	-----	-----
Mean Depth (ft)	1.72	1.81	1.62
Maximum Depth (ft)	2.08	2.08	2.07
Width/Depth Ratio	9.6	4.55	5.09
Bankfull Area (sq ft)	28.35	14.98	13.37
Wetted Perimeter (ft)	17.92	11.18	10.88
Hydraulic Radius (ft)	1.58	1.34	1.23
Begin BKF Station	196.85	196.85	205.11
End BKF Station	213.36	205.11	213.36

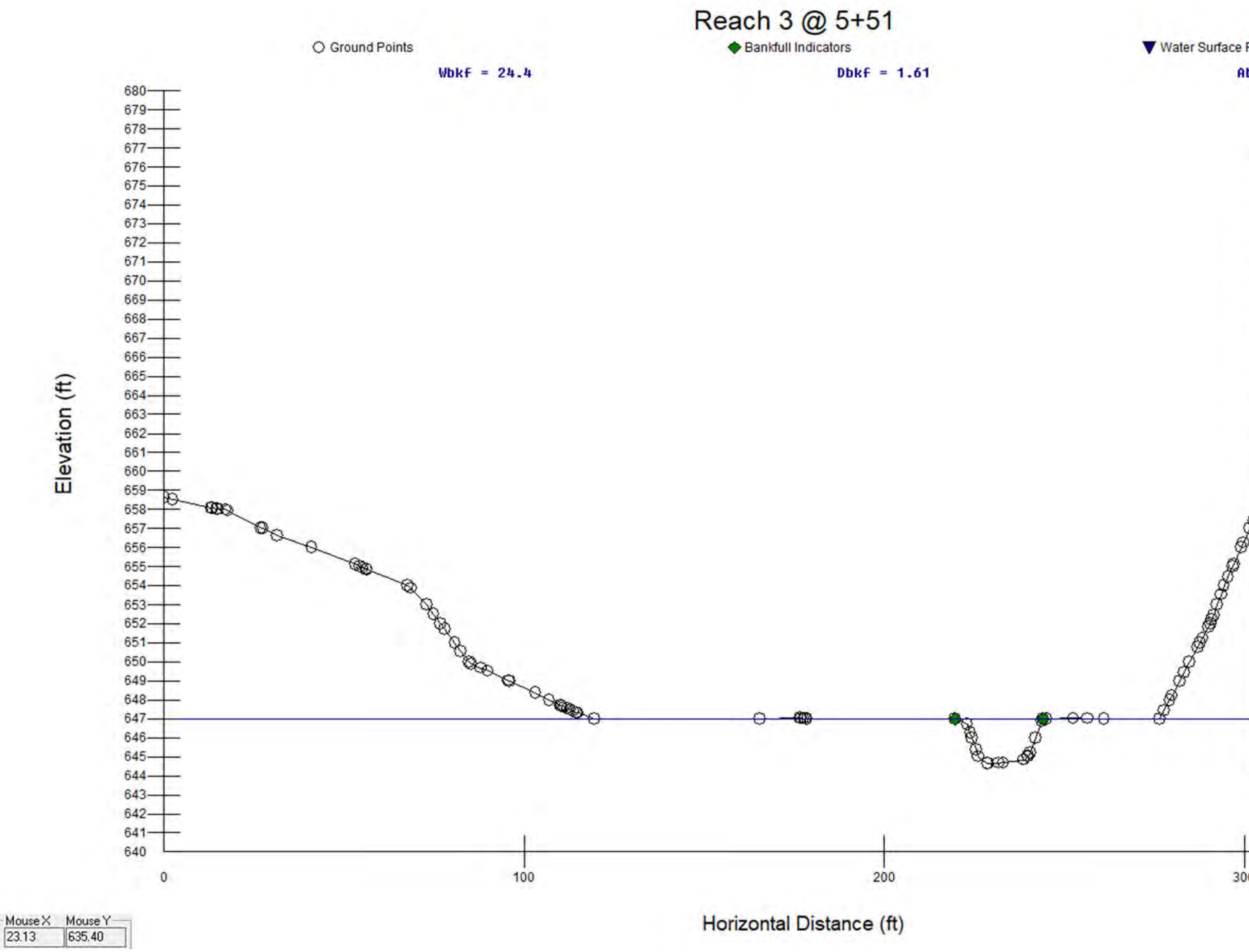
Broad Level Stream Classification

Entrenchment Ratio: 10.29 (Slightly Entrenched)
Width to Depth Ratio: 9.6 (Low)
Classification: E

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0038	0	0
Shear Stress (lb/sq ft)	0.37		
Movable Particle (mm)	20.0		



	Channel	Left	Right
Floodprone Elevation (ft)	649.35	649.35	649.35
Bankfull Elevation (ft)	647	647	647
Floodprone Width (ft)	191.19	-----	-----
Bankfull Width (ft)	24.41	12.2	12.21
Entrenchment Ratio	7.83	-----	-----
Mean Depth (ft)	1.61	1.39	1.82
Maximum Depth (ft)	2.35	2.35	2.33
Width/Depth Ratio	15.16	8.78	6.71
Bankfull Area (sq ft)	39.2	16.95	22.25
Wetted Perimeter (ft)	25.36	15	15.01
Hydraulic Radius (ft)	1.55	1.13	1.48
Begin BKF Station	219.62	219.62	231.82
End BKF Station	244.03	231.82	244.03

Broad Level Stream Classification

Entrenchment Ratio: 7.83 (Slightly Entrenched)

Width to Depth Ratio: 15.16 (Moderate to High)

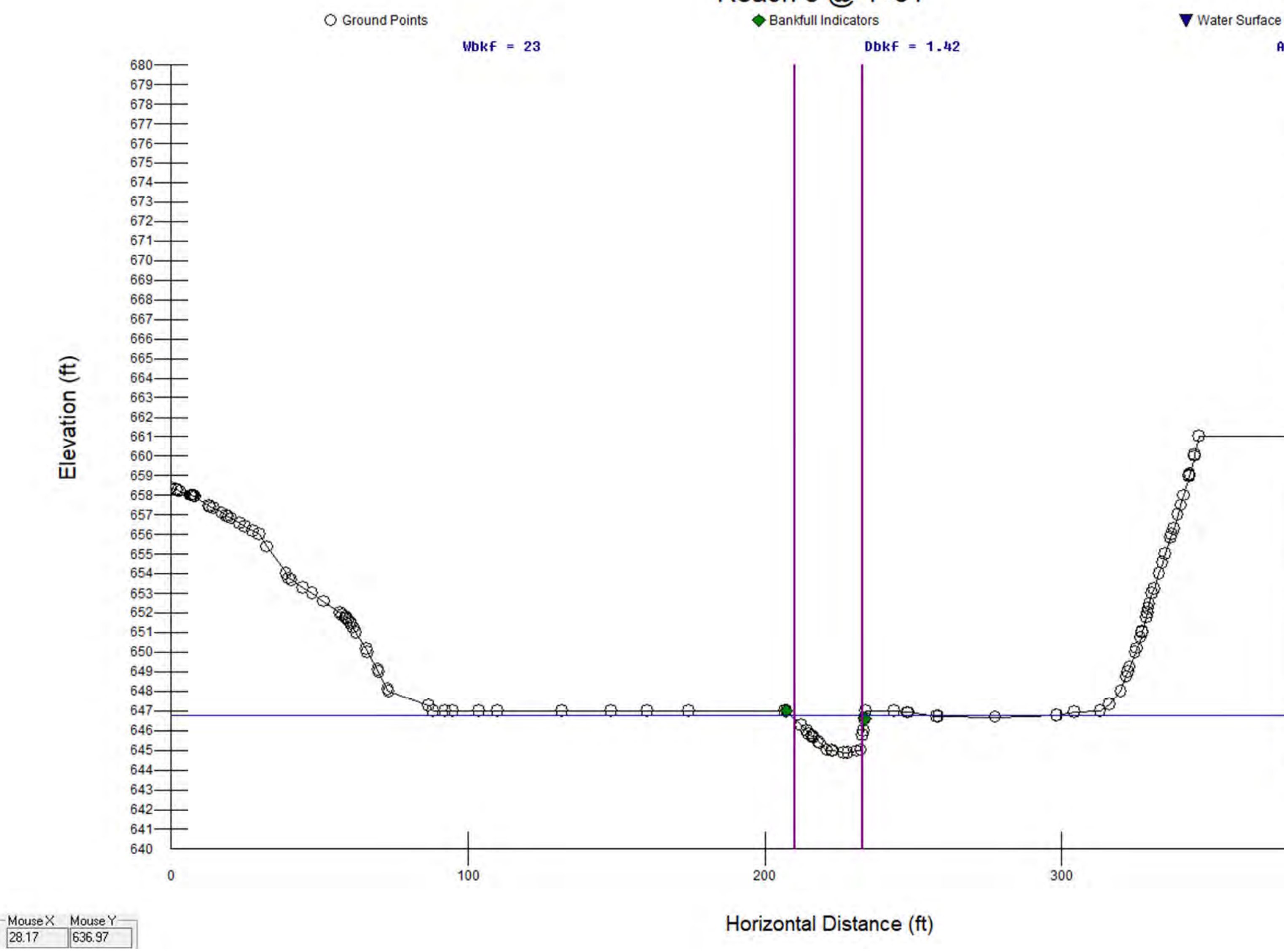
Classification: C

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0029	0	0
Shear Stress (lb/sq ft)	0.28		
Movable Particle (mm)	15.3		

Reach 3 @ 4+51



	Channel	Left	Right
Floodprone Elevation (ft)	648.7	648.7	648.7
Bankfull Elevation (ft)	646.78	646.78	646.78
Floodprone Width (ft)	250.77	-----	-----
Bankfull Width (ft)	23	10.68	12.32
Entrenchment Ratio	10.9	-----	-----
Mean Depth (ft)	1.42	0.96	1.83
Maximum Depth (ft)	1.92	1.73	1.92
Width/Depth Ratio	16.2	11.14	6.73
Bankfull Area (sq ft)	32.73	10.24	22.49
Wetted Perimeter (ft)	24.69	12.72	15.44
Hydraulic Radius (ft)	1.33	0.81	1.46
Begin BKF Station	210	210	220.68
End BKF Station	233	220.68	233

Broad Level Stream Classification

Entrenchment Ratio: 10.9 (Slightly Entrenched)

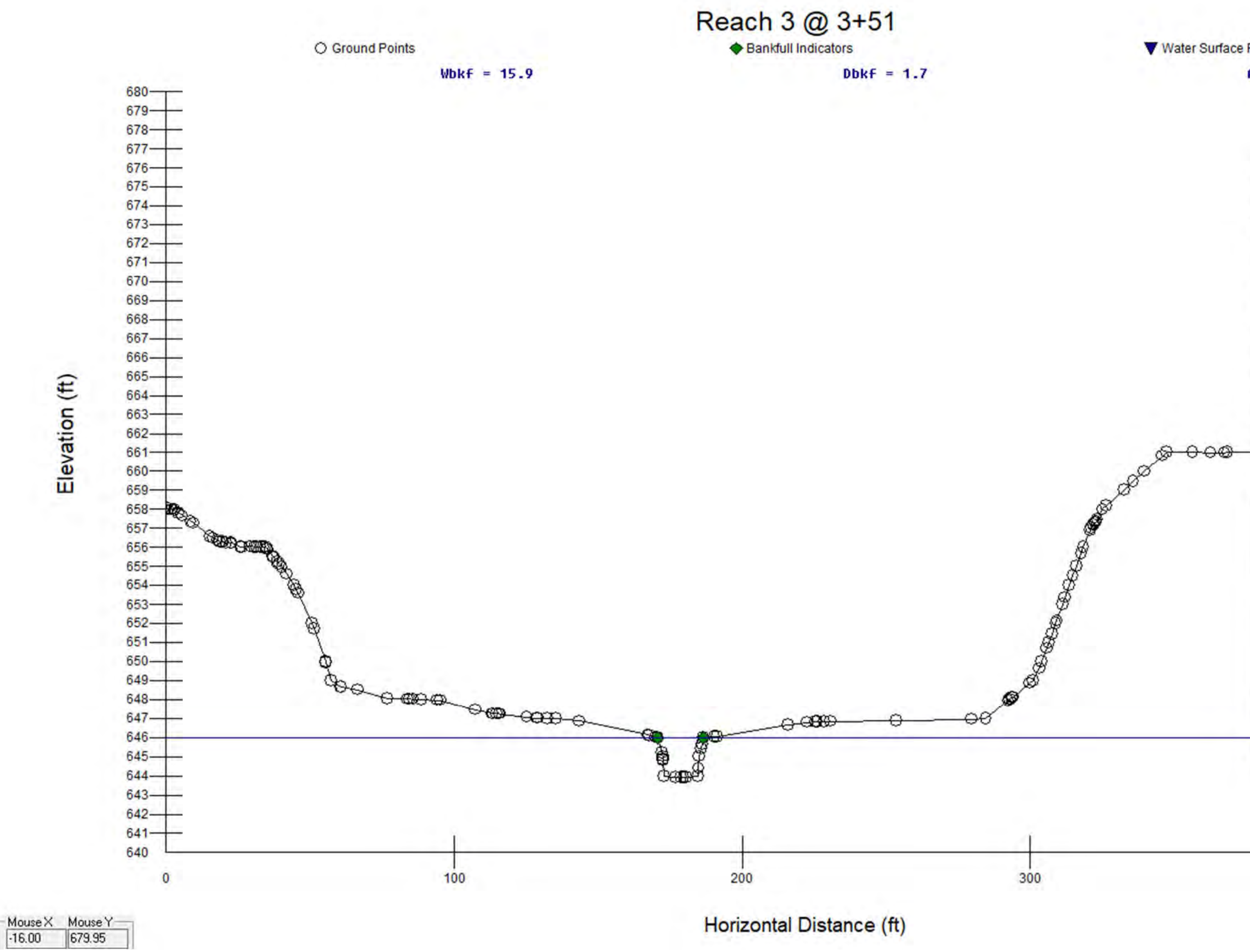
Width to Depth Ratio: 16.2 (Moderate to High)

Classification: C

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0056	0	0
Shear Stress (lb/sq ft)	0.46		
Movable Particle (mm)	26.4		



	Channel	Left	Right
Floodprone Elevation (ft)	648.09	648.09	648.09
Bankfull Elevation (ft)	646	646	646
Floodprone Width (ft)	217.85	-----	-----
Bankfull Width (ft)	15.93	7.96	7.97
Entrenchment Ratio	13.68	-----	-----
Mean Depth (ft)	1.7	1.66	1.73
Maximum Depth (ft)	2.09	2.09	2.09
Width/Depth Ratio	9.37	4.79	4.61
Bankfull Area (sq ft)	27.02	13.22	13.8
Wetted Perimeter (ft)	18.02	10.98	11.22
Hydraulic Radius (ft)	1.5	1.2	1.23
Begin BKF Station	170.67	170.67	178.63
End BKF Station	186.6	178.63	186.6

Broad Level Stream Classification

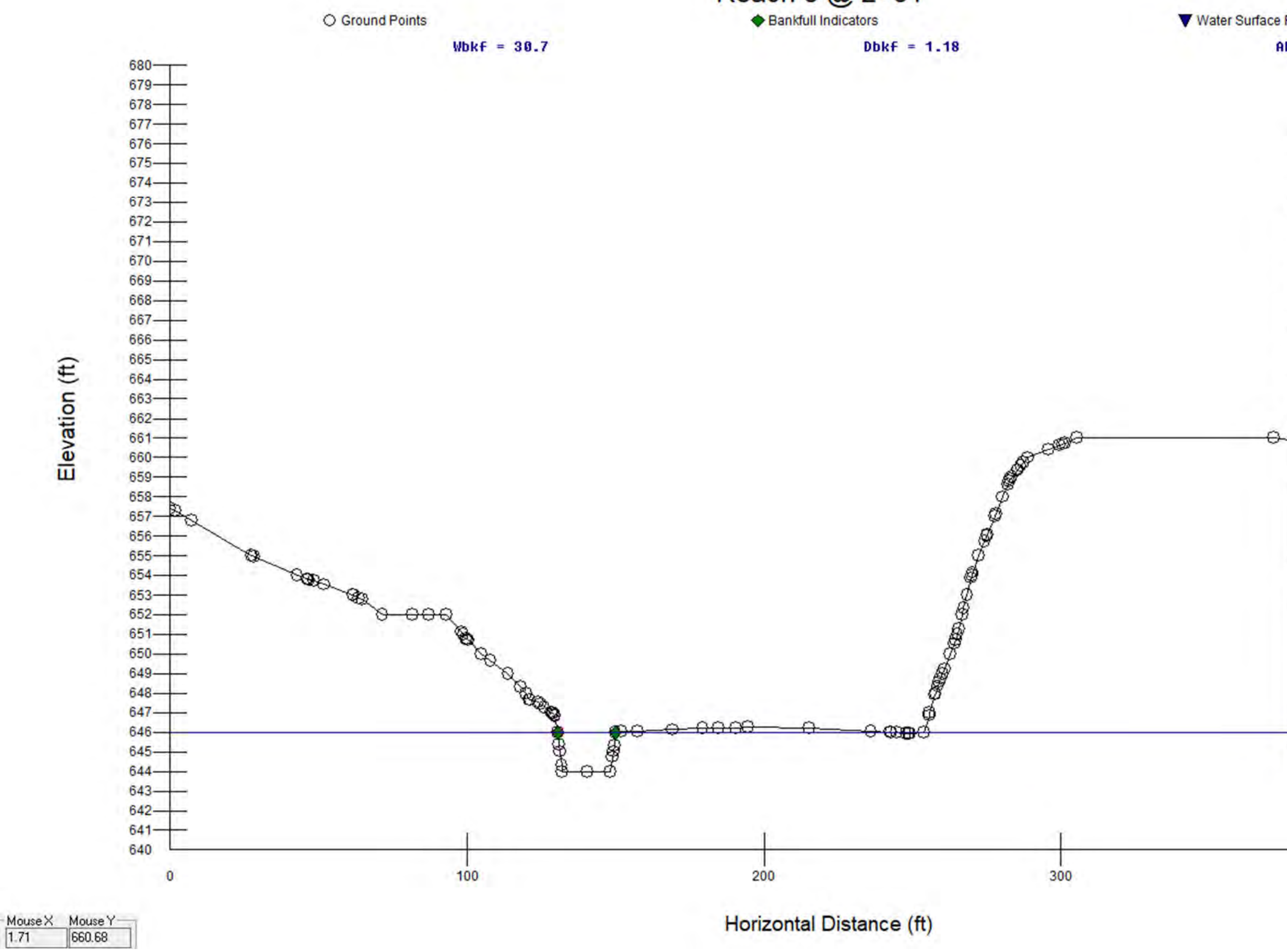
Entrenchment Ratio: 13.68 (Slightly Entrenched)
Width to Depth Ratio: 9.37 (Low)
Classification: E

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0024	0	0
Shear Stress (lb/sq ft)	0.22		
Movable Particle (mm)	12.7		

Reach 3 @ 2+51



	Channel	Left	Right
Floodprone Elevation (ft)	648	648	648
Bankfull Elevation (ft)	646	646	646
Floodprone Width (ft)	137.88	-----	-----
Bankfull Width (ft)	30.72	15.36	108.25
Entrenchment Ratio	4.49	-----	-----
Mean Depth (ft)	1.18	1.9	0.47
Maximum Depth (ft)	2	2	2
Width/Depth Ratio	26.03	8.1	230.32
Bankfull Area (sq ft)	36.37	29.14	7.23
Wetted Perimeter (ft)	32.66	18.29	18.37
Hydraulic Radius (ft)	1.11	1.59	0.39
Begin BKF Station	130.43	130.43	145.79
End BKF Station	254.04	145.79	254.04

Broad Level Stream Classification

Entrenchment Ratio: 4.49 (Slightly Entrenched)

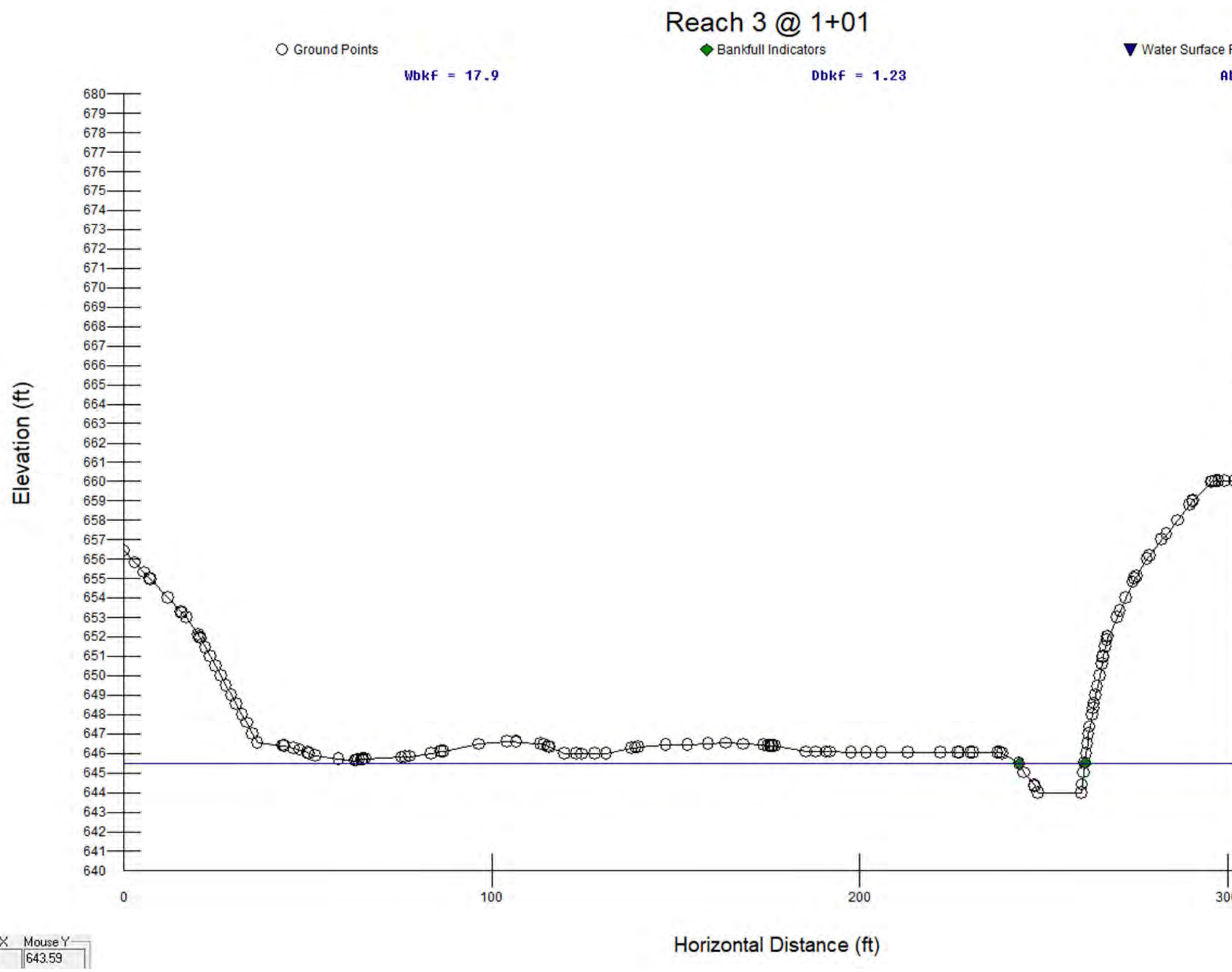
Width to Depth Ratio: 26.03 (Moderate to High)

Classification: C

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0018	0	0
Shear Stress (lb/sq ft)	0.12		
Movable Particle (mm)	8.0		



	Channel	Left	Right
Floodprone Elevation (ft)	646.98	646.98	646.98
Bankfull Elevation (ft)	645.49	645.49	645.49
Floodprone Width (ft)	227.13	-----	-----
Bankfull Width (ft)	17.92	8.96	8.96
Entrenchment Ratio	12.67	-----	-----
Mean Depth (ft)	1.23	1.06	1.4
Maximum Depth (ft)	1.49	1.49	1.49
Width/Depth Ratio	14.57	8.44	6.4
Bankfull Area (sq ft)	22.07	9.51	12.56
Wetted Perimeter (ft)	18.9	10.67	11.21
Hydraulic Radius (ft)	1.17	0.89	1.12
Begin BKF Station	243.36	243.36	252.32
End BKF Station	261.28	252.32	261.28

Broad Level Stream Classification

Entrenchment Ratio: 12.67 (Slightly Entrenched)

Width to Depth Ratio: 14.57 (Moderate to High)

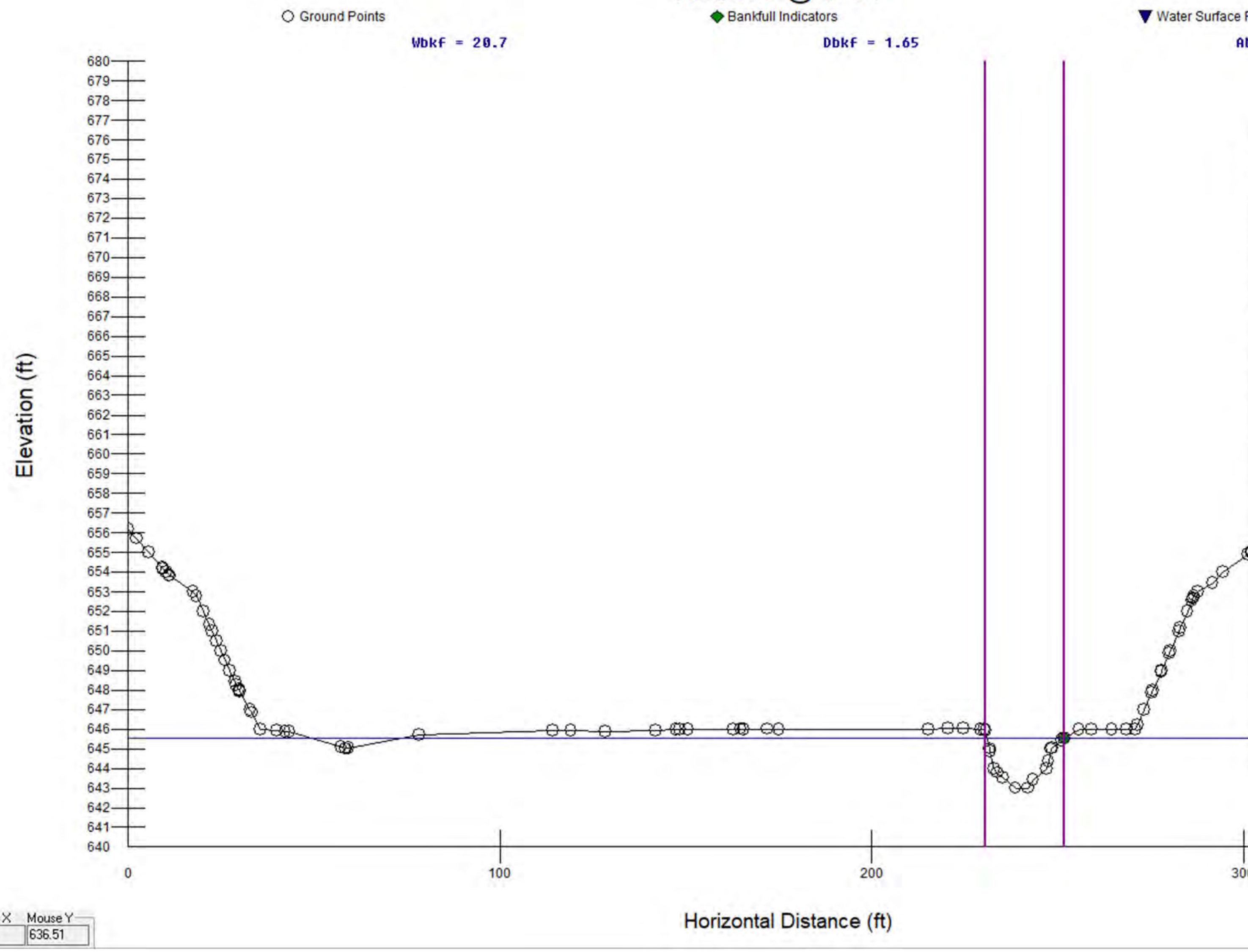
Classification: C

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0089	0	0
Shear Stress (lb/sq ft)	0.65		
Movable Particle (mm)	39.4		

Reach 3 @ 0+51



	Channel	Left	Right
Floodprone Elevation (ft)	648	648	648
Bankfull Elevation (ft)	645.5	645.5	645.5
Floodprone Width (ft)	245.76	-----	-----
Bankfull Width (ft)	20.37	10.22	10.14
Entrenchment Ratio	12.07	-----	-----
Mean Depth (ft)	1.64	1.94	1.33
Maximum Depth (ft)	2.5	2.5	2.5
Width/Depth Ratio	12.42	5.27	7.62
Bankfull Area (sq ft)	33.33	19.85	13.48
Wetted Perimeter (ft)	21.55	13.38	13.17
Hydraulic Radius (ft)	1.55	1.48	1.02
Begin BKF Station	231.1	231.1	241.32
End BKF Station	251.46	241.32	251.46

Broad Level Stream Classification

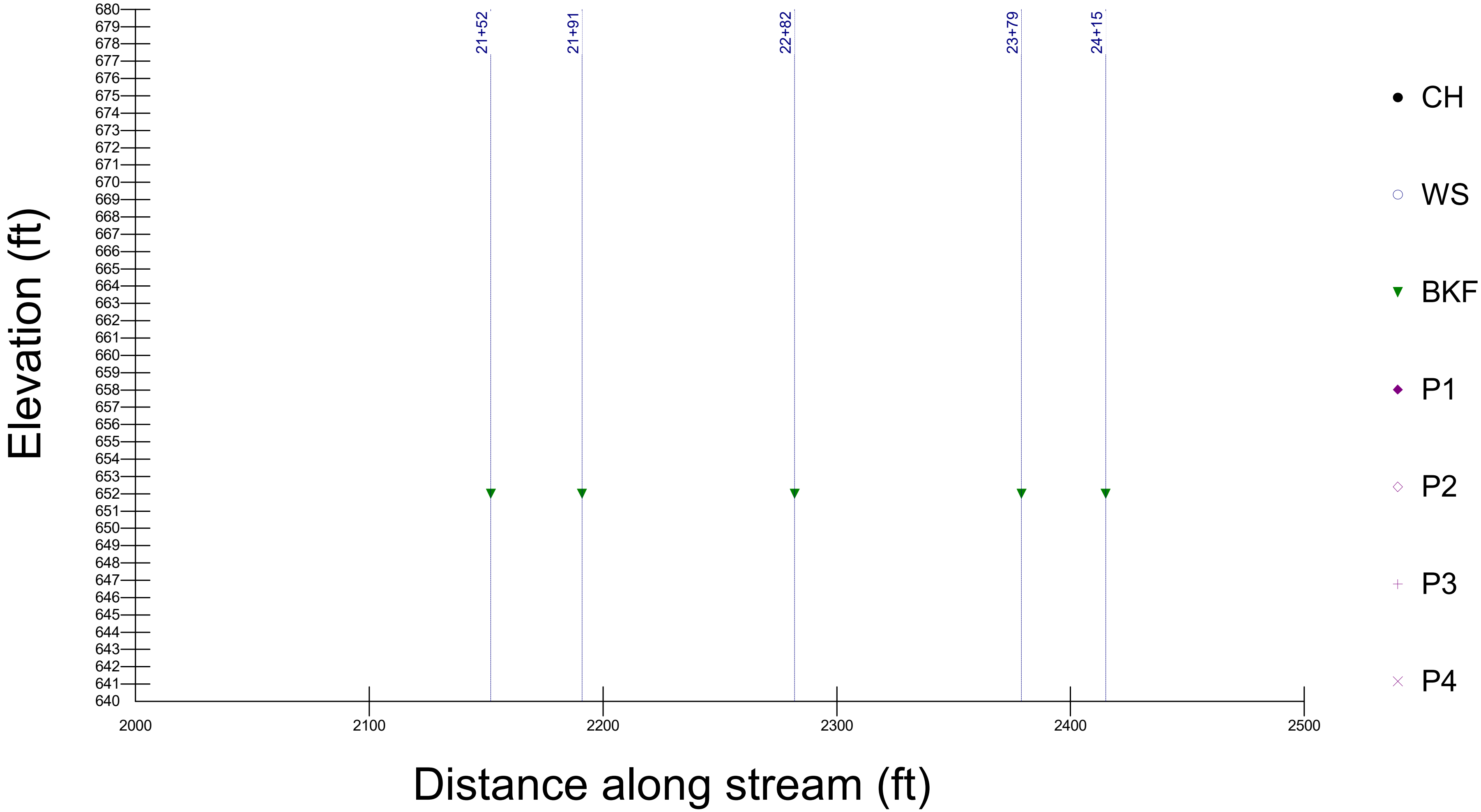
Entrenchment Ratio: 12.07 (Slightly Entrenched)
Width to Depth Ratio: 12.42 (Moderate to High)
Classification: C

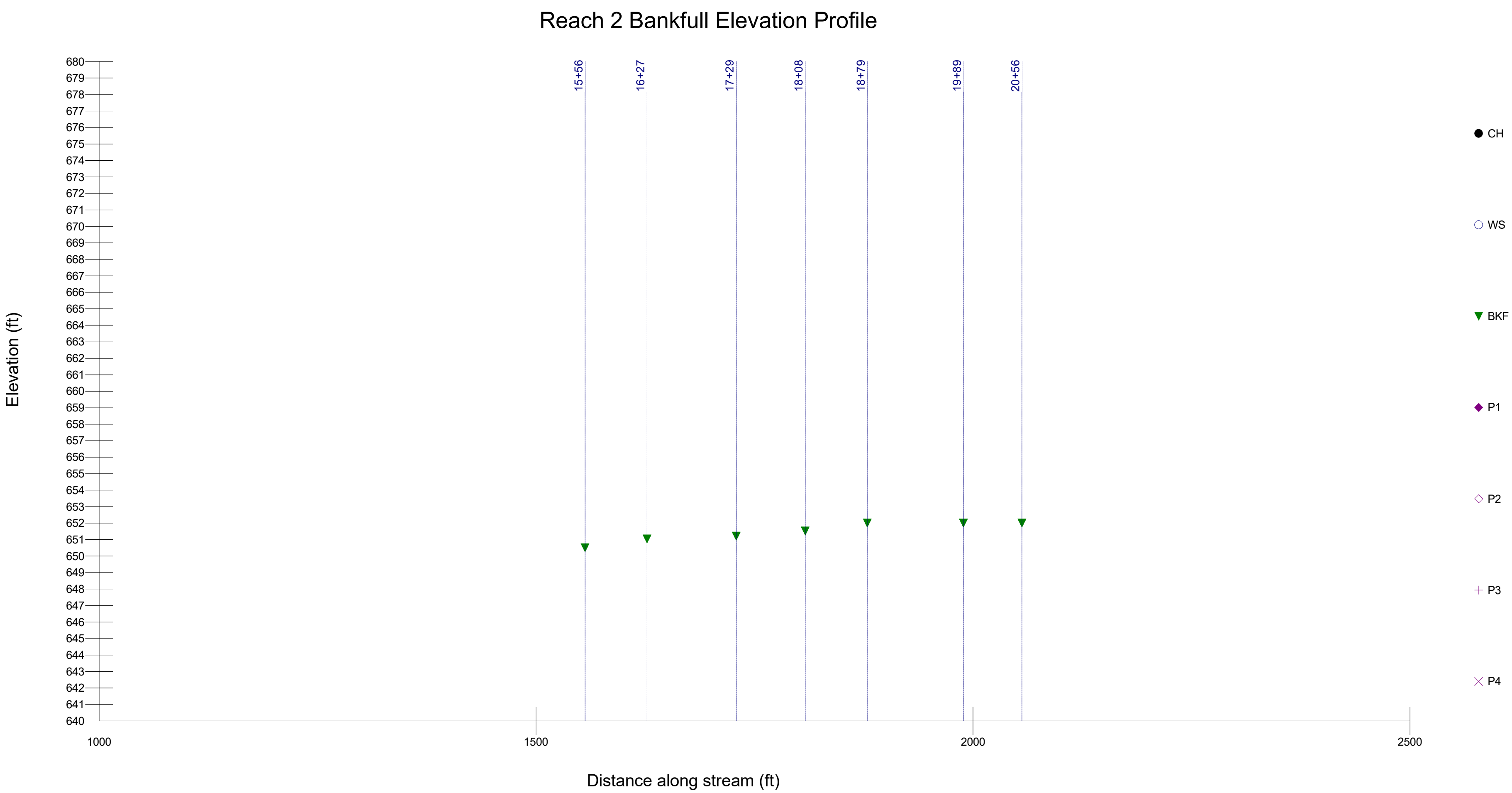
Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0043	0	0
Shear Stress (lb/sq ft)	0.42		
Movable Particle (mm)	22.9		

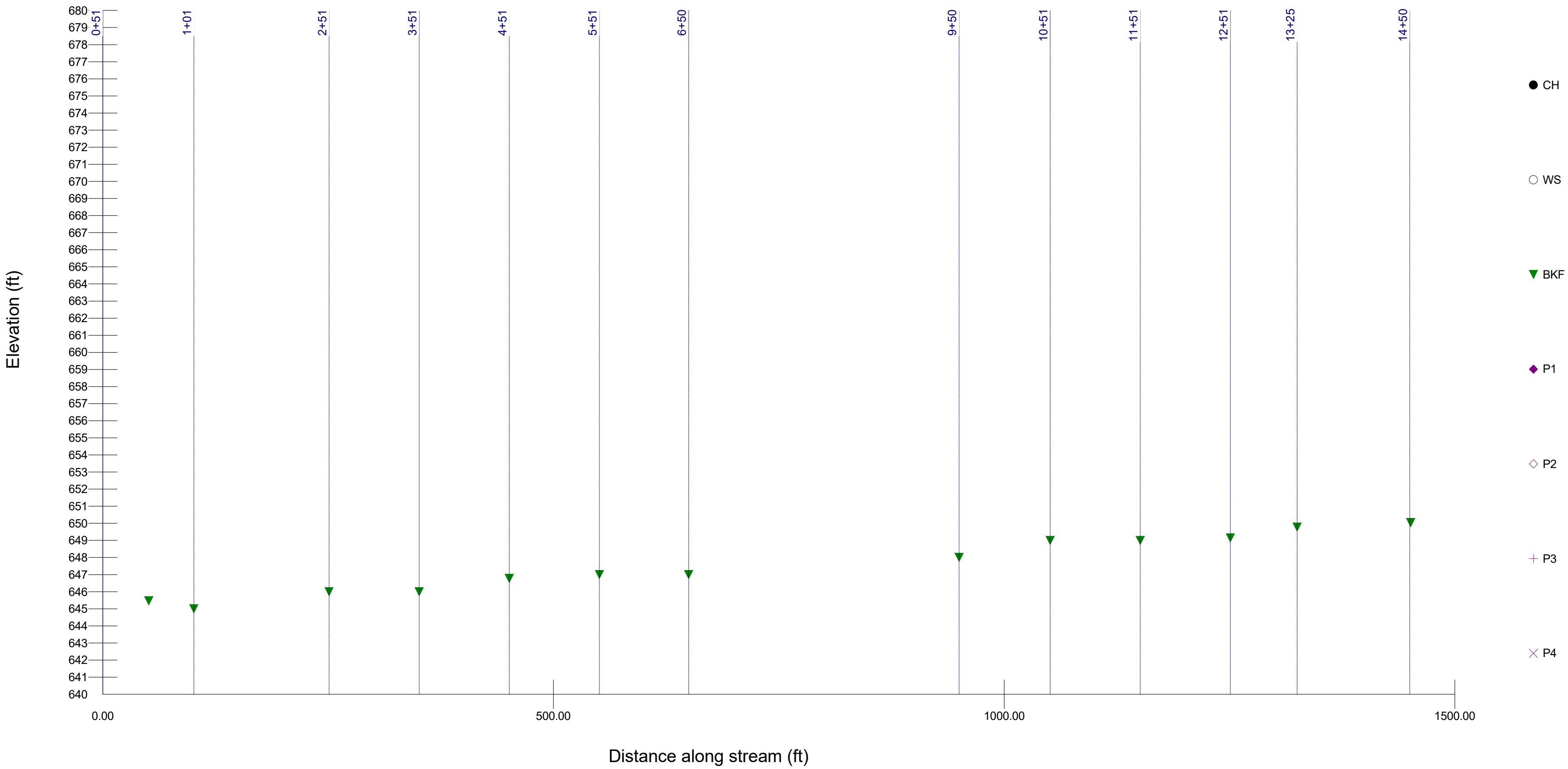
Reach 1 Bankfull Elevation Profile





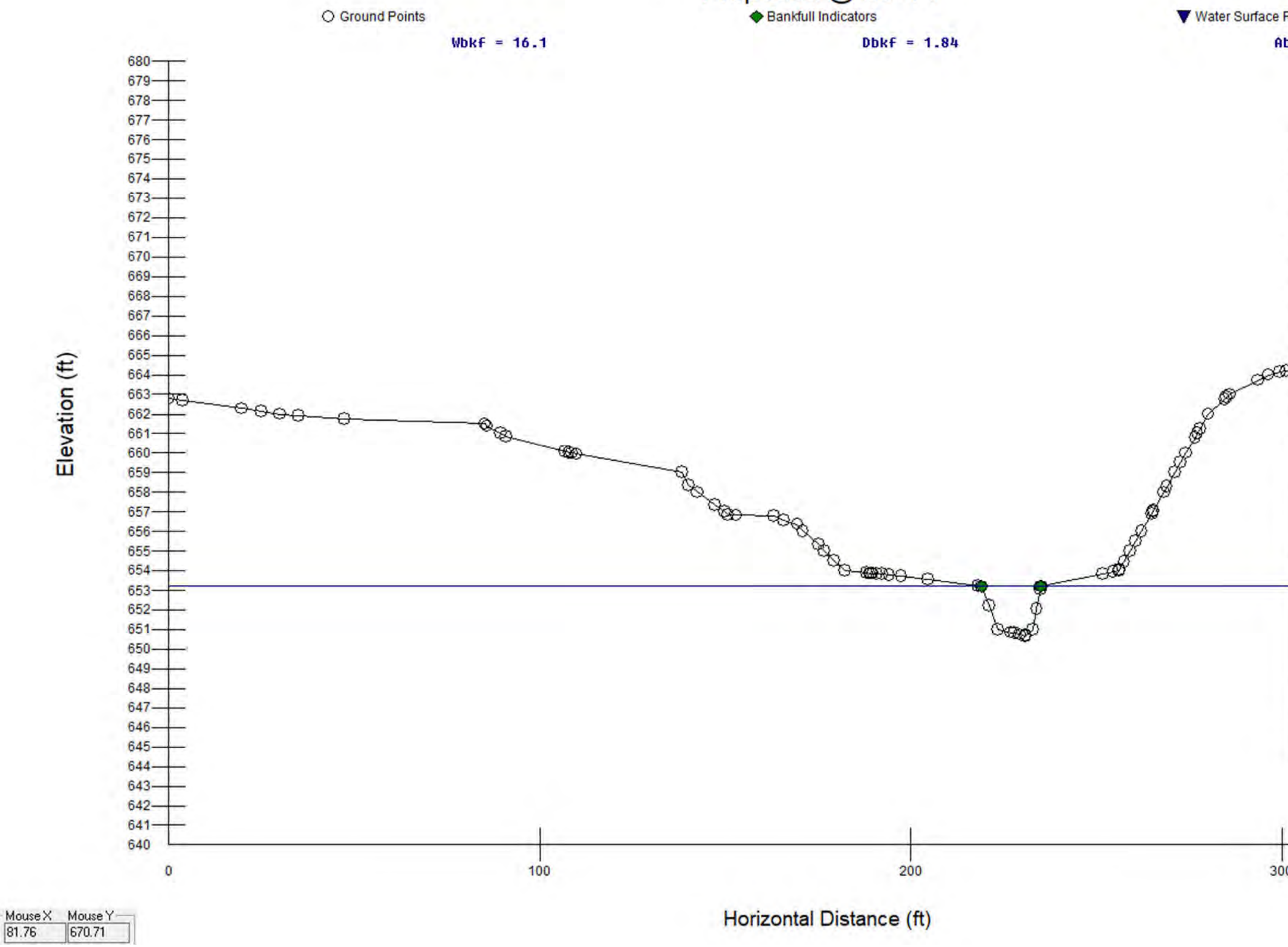
Reach 2 Bankfull Elevation Profile
Elevation (ft)
680
679
678
677
676
675
674
673
672
671
670
669
668
667
666
665
664
663
662
661
660
659
658
657
656
655
654
653
652
651
650
649
648
647
646
645
644
643
642
641
640
1000
1500
2000
2500
Distance along stream (ft)
15+56
16+27
17+29
18+08
18+79
19+89
20+56
CH
WS
BKF
P1
P2
P3
P4

Reach 3 Bankfull Elevation Profile



Appendix E

Proposed @ 25+71



	Channel	Left	Right
Floodprone Elevation (ft)	655.75	655.75	655.75
Bankfull Elevation (ft)	653.2	653.2	653.2
Floodprone Width (ft)	88.9	-----	-----
Bankfull Width (ft)	16.07	8.04	8.03
Entrenchment Ratio	5.53	-----	-----
Mean Depth (ft)	1.84	1.62	2.05
Maximum Depth (ft)	2.55	2.35	2.55
Width/Depth Ratio	8.73	4.95	3.92
Bankfull Area (sq ft)	29.52	13.05	16.47
Wetted Perimeter (ft)	17.54	10.91	11.32
Hydraulic Radius (ft)	1.68	1.2	1.45
Begin BKF Station	218.99	218.99	227.03
End BKF Station	235.06	227.03	235.06

Broad Level Stream Classification

Entrenchment Ratio: 5.53 (Slightly Entrenched)

Width to Depth Ratio: 8.73 (Low)

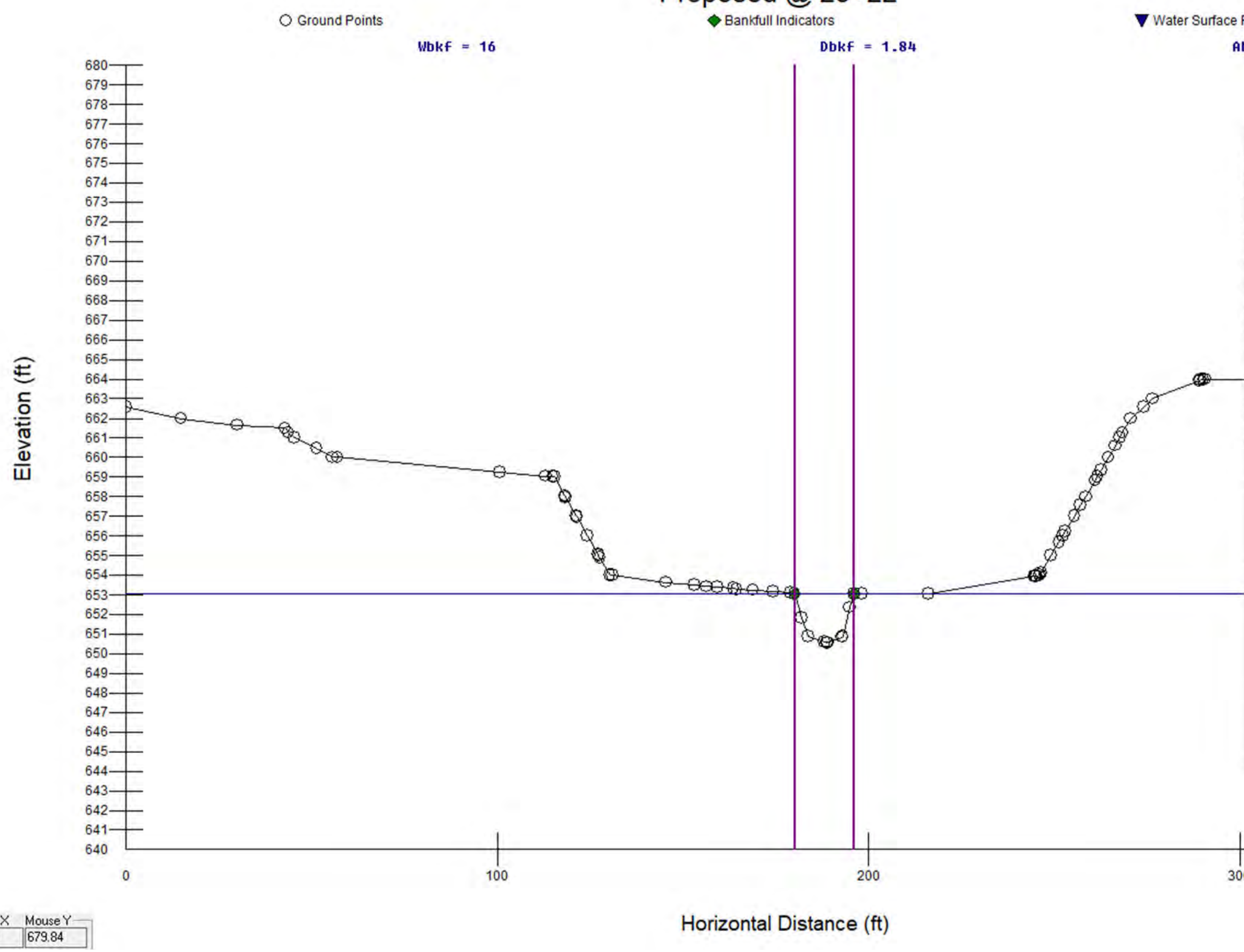
Classification: E

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0027	0	0
Shear Stress (lb/sq ft)	0.28		
Movable Particle (mm)	15.4		

Proposed @ 25+22



	Channel	Left	Right
Floodprone Elevation (ft)	655.57	655.57	655.57
Bankfull Elevation (ft)	653.07	653.07	653.07
Floodprone Width (ft)	125.36	-----	-----
Bankfull Width (ft)	15.95	7.98	7.97
Entrenchment Ratio	7.86	-----	-----
Mean Depth (ft)	1.84	1.79	1.89
Maximum Depth (ft)	2.5	2.46	2.5
Width/Depth Ratio	8.67	4.45	4.22
Bankfull Area (sq ft)	29.33	14.3	15.03
Wetted Perimeter (ft)	17.33	11.07	11.17
Hydraulic Radius (ft)	1.69	1.29	1.35
Begin BKF Station	180.05	180.05	188.03
End BKF Station	196	188.03	196

Broad Level Stream Classification

Entrenchment Ratio: 7.86 (Slightly Entrenched)

Width to Depth Ratio: 8.67 (Low)

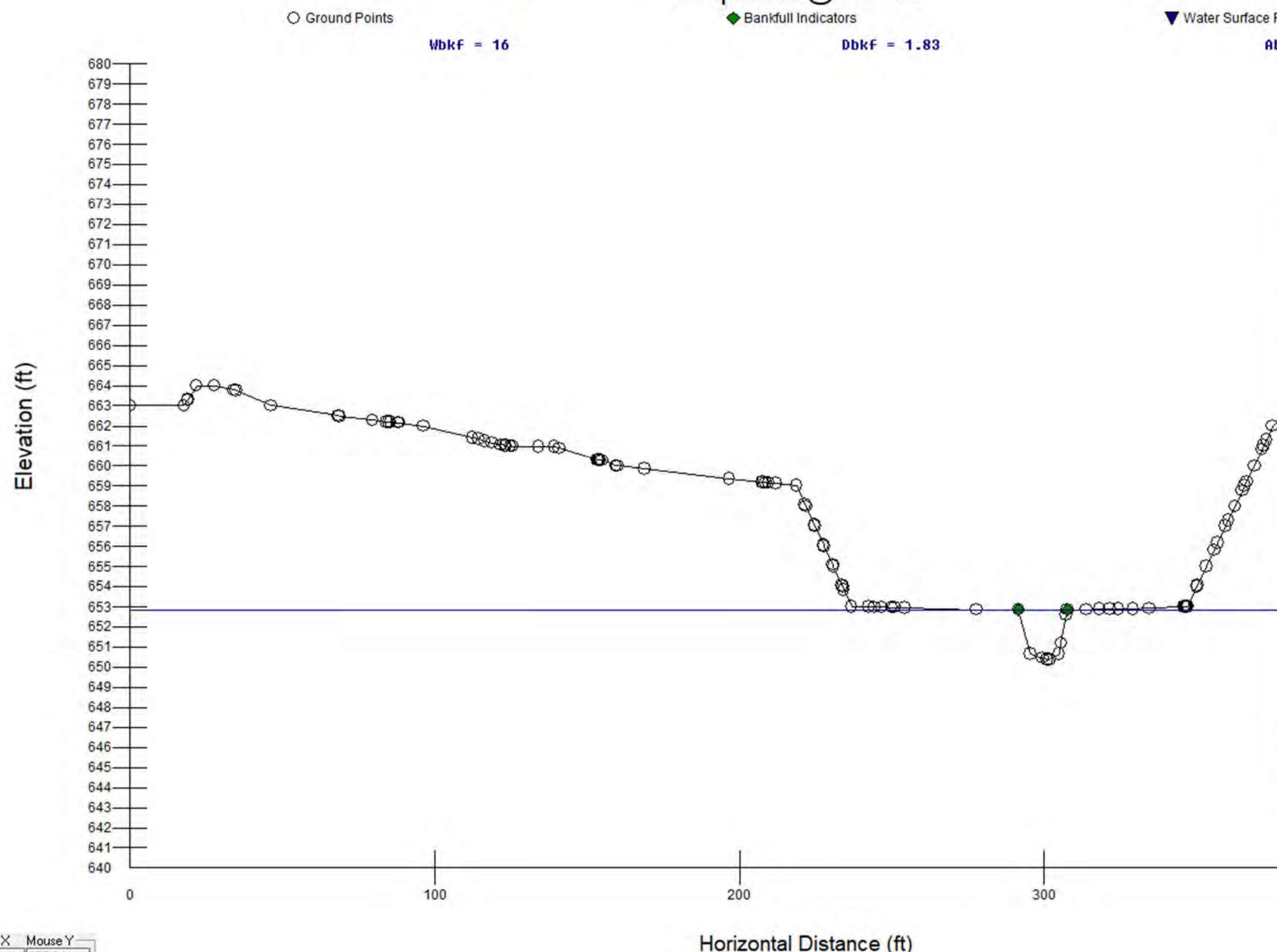
Classification: E

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0027	0	0
Shear Stress (lb/sq ft)	0.28		
Movable Particle (mm)	15.5		

Proposed @ 24+41



	Channel	Left	Right
Floodprone Elevation (ft)	655.36	655.36	655.36
Bankfull Elevation (ft)	652.86	652.86	652.86
Floodprone Width (ft)	124.76	-----	-----
Bankfull Width (ft)	16	8	8
Entrenchment Ratio	7.8	-----	-----
Mean Depth (ft)	1.83	1.72	1.94
Maximum Depth (ft)	2.5	2.4	2.5
Width/Depth Ratio	8.74	4.66	4.12
Bankfull Area (sq ft)	29.28	13.72	15.56
Wetted Perimeter (ft)	17.37	10.98	11.19
Hydraulic Radius (ft)	1.69	1.25	1.39
Begin BKF Station	291.68	291.68	299.68
End BKF Station	307.68	299.68	307.68

Broad Level Stream Classification

Entrenchment Ratio: 7.8 (Slightly Entrenched)

Width to Depth Ratio: 8.74 (Low)

Classification: E

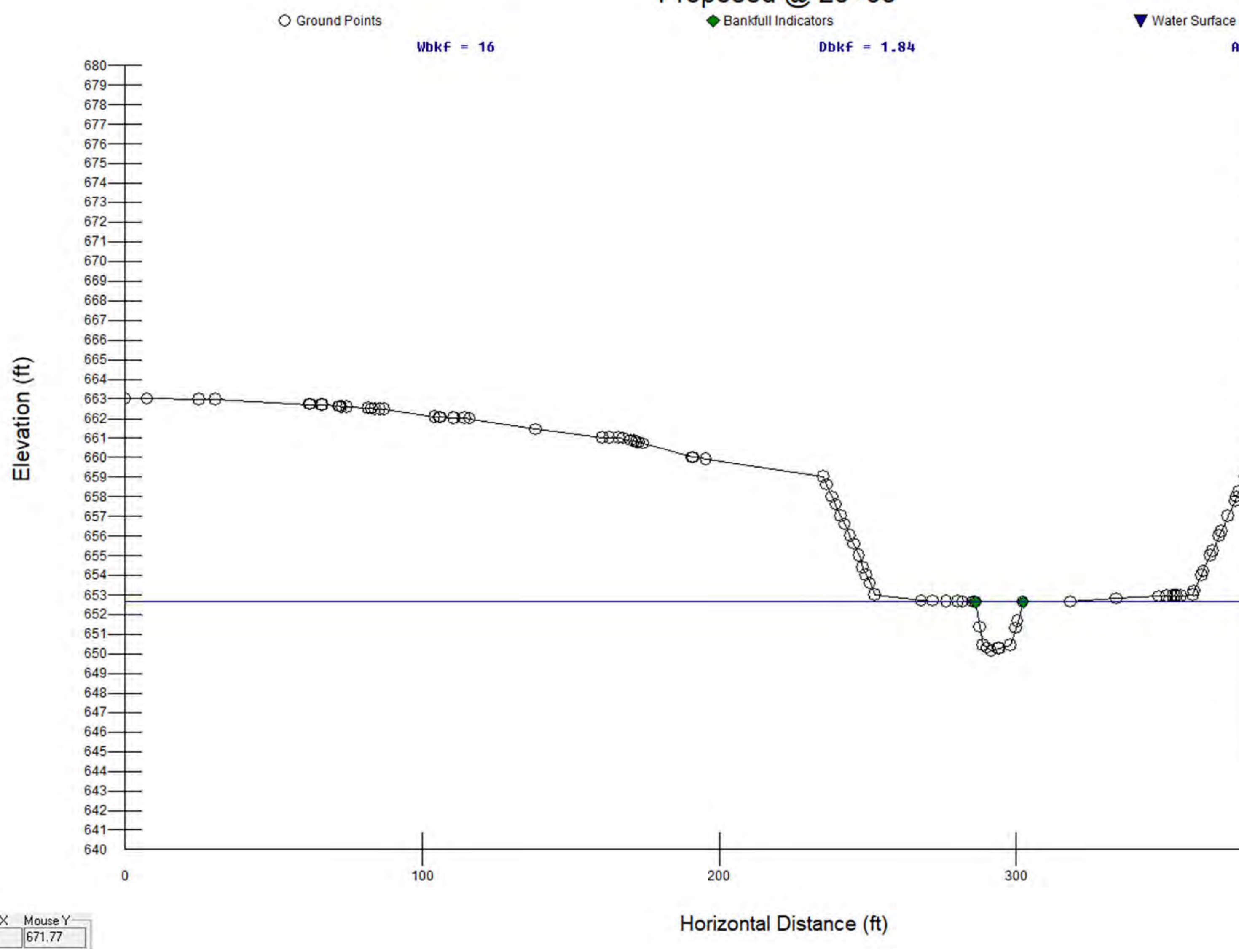
Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0028	0	0
Shear Stress (lb/sq ft)	0.30		
Movable Particle (mm)	16.0		

Mouse X	Mouse Y
-18.92	677.34

Proposed @ 23+58



	Channel	Left	Right
Floodprone Elevation (ft)	655.14	655.14	-----
Bankfull Elevation (ft)	652.64	652.64	-----
Floodprone Width (ft)	119.23	-----	-----
Bankfull Width (ft)	16.01	16.08	-----
Entrenchment Ratio	7.45	-----	-----
Mean Depth (ft)	1.84	1.84	-----
Maximum Depth (ft)	2.5	2.5	-----
Width/Depth Ratio	8.7	8.76	-----
Bankfull Area (sq ft)	29.39	29.39	-----
Wetted Perimeter (ft)	17.41	17.41	-----
Hydraulic Radius (ft)	1.69	1.69	-----
Begin BKF Station	286.35	286.35	-----
End BKF Station	302.36	302.36	-----

Broad Level Stream Classification

Entrenchment Ratio: 7.45 (Slightly Entrenched)

Width to Depth Ratio: 8.7 (Low)

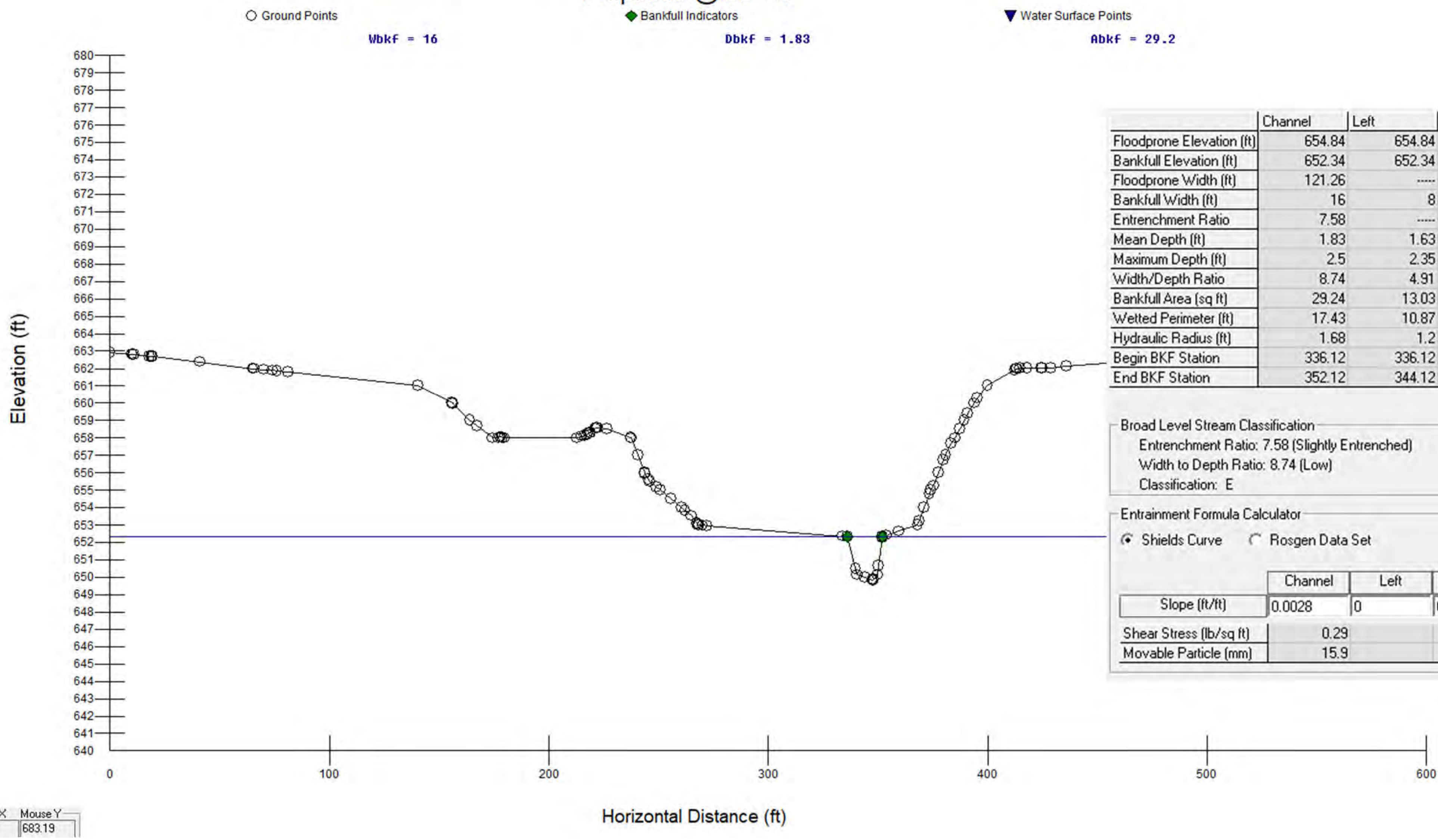
Classification: E

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0027	0	0
Shear Stress (lb/sq ft)	0.28		
Movable Particle (mm)	15.5		

Proposed @ 22+40



	Channel	Left	Right
Floodprone Elevation (ft)	654.84	654.84	654.84
Bankfull Elevation (ft)	652.34	652.34	652.34
Floodprone Width (ft)	121.26	-----	-----
Bankfull Width (ft)	16	8	8
Entrenchment Ratio	7.58	-----	-----
Mean Depth (ft)	1.83	1.63	2.03
Maximum Depth (ft)	2.5	2.35	2.5
Width/Depth Ratio	8.74	4.91	3.94
Bankfull Area (sq ft)	29.24	13.03	16.21
Wetted Perimeter (ft)	17.43	10.87	11.26
Hydraulic Radius (ft)	1.68	1.2	1.44
Begin BKF Station	336.12	336.12	344.12
End BKF Station	352.12	344.12	352.12

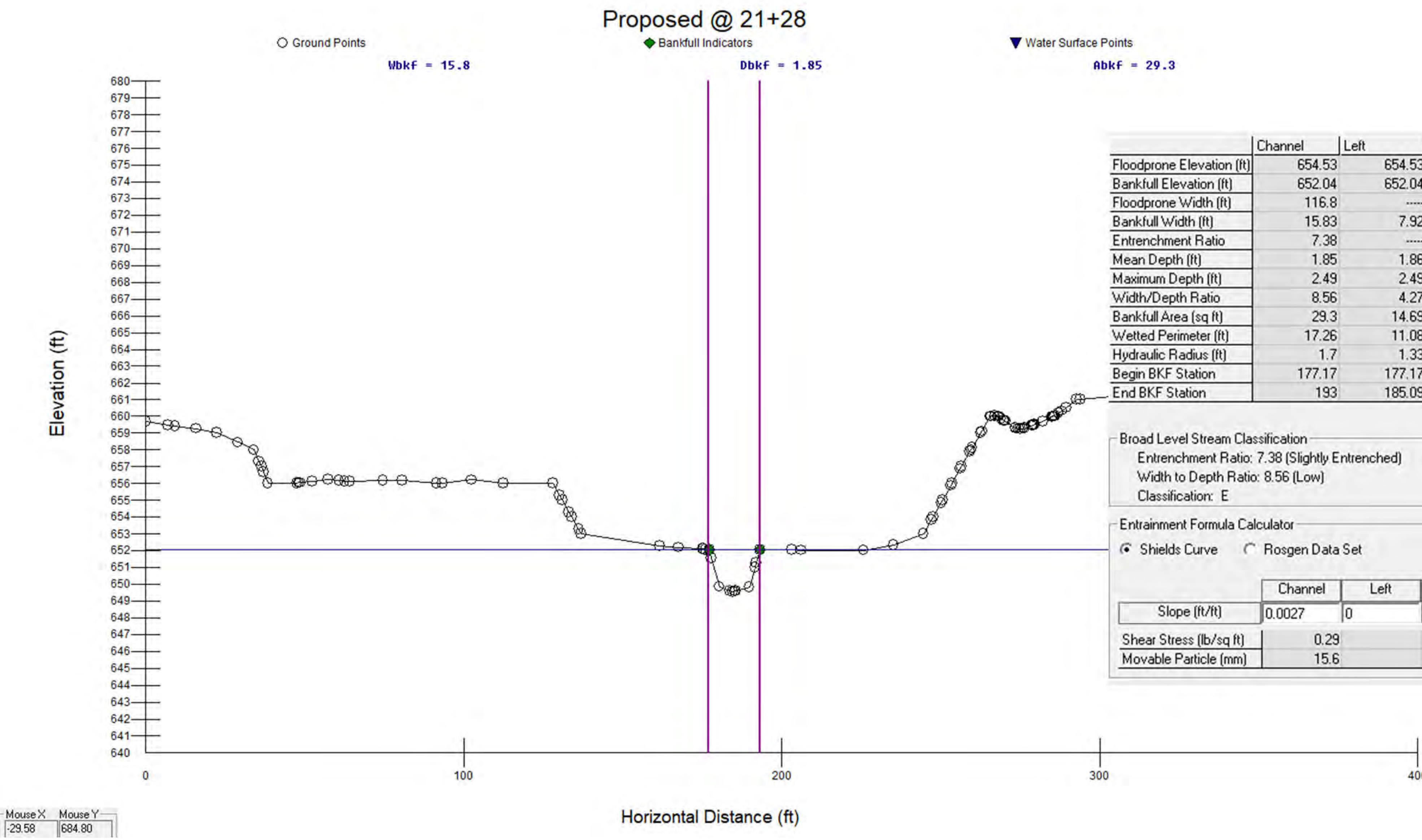
Broad Level Stream Classification

Entrenchment Ratio: 7.58 (Slightly Entrenched)
Width to Depth Ratio: 8.74 (Low)
Classification: E

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0028	0	0
Shear Stress (lb/sq ft)	0.29		
Movable Particle (mm)	15.9		



	Channel	Left	Right
Floodprone Elevation (ft)	654.53	654.53	654.53
Bankfull Elevation (ft)	652.04	652.04	652.04
Floodprone Width (ft)	116.8	-----	-----
Bankfull Width (ft)	15.83	7.92	7.91
Entrenchment Ratio	7.38	-----	-----
Mean Depth (ft)	1.85	1.86	1.85
Maximum Depth (ft)	2.49	2.49	2.47
Width/Depth Ratio	8.56	4.27	4.28
Bankfull Area (sq ft)	29.3	14.69	14.61
Wetted Perimeter (ft)	17.26	11.08	11.12
Hydraulic Radius (ft)	1.7	1.33	1.31
Begin BKF Station	177.17	177.17	185.09
End BKF Station	193	185.09	193

Broad Level Stream Classification

Entrenchment Ratio: 7.38 (Slightly Entrenched)

Width to Depth Ratio: 8.56 (Low)

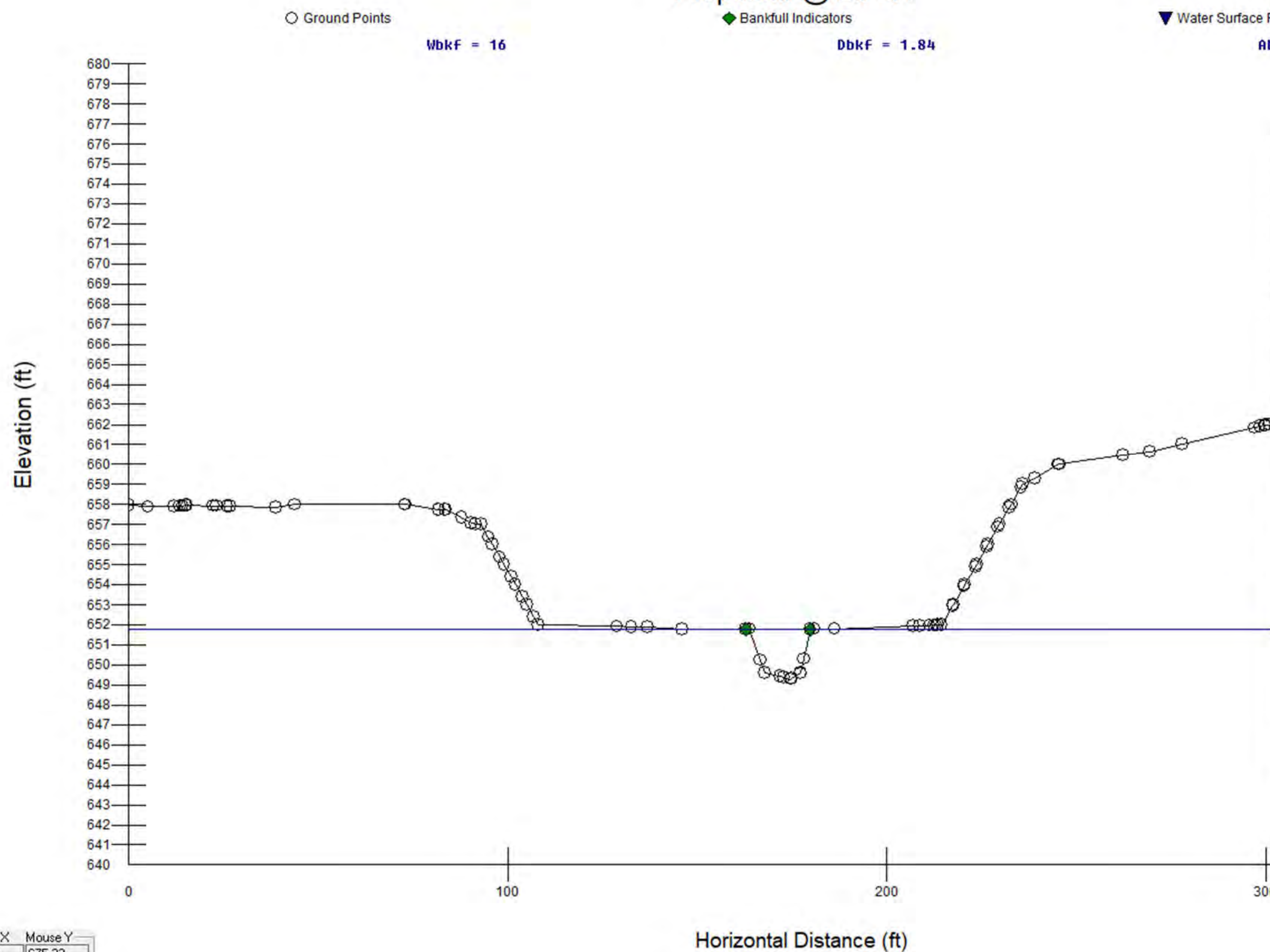
Classification: E

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0027	0	0
Shear Stress (lb/sq ft)	0.29		
Movable Particle (mm)	15.6		

Proposed @ 20+31



	Channel	Left	Right
Floodprone Elevation (ft)	654.29	654.29	654.29
Bankfull Elevation (ft)	651.79	651.79	651.79
Floodprone Width (ft)	120.39	-----	-----
Bankfull Width (ft)	16	8	8
Entrenchment Ratio	7.52	-----	-----
Mean Depth (ft)	1.84	1.68	2
Maximum Depth (ft)	2.5	2.37	2.5
Width/Depth Ratio	8.7	4.76	4
Bankfull Area (sq ft)	29.47	13.45	16.03
Wetted Perimeter (ft)	17.42	10.93	11.24
Hydraulic Radius (ft)	1.69	1.23	1.43
Begin BKF Station	163.74	163.74	171.74
End BKF Station	179.74	171.74	179.74

Broad Level Stream Classification

Entrenchment Ratio: 7.52 (Slightly Entrenched)

Width to Depth Ratio: 8.7 (Low)

Classification: E

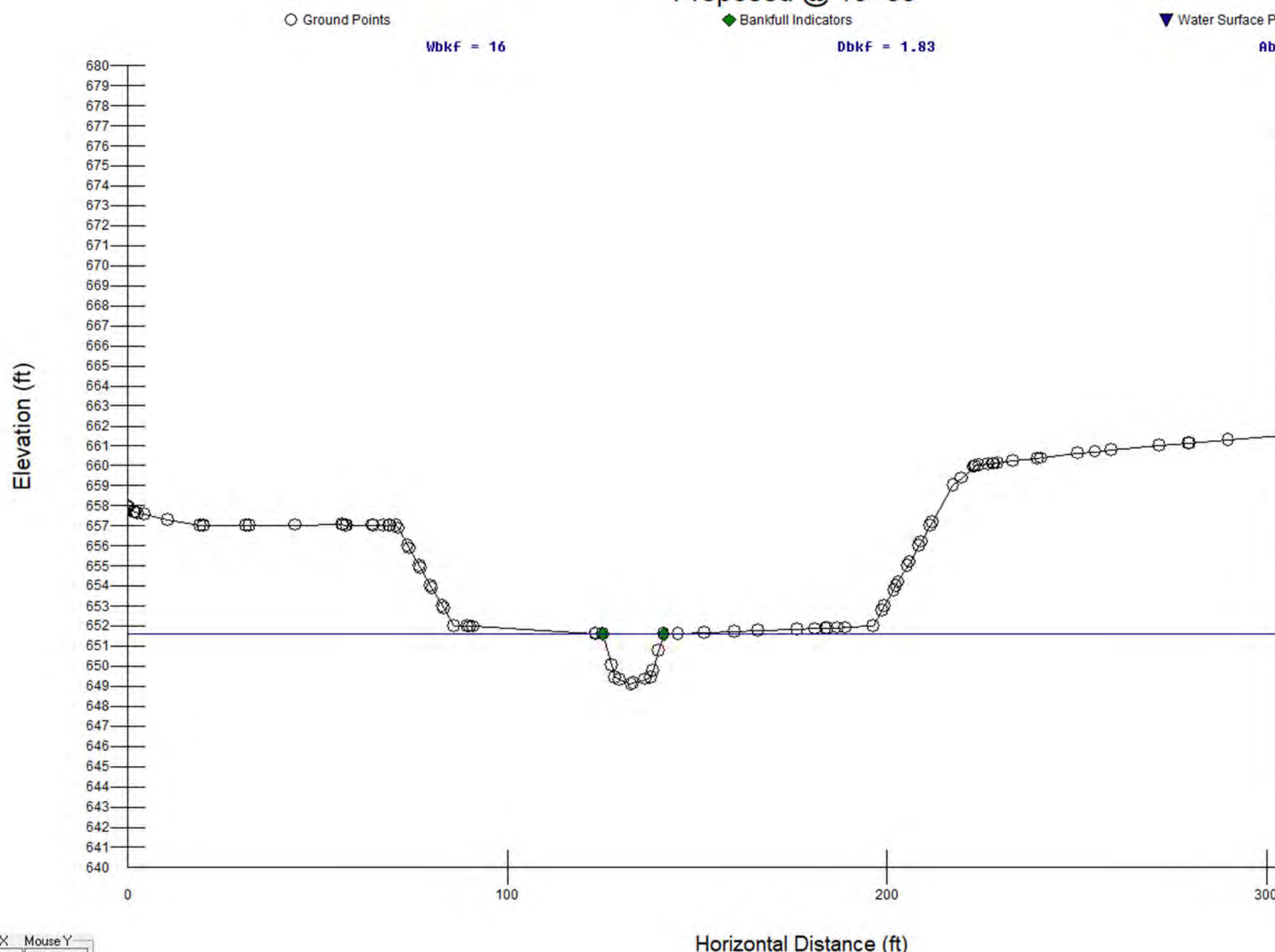
Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0027	0	0
Shear Stress (lb/sq ft)	0.28		
Movable Particle (mm)	15.5		

Mouse X	Mouse Y
-29.90	675.22

Proposed @ 19+65



	Channel	Left	Right
Floodprone Elevation (ft)	654.12	654.12	654.12
Bankfull Elevation (ft)	651.62	651.62	651.62
Floodprone Width (ft)	123.34	-----	-----
Bankfull Width (ft)	16.01	8	8.01
Entrenchment Ratio	7.7	-----	-----
Mean Depth (ft)	1.83	1.86	1.8
Maximum Depth (ft)	2.5	2.5	2.46
Width/Depth Ratio	8.75	4.3	4.45
Bankfull Area (sq ft)	29.27	14.88	14.39
Wetted Perimeter (ft)	17.36	11.16	11.12
Hydraulic Radius (ft)	1.69	1.33	1.29
Begin BKF Station	125.13	125.13	133.13
End BKF Station	141.14	133.13	141.14

Broad Level Stream Classification

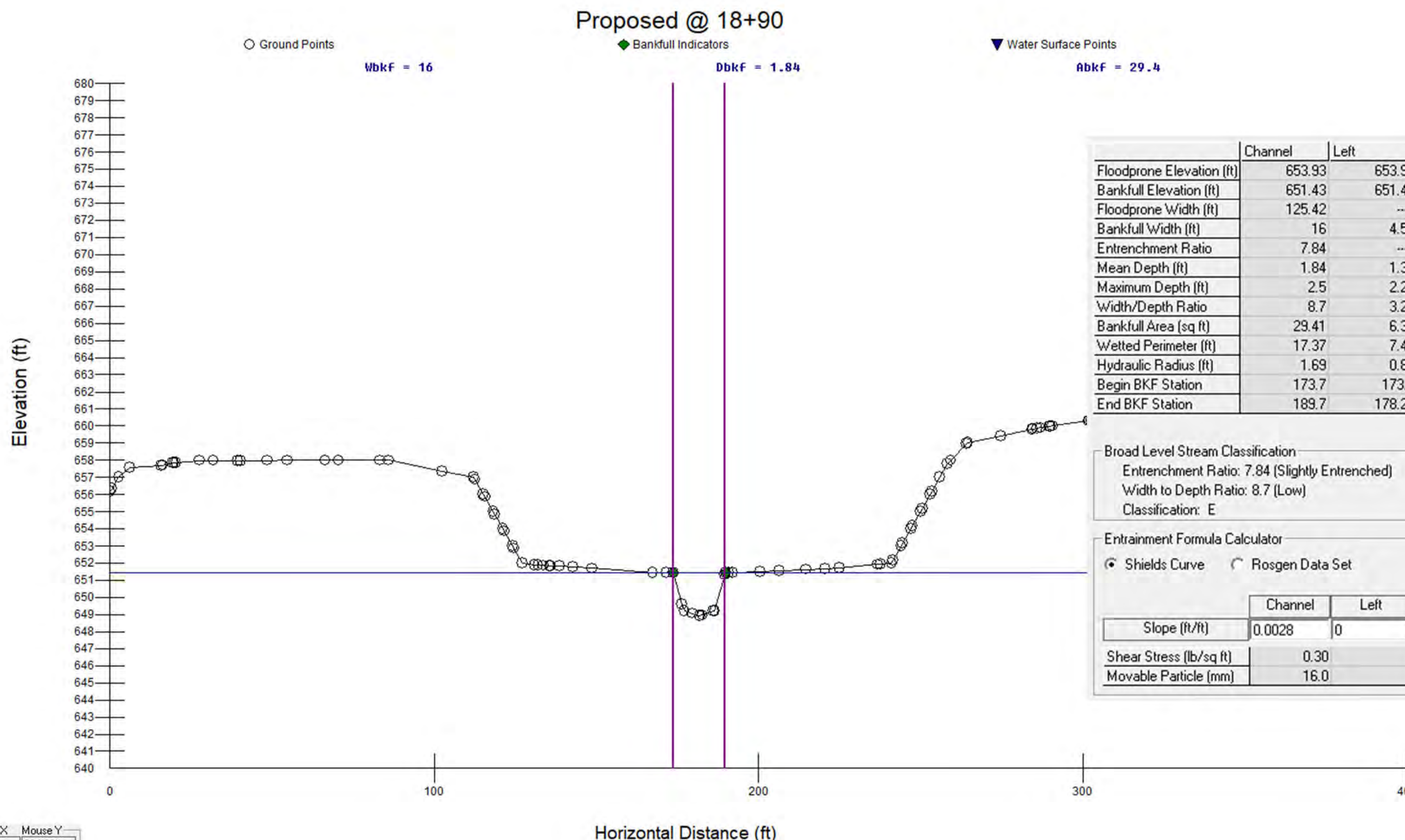
Entrenchment Ratio: 7.7 (Slightly Entrenched)
Width to Depth Ratio: 8.75 (Low)
Classification: E

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0028	0	0
Shear Stress (lb/sq ft)	0.30		
Movable Particle (mm)	16.0		

Mouse X	Mouse Y
-37.56	673.06



	Channel	Left	Right
Floodprone Elevation (ft)	653.93	653.93	653.93
Bankfull Elevation (ft)	651.43	651.43	651.43
Floodprone Width (ft)	125.42	-----	-----
Bankfull Width (ft)	16	4.54	11.46
Entrenchment Ratio	7.84	-----	-----
Mean Depth (ft)	1.84	1.39	2.01
Maximum Depth (ft)	2.5	2.27	2.5
Width/Depth Ratio	8.7	3.25	5.7
Bankfull Area (sq ft)	29.41	6.33	23.08
Wetted Perimeter (ft)	17.37	7.48	14.44
Hydraulic Radius (ft)	1.69	0.85	1.6
Begin BKF Station	173.7	173.7	178.24
End BKF Station	189.7	178.24	189.7

Broad Level Stream Classification

Entrenchment Ratio: 7.84 (Slightly Entrenched)

Width to Depth Ratio: 8.7 (Low)

Classification: E

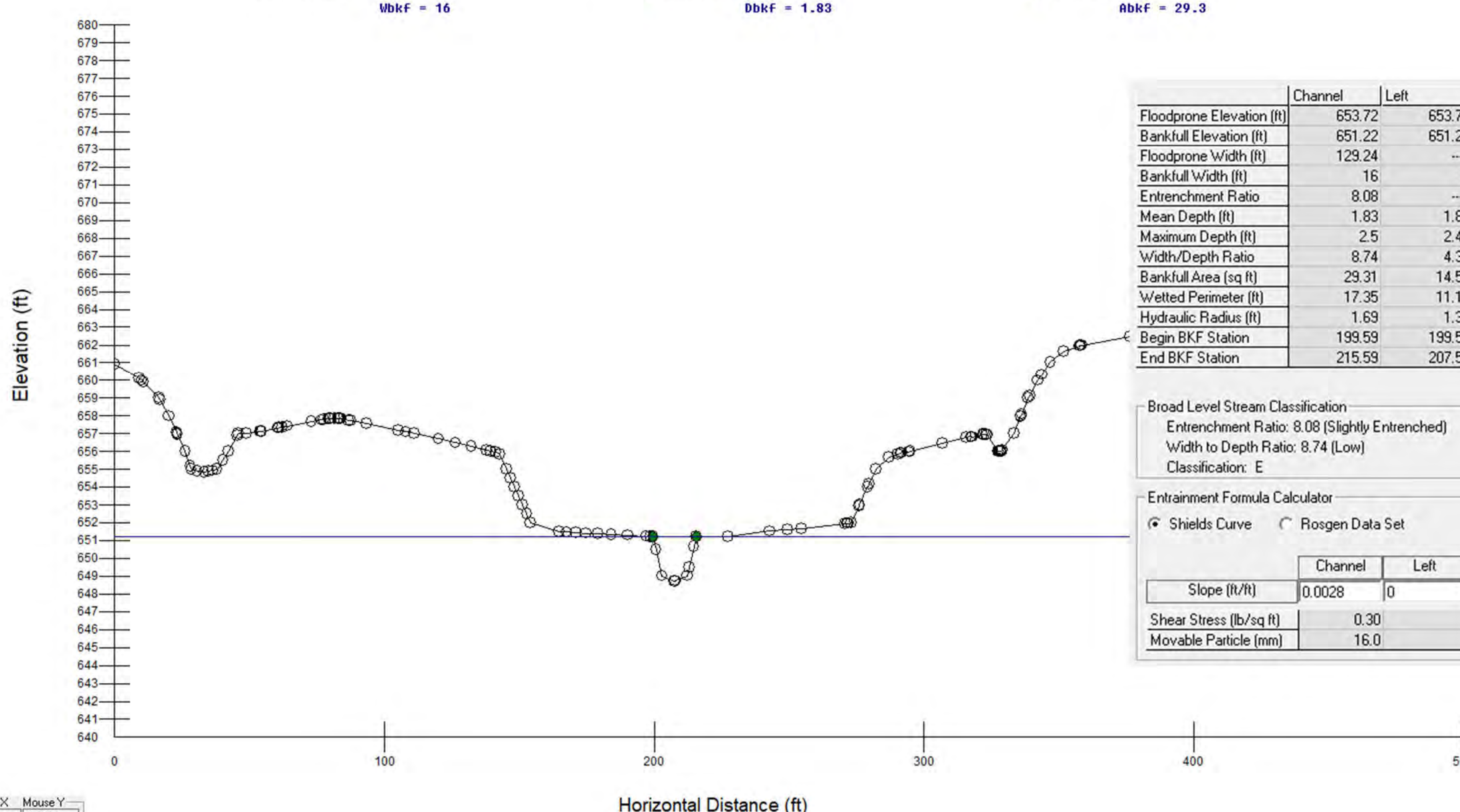
Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0028	0	0
Shear Stress (lb/sq ft)	0.30		
Movable Particle (mm)	16.0		

Mouse X	Mouse Y
-33.43	684.36

Proposed @ 18+12



	Channel	Left	Right
Floodprone Elevation (ft)	653.72	653.72	653.72
Bankfull Elevation (ft)	651.22	651.22	651.22
Floodprone Width (ft)	129.24	-----	-----
Bankfull Width (ft)	16	8	8
Entrenchment Ratio	8.08	-----	-----
Mean Depth (ft)	1.83	1.82	1.84
Maximum Depth (ft)	2.5	2.49	2.5
Width/Depth Ratio	8.74	4.39	4.35
Bankfull Area (sq ft)	29.31	14.58	14.73
Wetted Perimeter (ft)	17.35	11.16	11.17
Hydraulic Radius (ft)	1.69	1.31	1.32
Begin BKF Station	199.59	199.59	207.59
End BKF Station	215.59	207.59	215.59

Broad Level Stream Classification

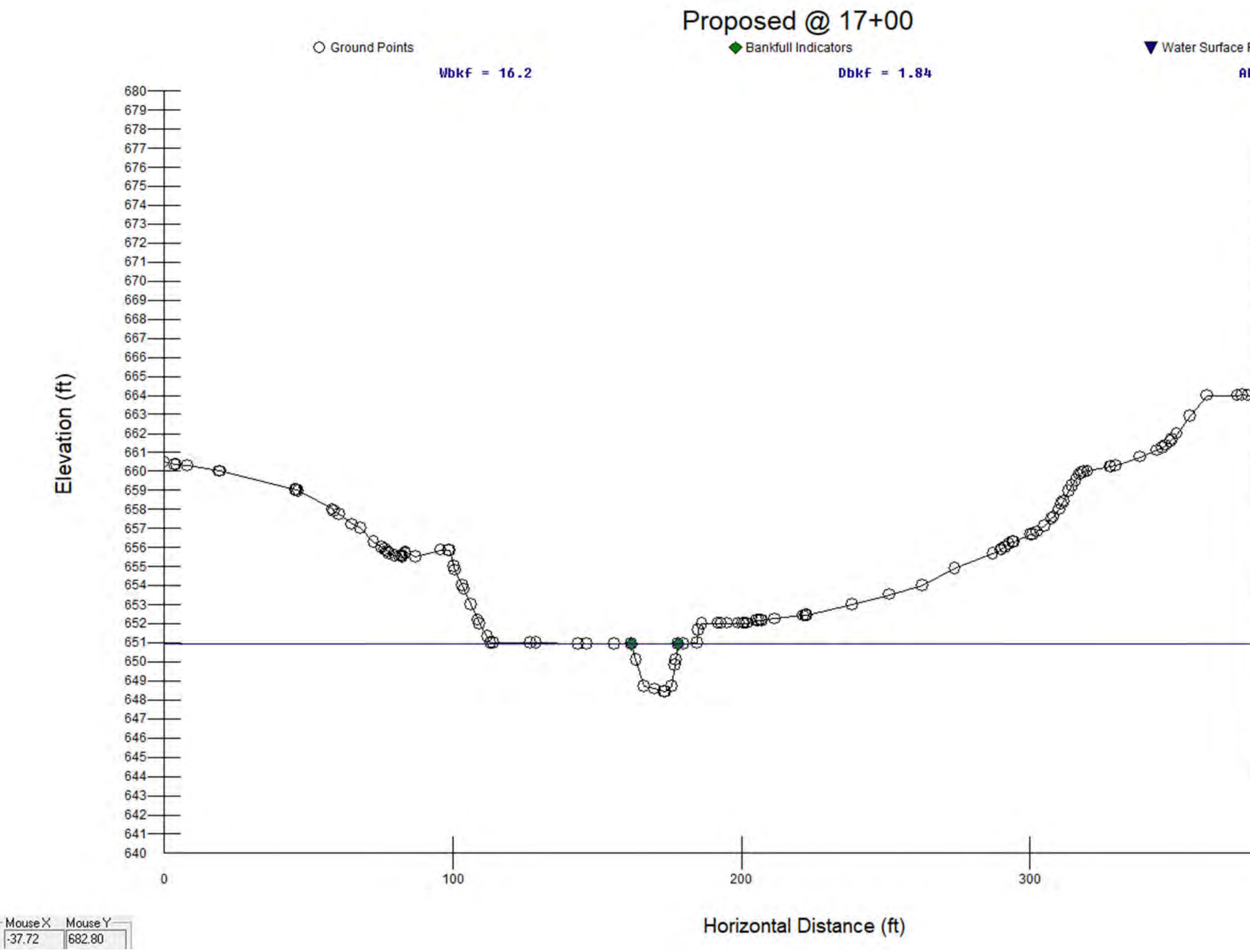
Entrenchment Ratio: 8.08 (Slightly Entrenched)
Width to Depth Ratio: 8.74 (Low)
Classification: E

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0028	0	0
Shear Stress (lb/sq ft)	0.30		
Movable Particle (mm)	16.0		

Mouse X	Mouse Y
-9.76	675.50



	Channel	Left	Right
Floodprone Elevation (ft)	653.44	653.44	653.44
Bankfull Elevation (ft)	650.93	650.93	650.93
Floodprone Width (ft)	144.11	-----	-----
Bankfull Width (ft)	16.16	8.08	8.08
Entrenchment Ratio	8.92	-----	-----
Mean Depth (ft)	1.84	1.63	2.05
Maximum Depth (ft)	2.51	2.35	2.51
Width/Depth Ratio	8.78	4.96	3.94
Bankfull Area (sq ft)	29.7	13.15	16.54
Wetted Perimeter (ft)	17.62	10.95	11.37
Hydraulic Radius (ft)	1.69	1.2	1.46
Begin BKF Station	161.8	161.8	169.88
End BKF Station	177.96	169.88	177.96

Broad Level Stream Classification

Entrenchment Ratio: 8.92 (Slightly Entrenched)

Width to Depth Ratio: 8.78 (Low)

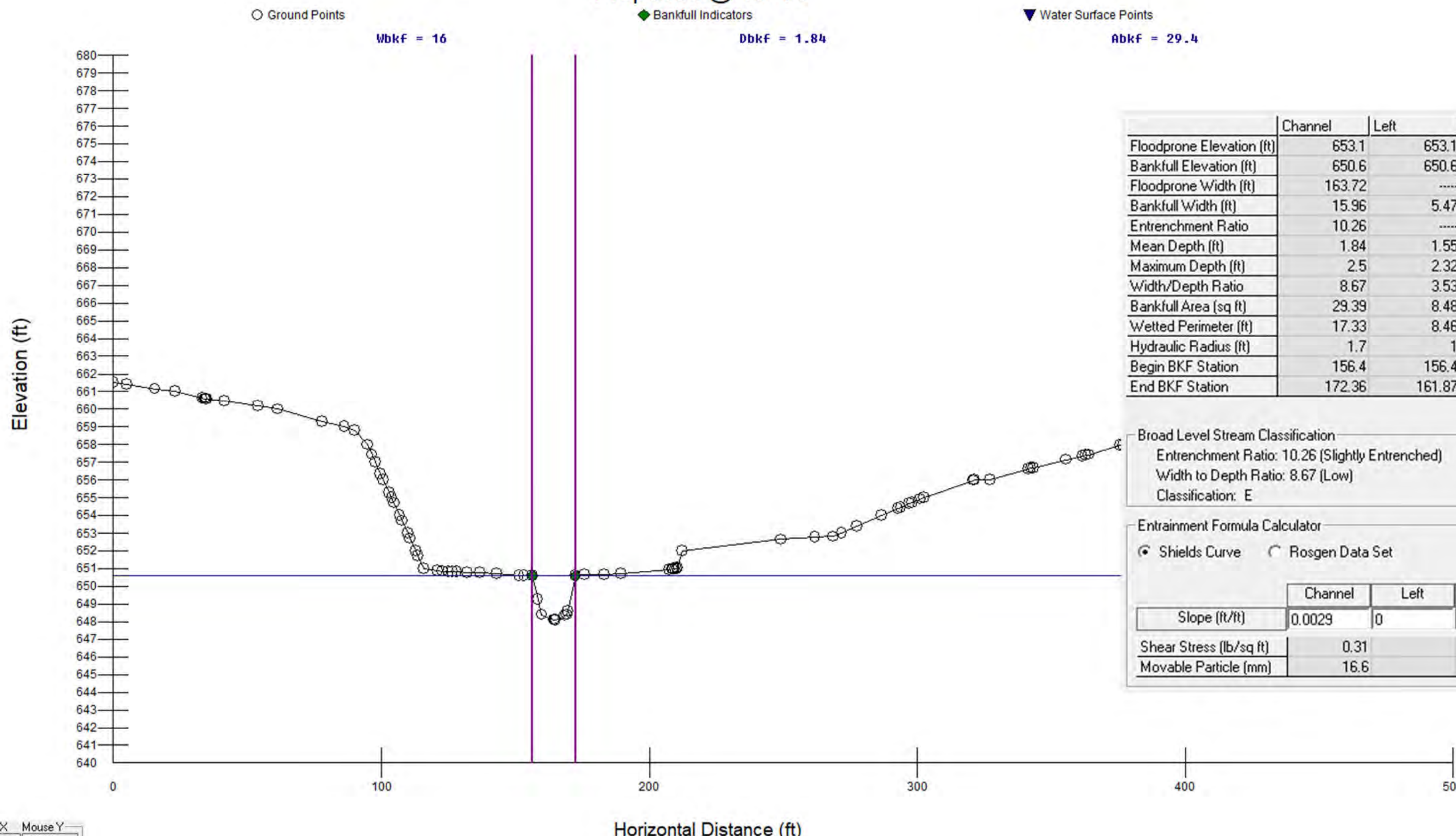
Classification: E

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0028	0	0
Shear Stress (lb/sq ft)	0.30		
Movable Particle (mm)	16.0		

Proposed @ 15+73



	Channel	Left	Right
Floodprone Elevation (ft)	653.1	653.1	653.1
Bankfull Elevation (ft)	650.6	650.6	650.6
Floodprone Width (ft)	163.72	-----	-----
Bankfull Width (ft)	15.96	5.47	10.49
Entrenchment Ratio	10.26	-----	-----
Mean Depth (ft)	1.84	1.55	1.99
Maximum Depth (ft)	2.5	2.32	2.5
Width/Depth Ratio	8.67	3.53	5.27
Bankfull Area (sq ft)	29.39	8.48	20.91
Wetted Perimeter (ft)	17.33	8.46	13.52
Hydraulic Radius (ft)	1.7	1	1.55
Begin BKF Station	156.4	156.4	161.87
End BKF Station	172.36	161.87	172.36

Broad Level Stream Classification

Entrenchment Ratio: 10.26 (Slightly Entrenched)

Width to Depth Ratio: 8.67 (Low)

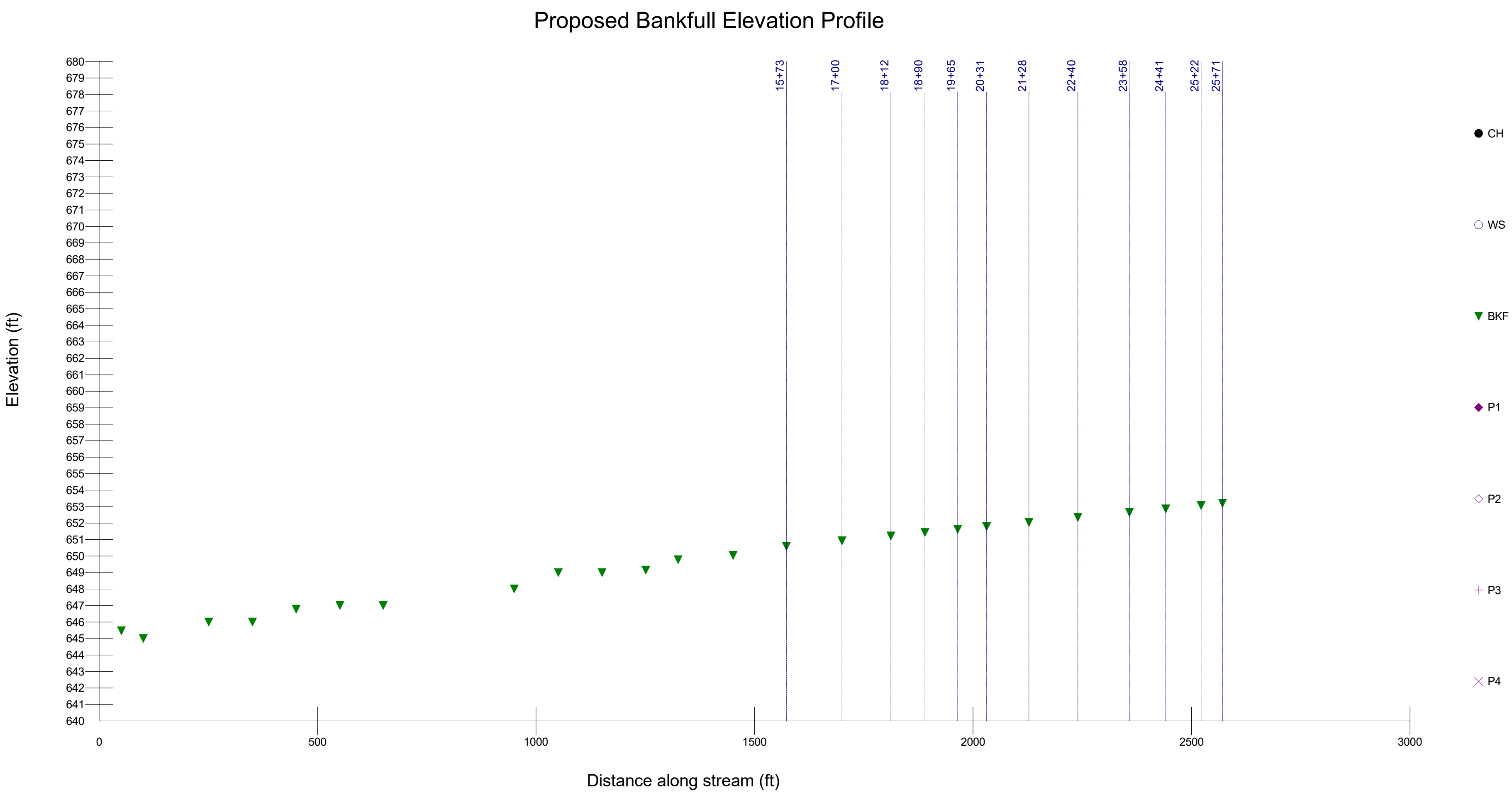
Classification: E

Entrainment Formula Calculator

(•) Shields Curve ( ) Rosgen Data Set

	Channel	Left	Right
Slope (ft/ft)	0.0029	0	0
Shear Stress (lb/sq ft)	0.31		
Movable Particle (mm)	16.6		

Mouse X	Mouse Y
58.37	669.32



Proposed Bankfull Elevation Profile
Elevation (ft)
Distance along stream (ft)
15+73
17+00
18+12
18+90
19+65
20+31
21+28
22+40
23+58
24+41
25+22
25+71
CH
WS
BKF
P1
P2
P3
P4

Appendix F

Appendix 2

BEHI Field Form - Complete

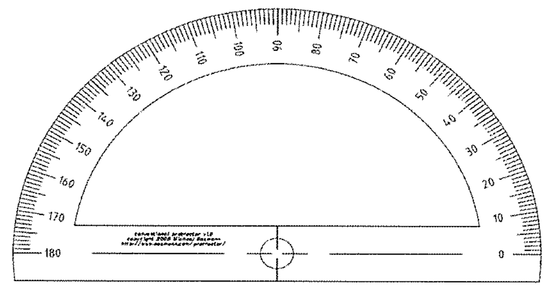
Location description: Bend 1 Reach 1 Analysis by: MB/SR/AK/SD Date: 11/29/18

Latitude: Longitude:

BEHI category	A		B (90)		C (75)		D (80)		E (75)	
	Bank height	BH score	Root depth	RDH score	Root density	RD score	Surface protection	SP score	Bank angle	BA score
Very low	1.0 – 1.1	1	90 - 100	(1)	80 - 100	1	80 - 100	(1)	0 - 20	1
Low	1.1 – 1.2	3	50 - 89	3	55 - 79	(3)	55 - 79	3	21 - 60	3
Moderate	1.3 – 1.5	5	30 - 49	5	30 - 54	5	30 - 54	5	61 - 80	(5)
High	1.6 – 2.0	(7)	15 - 29	7	15 - 29	7	15 - 29	7	81 - 90	7
Very high	2.1 – 2.8	8.5	5 - 14	8.5	5 - 14	8.5	10 - 14	8.5	91 - 119	8.5
Extreme	> 2.8	10	< 5	10	< 5	10	< 14	10	> 119	10

Material adjustment (F)	
Bedrock - automatically	Very low
Boulder - automatically	Low
Cobble	(-) 10
Gravel or mostly gravel	(+) 5
Sand or mostly sands	(+) 10
(**Silt/loam**)	(No adjustment)
Clay	(-) 20

Stratification adjustment (G)		Total Score (Sum **A-G**)
(No layer)	(No adjustment)	17
Single layer	(+) 5	
Multiple layers	(+) 10	



BEHI Category: Low

Very low	Low	Moderate	High	Very high	Extreme
≤ 9.5	(10 - 19.5)	20 - 29.5	30 - 39.5	40 - 45	> 45

Comments:

TOB = 116

BKF_H = 75

116/75 = 1.55

Appendix 2

BEHI Field Form - Complete

Location description: Reach 1 Bnk 2 Analysis by: MB/AK/SD/SR Date: 11/29/18

Latitude: ______ Longitude: ______

BEHI category	A		B (90)		C (90)		D (70)		E (90)	
	Bank height	BH score	Root depth	RDH score	Root density	RD score	Surface protection	SP score	Bank angle	BA score
Very low	1.0 – 1.1	1	90 - 100	1	80 - 100	1	80 - 100	1	0 - 20	1
Low	1.1 – 1.2	3	50 - 89	3	55 - 79	3	55 - 79	3	21 - 60	3
Moderate	1.3 – 1.5	5	30 - 49	5	30 - 54	5	30 - 54	5	61 - 80	5
High	1.6 – 2.0	7	15 - 29	7	15 - 29	7	15 - 29	7	81 - 90	7
Very high	2.1 – 2.8	8.5	5 - 14	8.5	5 - 14	8.5	10 - 14	8.5	91 - 119	8.5
Extreme	> 2.8	10	< 5	10	< 5	10	< 14	10	> 119	10

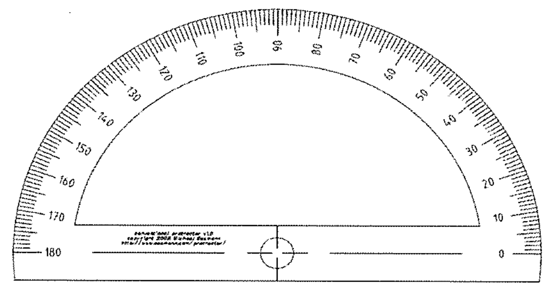
Material adjustment (F)	
Bedrock - automatically	Very low
Boulder - automatically	Low
Cobble	(-) 10
Gravel or mostly gravel	(+) 5
Sand or mostly sands	(+) 10
Silt/loam	No adjustment
Clay	(-) 20

average → -10

Stratification adjustment (G)	
No layer	No adjustment
Single layer	(+) 5
Multiple layers	(+) 10

Total Score (Sum A-G)
14

bottom layer is clay, top layer is silt/loam



BEHI Category: Low

Very low	Low	Moderate	High	Very high	Extreme
≤ 9.5	10 - 19.5	20 - 29.5	30 - 39.5	40 - 45	> 45

Comments:
TOB 92 $92/58 = 1.59$
BKF_H 58

Appendix 2

BEHI Field Form - Complete

Location description: Reach 2 BEHI 1 Analysis by: SR Date: 11/~~30~~ 29/18

Latitude: Longitude:

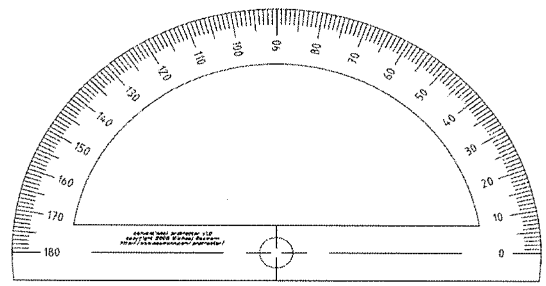
BEHI category	A: Bank height	BH score	B: Root depth	RDH score	C: Root density	RD score	D: Surface protection	SP score	E: Bank angle	BA score
Very low	1.0 – 1.1	1	90 - 100	1	80 - 100	1	80 - 100	1	0 - 20	1
Low	1.1 – 1.2	3	50 - 89	3	55 - 79	3	55 - 79	3	21 - 60	3
Moderate	1.3 – 1.5	5	30 - 49	5	30 - 54	5	30 - 54	5	61 - 80	5
High	1.6 – 2.0	7	15 - 29	7	15 - 29	7	15 - 29	7	81 - 90	7
Very high	2.1 – 2.8	8.5	5 - 14	8.5	5 - 14	8.5	10 - 14	8.5	91 - 119	8.5
Extreme	> 2.8	10	< 5	10	< 5	10	< 14	10	> 119	10

Bank ht = ~~115~~ 113 mm
Bankfull = 74 mm
R Depth = 100
R density = 80
Surf prot. = 30
Bank ∠ = 45°

Material adjustment (F)	
Bedrock - automatically	Very low
Boulder - automatically	Low
Cobble	(-) 10
Gravel or mostly gravel	(+) 5
Sand or mostly sands	(+) 10
Silt/loam	No adjustment
Clay	(-) 20

Stratification adjustment (G)	
No layer	No adjustment
Single layer	(+) 5
Multiple layers	(+) 10

Total Score (Sum **A-G**)
15



BEHI Category: Low

Very low	Low	Moderate	High	Very high	Extreme
≤ 9.5	10 - 19.5	20 - 29.5	30 - 39.5	40 - 45	> 45

Comments:

TOB = 113 mm
BKFt = 74 mm

113/74 = 1.53

Appendix 2

BEHI Field Form - Complete

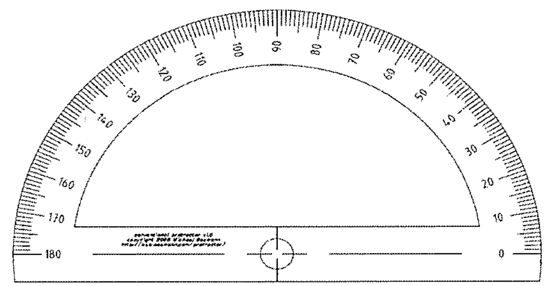
Location description: Reach 2 BEHI 2 Analysis by: SR Date: 11/29/18

Latitude: ______ Longitude: ______

BEHI category	A		B		C		D		E	
	Bank height	BH score	Root depth	RDH score	Root density	RD score	Surface protection	SP score	Bank angle	BA score
Very low	1.0 – 1.1	1	90 - 100	1	80 - 100	1	80 - 100	1	0 - 20	1
Low	1.1 – 1.2	3	50 - 89	3	55 - 79	3	55 - 79	3	21 - 60	3
Moderate	1.3 – 1.5	5	30 - 49	5	30 - 54	5	30 - 54	5	61 - 80	5
High	1.6 – 2.0	7	15 - 29	7	15 - 29	7	15 - 29	7	81 - 90	7
Very high	2.1 – 2.8	8.5	5 - 14	8.5	5 - 14	8.5	10 - 14	8.5	91 - 119	8.5
Extreme	> 2.8	10	< 5	10	< 5	10	< 14	10	> 119	10

Bank Ht = 229
Bankfull = 97
Root depth = 100
Rt density = 80
Surf prot ± 40
Bank ∠ = 90°

Material adjustment (F)		Stratification adjustment (G)		Total Score (Sum **A-G**)
Bedrock - automatically	Very low	No layer	No adjustment	
Boulder - automatically	Low	Single layer	(+) 5	22.5
Cobble	(-) 10	Multiple layers	(+) 10	
Gravel or mostly gravel	(+) 5			
Sand or mostly sands	(+) 10			
Silt/loam	No adjustment			
Clay	(-) 20			



BEHI Category: Moderate

Very low	Low	Moderate	High	Very high	Extreme
≤ 9.5	10 - 19.5	20 - 29.5	30 - 39.5	40 - 45	> 45

Comments:

TOB = 229

BKF_H = 97

229/97 = 2.36

Appendix 2

BEHI Field Form - Complete

Location description: Reach 3 BEHI 1 Analysis by: AK, SD, MB Date: 12/6/18

Latitude: Longitude:

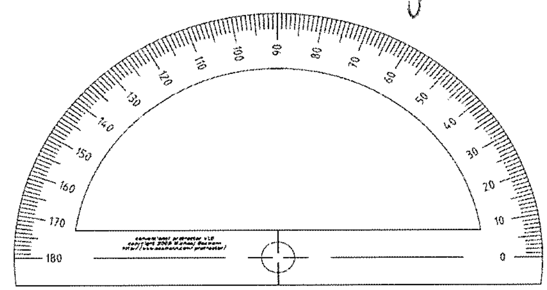
BEHI category	A		B		C		D		E	
	Bank height	BH score	Root depth	RDH score	Root density	RD score	Surface protection	SP score	Bank angle	BA score
Very low	1.0 – 1.1	1	90 - 100	1	80 - 100	1	80 - 100	1	0 - 20	1
Low	1.1 – 1.2	3	50 - 89	3	55 - 79	3	55 - 79	3	21 - 60	3
Moderate	1.3 – 1.5	5	30 - 49	5	30 - 54	5	30 - 54	5	61 - 80	5
High	1.6 – 2.0	7	15 - 29	7	15 - 29	7	15 - 29	7	81 - 90	7
Very high	2.1 – 2.8	8.5	5 - 14	8.5	5 - 14	8.5	10 - 14	8.5	91 - 119	8.5
Extreme	> 2.8	10	< 5	10	< 5	10	< 14	10	> 119	10

bank height: 6 ft
bankfull: 2.17 ft
root depth: 90
root density: 50
surface protection: 25
bank angle: 60

Material adjustment (F)	
Bedrock - automatically	Very low
Boulder - automatically	Low
Cobble	(-) 10
Gravel or mostly gravel	(+) 5
Sand or mostly sands	(+) 10
Silt/loam	No adjustment
Clay	(-) 20

upper: Silt/loam; toe: Clay — average -10

Stratification adjustment (G)		Total Score (Sum **A-G**)
No layer	No adjustment	19.5
Single layer	(+) 5	
Multiple layers	(+) 10	



BEHI Category: Low

Very low	Low	Moderate	High	Very high	Extreme
≤ 9.5	10 - 19.5	20 - 29.5	30 - 39.5	40 - 45	> 45

Comments:

TOB = 6'
BKF_H = 2.17

6/2.17 = 2.76

Appendix 2

BEHI Field Form - Complete

Location description: Reach 3 BEHI 2 Analysis by: AK, SD, MB Date: 12/6/18

Latitude: Longitude:

BEHI category	A		B		C		D		E	
	Bank height	BH score	Root depth	RDH score	Root density	RD score	Surface protection	SP score	Bank angle	BA score
Very low	1.0 – 1.1	1	90 - 100	1	80 - 100	1	80 - 100	1	0 - 20	1
Low	1.1 – 1.2	3	50 - 89	3	55 - 79	3	55 - 79	3	21 - 60	3
Moderate	1.3 – 1.5	5	30 - 49	5	30 - 54	5	30 - 54	5	61 - 80	5
High	1.6 – 2.0	7	15 - 29	7	15 - 29	7	15 - 29	7	81 - 90	7
Very high	2.1 – 2.8	8.5	5 - 14	8.5	5 - 14	8.5	10 - 14	8.5	91 - 119	8.5
Extreme	> 2.8	10	< 5	10	< 5	10	< 14	10	> 119	10

bank height: 12 ft
bankfull: 1.32 ft
root depth: 90
root density: 60
surface protection: 60
bank angle: ~~70~~ 75

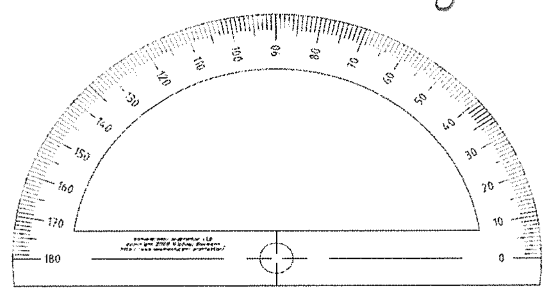
Material adjustment (F)	
Bedrock - automatically	Very low
Boulder - automatically	Low
Cobble	(-) 10
Gravel or mostly gravel	(+) 5
Sand or mostly sands	(+) 10
Silt/loam	No adjustment
Clay	(-) 20

upper toe of bank

7 average
-10

Stratification adjustment (G)	
No layer	No adjustment
Single layer	(+) 5
Multiple layers	(+) 10

Total Score (Sum **A-G**)
17



BEHI Category: Low

Very low	Low	Moderate	High	Very high	Extreme
≤ 9.5	10 - 19.5	20 - 29.5	30 - 39.5	40 - 45	> 45

Comments:

TOB = 12'

BKF_{ft} = 1.32'

12/1.32 = 9.09

Appendix 2

BEHI Field Form - Complete

Location description: Reach 3 BEHI 3 Analysis by: AK, SD, MB Date: 12/6/18

Latitude: Longitude:

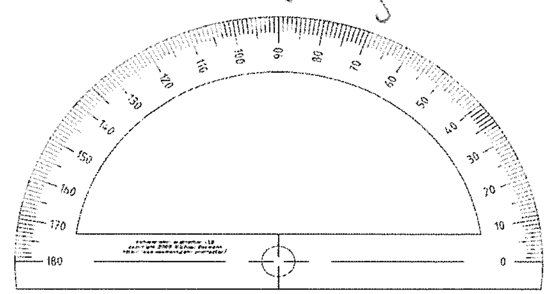
BEHI category	A		B		C		D		E	
	Bank height	**BH score**	Root depth	**RDH score**	Root density	**RD score**	Surface protection	**SP score**	Bank angle	**BA score**
Very low	1.0 – 1.1	**1**	90 - 100	**1**	80 - 100	**1**	80 - 100	**1**	0 - 20	**1**
Low	1.1 – 1.2	**3**	50 - 89	**3**	55 - 79	**3**	55 - 79	**3**	21 - 60	**3**
Moderate	1.3 – 1.5	**5**	30 - 49	**5**	30 - 54	**5**	30 - 54	**5**	61 - 80	**5**
High	1.6 – 2.0	**7**	15 - 29	**7**	15 - 29	**7**	15 - 29	**7**	81 - 90	**7**
Very high	2.1 – 2.8	**8.5**	5 - 14	**8.5**	5 - 14	**8.5**	10 - 14	**8.5**	91 - 119	**8.5**
Extreme	> 2.8	**10**	< 5	**10**	< 5	**10**	< 14	**10**	> 119	**10**

bank height: 3.70, ft
bankfull: 3.12 ft
root depth: 75
root density: 35
Surface protection: 50
bank angle: 80

Material adjustment (F)	
Bedrock - automatically	Very low
Boulder - automatically	Low
Cobble	(-) 10
Gravel or mostly gravel	(+) 5
Sand or mostly sands	(+) 10
Silt/loam	No adjustment
Clay	(-) 20

Stratification adjustment (G)		**Total Score (Sum A-G)**
No layer	No adjustment	1
Single layer	(+) 5	
Multiple layers	(+) 10	

90% of bank is clay



BEHI Category: Very Low

Very low	Low	Moderate	High	Very high	Extreme
≤ 9.5	10 - 19.5	20 - 29.5	30 - 39.5	40 - 45	> 45

Comments:

TOB = 3.7'
BKFt = 3.12'
3.7/3.12 = 1.19

Appendix 2

BEHI Field Form - Complete

Location description: Reach 3 BEHI 4 Analysis by: AK MB, SD Date: 12/6/18

Latitude: Longitude:

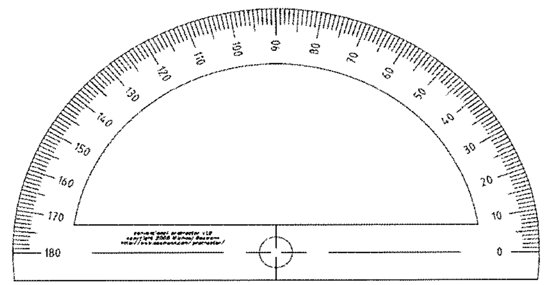
BEHI category	A		B		C		D		E	
	Bank height	BH score	Root depth	RDH score	Root density	RD score	Surface protection	SP score	Bank angle	BA score
Very low	1.0 – 1.1	1	90 - 100	1	80 - 100	1	80 - 100	1	0 - 20	1
Low	1.1 – 1.2	3	50 - 89	(3)	55 - 79	3	55 - 79	3	21 - 60	(3)
Moderate	1.3 – 1.5	5	30 - 49	5	30 - 54	(5)	30 - 54	(5)	61 - 80	5
High	1.6 – 2.0	7	15 - 29	7	15 - 29	7	15 - 29	7	81 - 90	7
Very high	2.1 – 2.8	8.5	5 - 14	8.5	5 - 14	8.5	10 - 14	8.5	91 - 119	8.5
Extreme	> 2.8	(10)	< 5	10	< 5	10	< 14	10	> 119	10

bank height: 12 ft
bankfull: 2.1 ft
root depth: 50
root density: 30
surface protection: 35
bank angle: 50

Material adjustment (F)	
Bedrock - automatically	Very low
Boulder - automatically	Low
Cobble	(-) 10
Gravel or mostly gravel	(+) 5
Sand or mostly sands	(+) 10
Silt/loam	No adjustment
(**Clay**)	((-) 20)

Stratification adjustment (G)	
(No layer)	(No adjustment)
Single layer	(+) 5
Multiple layers	(+) 10

Total Score (Sum **A-G**)
6



BEHI Category: very low

(Very low ≤ 9.5)	Low 10 - 19.5	Moderate 20 - 29.5	High 30 - 39.5	Very high 40 - 45	Extreme > 45

Comments:

TOB = 12'
BKF_H = 2.1' ≈ 12/2.1 = 5.71

Appendix G

Worksheet A-14. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure A-9** variables to determine BEHI Score.

Stream: Tamarack Creek	Location: Proposed Reaches 1 and 2
Station:	Observers: N/A - Projections Only
Date: Stream Type:	Valley Type:

Variable	Value	Variable	Value	Calculation	Result	BEHI Score (Fig. A-9)
Study Bank Height / Bankfull Height (C)						
Study Bank Height (ft) =	2.2 (A)	Bankfull Height (ft) =	2.2 (B)	(A)/(B) =	1 (C)	1
Root Depth / Study Bank Height (E)						
Root Depth (ft) =	1 (D)	Study Bank Height (ft) =	2.2 (A)	(D)/(A) =	0.45 (E)	4
Weighted Root Density (G)						
		Root Density as % =	70% (F)	(F)×(E) =	32 (G)	6
Bank Angle (H)						
				Bank Angle as *Degrees* =	27 (H)	3
Surface Protection (I)						
				Surface Protection as % =	50 (I)	4

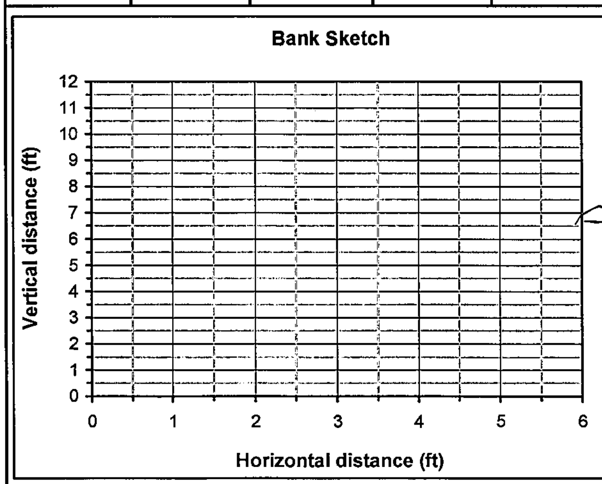
Bank Material Adjustment:
- **Bedrock** (Overall Very Low BEHI)
- **Boulders** (Overall Low BEHI)
- **Cobble** (Subtract 10 points if uniform medium to large cobble)
- **Gravel or Composite Matrix** (Add 5–10 points depending on percentage of bank material that is composed of sand)
- **Sand** (Add 10 points)
- **Silt/Clay** (no adjustment)

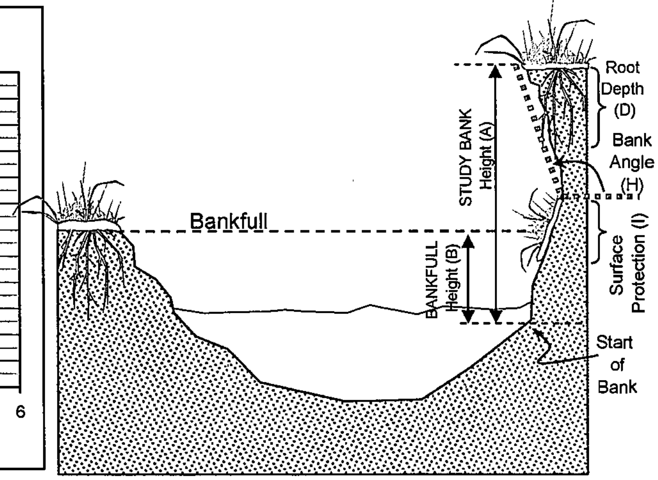
Bank Material Adjustment: 0

Stratification Adjustment
Add 5–10 points, depending on position of unstable layers in relation to bankfull stage: 0

Very Low	Low	Moderate	High	Very High	Extreme
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50

Adjective Rating and Total Score: Low 18





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Appendix H

Reach 1 Final

PS = 83
DDS = 31 * 5 = 155 } 238

LARGE WOODY DEBRIS FIELD FORM

Date Revised: 10/19/2016

Investigator(s)	Hymphriss	State	Southfield, MI	Forest Type	Deciduous Evergreen Mixed Other
Date	11/26/19	County		Forest Age (yrs)	
Stream Name	Tamarack Creek	Phys. Province		Latitude (dd)	
Reach ID	1	Drainage Area (mi^2)		Longitude (dd)	
Watershed Name		Dominant Species			
Survey Length (ft)	328 — Survey Length = 328 ft/100 m	BKF Width (ft)		Slope (ft/ft)	
Stream Classification	Ephemeral Intermittent Perennial	BKF Mean Depth (ft)		Bed material	
Stream Condition	Degraded Restored Reference Managed	Floodprone Width (ft)		Rosgen Type	
Field Notes:					

SCORE

CATEGORY	1		2		3		4		5		TOTAL PIECES
*** PIECES ***											
Length/BKF Width	0 to 0.4		0.4 to 0.6	•	0.6 to 0.8		0.8 to 1.0	• •	> 1.0	• •	5
Diameter (cm)	4 8 10 to 20	• • • •	8 12 20 to 30	•	12 16 30 to 40		16 20 40 to 50		>20 >50		5
Location	Zone 4 (Above BKF/Extending into Channel)	• •			Zone 3 (Above BKF/Within Streambanks)	•	Zone 2 (Above WS/Below BKF)	• •	Zone 1 (Below WS)		5
Type	Bridge				Ramp	• • • •	Submersed		Buried		5
Structure	Plain	• •	Plain/Int	• •	Intermediate	•	Int/Sticky		Sticky		5
Stability	Moveable	• • •	Mov/Int		Intermediate	•	Int/Sec	•	Secured		5
Orientation (deg)	0 to 20	• • •	20 to 40	•	40 to 60		60 to 80		80 to 90	•	5
CATEGORY	1 * 14 = 14		2 * 5 = 10		**** DEBRIS DAMS **** 3*8=24		4*5=20		5*3=15		**TOTAL DAMS**
Length (% of BKF Width)	0 to 20		20 to 40	•	40 to 60	•	60 to 80		80 to 100		2
Height (% of BKF Depth)	0 to 20		20 to 40		40 to 60		60 to 80		80 to 100	• •	2
Structure	Coarse		Coarse/Int	•	Intermediate	•	Int/Fine		Fine		2
Location	Partially high flow		In high flow	•	Partially low flow		Mid low flow	•	In low flow		2
Stability	Moveable		Mov/Int	•	Intermediate	•	Int/Sec		Secured		2

* Pieces - Non-living wood that has a large end diameter ≥ 10 cm and has a length ≥ 1 m. ** Debris Dams - Three (3) or more pieces touching.

1*0=0 2*4=8 3*3=9 4*1=4 5*2=10

Dix (3) Dagnew Humphriss

Reach 2 Final

PS = 317
DDS = 17*5=85 } 402

LARGE WOODY DEBRIS FIELD FORM

Date Revised: 10/19/2016

Investigator(s)	(3) + Humphriss	State	Southfield, MI	Forest Type	Deciduous Evergreen Mixed Other
Date	11/22/19 + 11/26/19	County		Forest Age (yrs)	
Stream Name	Tamarack Creek	Phys. Province		Latitude (dd)	
Reach ID	2	Drainage Area (mi²)		Longitude (dd)	
Watershed Name		Dominant Species			
Survey Length (ft)	328 Survey Length = 328 ft/100 m	BKF Width (ft)		Slope (ft/ft)	
Stream Classification	Ephemeral Intermittent Perennial	BKF Mean Depth (ft)		Bed material	
Stream Condition	Degraded Restored Reference Managed	Floodprone Width (ft)		Rosgen Type	
Field Notes:					

SCORE

CATEGORY	1		2		3		4		5		TOTAL PIECES
	*** PIECES ***										
Length/BKF Width	0 to 0.4	•	0.4 to 0.6	••	0.6 to 0.8		0.8 to 1.0	•	> 1.0	☒ •••	17
Diameter (cm)	10 to 20	☒	20 to 30	⊓ ••	30 to 40	•	40 to 50	•	>50		17
Location	Zone 4 (Above BKF/Extending into Channel)	☒			Zone 3 (Above BKF/Within Streambanks)	••	Zone 2 (Above WS/Below BKF)	••••	Zone 1 (Below WS)	••	17
Type	Bridge	••••			Ramp	☒ •	Submersed	••	Buried		17
Structure	Plain	☒ ⊓ ••	Plain/Int		Intermediate	••	Int/Sticky		Sticky		17
Stability	Moveable	••••	Mov/Int		Intermediate	••••	Int/Sec	•••	Secured	⊓ ••	17
Orientation (deg)	0 to 20	⊓ ••	20 to 40	••	40 to 60	••••	60 to 80	•	80 to 90	⊓ ••	17
CATEGORY	1*47		2*10=20		**** DEBRIS DAMS **** 3*24=72		4*12=48		5*26=130		**TOTAL DAMS**
Length (% of BKF Width)	0 to 20		20 to 40		40 to 60		60 to 80		80 to 100	•	1
Height (% of BKF Depth)	0 to 20		20 to 40		40 to 60		60 to 80		80 to 100	•	1
Structure	Coarse	•	Coarse/Int		Intermediate		Int/Fine		Fine		1
Location	Partially high flow	•	In high flow		Partially low flow		Mid low flow		In low flow		1
Stability	Moveable		Mov/Int		Intermediate		Int/Sec		Secured	•	1

* Pieces - Non-living wood that has a large end diameter ≥ 10 cm and has a length ≥ 1 m. ** Debris Dams - Three (3) or more pieces touching.

1*2=2 2*0=0 3*0=0 4*0=0 5*3=15

Reach 3 Final

PS = 223
DDS = 115*5 = 575
} 798

LARGE WOODY DEBRIS FIELD FORM

Date Revised: 10/19/2016

Investigator(s)	Dix, Dagnew, Humphries	State	Southfield, MI	Forest Type	Deciduous Evergreen Mixed Other
Date	11/22/19	County		Forest Age (yrs)	
Stream Name	Tamarack Creek	Phys. Province		Latitude (dd)	
Reach ID	3	Drainage Area (mi^2)		Longitude (dd)	
Watershed Name		Dominant Species			
Survey Length (ft)	328 — Survey Length = 328 ft/100 m	BKF Width (ft)		Slope (ft/ft)	
Stream Classification	Ephemeral Intermittent Perennial	BKF Mean Depth (ft)		Bed material	
Stream Condition	Degraded Restored Reference Managed	Floodprone Width (ft)		Rosgen Type	
Field Notes:	Correction w/subtraction was applied to account for over-run into Reach 2				

SCORE

CATEGORY	1		2		3		4		5		TOTAL PIECES
*** PIECES ***											
Length/BKF Width	0 to 0.4		0.4 to 0.6	5 (tally)	0.6 to 0.8	3 (tally)	0.8 to 1.0	1 (tally)	> 1.0	3 (tally)	12
Diameter (cm)	10 to 20	6 (tally)	20 to 30	5 (tally)	30 to 40	1 (tally)	40 to 50		>50		12
Location	**Zone 4** (Above BKF/Extending into Channel)	4 (tally)			**Zone 3** (Above BKF/Within Streambanks)	1 (tally)	**Zone 2** (Above WS/Below BKF)	6 (tally)	**Zone 1** (Below WS)	1 (tally)	12
Type	Bridge				Ramp	7 (tally)	Submersed	2 (tally)	Buried	3 (tally)	12
Structure	Plain	10 (tally)	Plain/Int	2 (tally)	Intermediate		Int/Sticky		Sticky		12
Stability	Moveable	1 (tally)	Mov/Int	1 (tally)	Intermediate		Int/Sec		Secured	10 (tally)	12
Orientation (deg)	0 to 20	8 (tally)	20 to 40	3 (tally)	40 to 60		60 to 80		80 to 90	1 (tally)	12
CATEGORY	1*29		2*16 = 32		**** DEBRIS DAMS **** 3*12 = 36		4*9 = 36		5*18 = 90		**TOTAL DAMS**
Length (% of BKF Width)	0 to 20		20 to 40		40 to 60	1 (tally)	60 to 80		80 to 100	5 (tally)	6
Height (% of BKF Depth)	0 to 20		20 to 40		40 to 60		60 to 80		80 to 100	6 (tally)	6
Structure	Coarse	1 (tally)	Coarse/Int	1 (tally)	Intermediate	3 (tally)	Int/Fine	1 (tally)	Fine		6
Location	Partially high flow		In high flow	3 (tally)	Partially low flow		Mid low flow	3 (tally)	In low flow		6
Stability	Moveable		Mov/Int		Intermediate	3 (tally)	Int/Sec	1 (tally)	Secured	2 (tally)	6

* Pieces - Non-living wood that has a large end diameter ≥ 10 cm and has a length ≥ 1 m. ** Debris Dams - Three (3) or more pieces touching.

1*1 2*4 = 8 3*7 = 21 4*5 = 20 5*13 = 65

Appendix I

Fluvial Geomorphic Analysis of Tamarack Drain

Tamarack Drain Phase I – Preliminary Study

OCDC

January, 2006

HUBBELL, ROTH & CLARK, INC.
CONSULTING ENGINEERS

Fluvial Geomorphic Analysis of Tamarack Drain

Tamarack Drain Phase I – Preliminary Study

January, 2006

SECTIONS

APPENDICES

SECTION 1. EXISTING CONDITIONS

A field assessment and stream survey were conducted at the outlet of the in-line detention basin for purposes of characterizing the channel conditions to assist in stable channel deign. In its current state, the basin provides a flow-through condition with no effective detention. Following the re-construction of the detention basin approximately 400 feet of the channel below the basin outlet will be stabilized.

The following brief summaries characterize the channel conditions:

- Water is conveyed through an open channel (Rosgen E5) in the basin to three concrete elliptical pipes. The pipes are set at a negative slope and are slightly perched 0.3-0.5 ft above the channel. At low flow, water flows half way through the left pipe and then under through a separation in the downstream section of pipe. According to the survey, the pipes are set at a negative slope.
- The project reach consists of approximately 400 feet of channel. The channel is somewhat incised by up to 1 ft (approximately) and moderately entrenched with a low sinuosity and very low width/depth ratio. The channel is highly modified due to fill material in the floodplain and impacts from historical concrete weirs. The project reach is an E4 channel with sections of B3c according to the Rosgen classification system.
- The bed material is a mix of litter, broken concrete, sand, and gravel deposited at depths varying from 0-1.2 ft over hardpan clay till.
- A section of an older concrete weir remains on an upper terrace near station 1+40. The weir no longer controls the grade but pieces of cobble-sized broken concrete make up much of the bed material along the riffle from station 1+54 to 2+48.
- Remnants of a newer rectangular concrete weir at station 3+69 are causing significant scour. There are pools on the upstream and downstream sides of the weir. The channel has flanked the right side wall. Sections of the right wing wall have fallen. Cobble-sized broken concrete makes up much of the bed material along the riffle downstream of station 4+41. Following snowmelt, there was significant groundwater seepage on the lower right bank near the downstream end of the weir.

Field survey was completed from the downstream end of the three concrete elliptical culverts (stn 0+00) at the outlet of the detention basin downstream for a distance of 441 feet (about 40 channel widths). The channel profile and three typical cross-sections were surveyed.

Channel-Forming Discharge and Hydraulic Parameters

Reach	Detention Basin	Project Reach	Reference Reach	USGS Gauge Evans Branch*
Drainage Area	0.89 mi^2	0.89 mi^2	1.1 mi^2	9.49 mi^2
Qbkf	43 ft^3/s	74.2 (80.9**)	100	N/A
$Q_{1.5}$	N/A	N/A	N/A	416 ft^3/s
Velocity	2.6 ft/s	3.6 ft/s	3.7 ft/s	2.6 ft/s
Shear Stress	0.05 lb/ft^2	0.38 lb/ft^2	0.25 lb/ft^2	0.48 lb/ft^2
Manning's 'n'	0.017	0.034	0.028	N/A

* Due to the difference in DA and lack of other gauge data in the area, the return interval could not be extrapolated.

** Discharge extrapolated from the reference reach by drainage area.

SECTION 2 CHANNEL STABILITY ASSESSMENT

2.1 Rapid Geomorphic Assessment (RGA)

Based on a RGA that was completed as part of the Distributed Runoff Control (DRC) methodology (Appendix B), the project reach (Stability Index 0.49) was considered to be ‘In adjustment’ and the reference reach (Stability Index 0.27) was considered to be ‘Transitional’.

> Interpretation
> Transitional or stressed – ‘Channel morphology is within the consensual range of variance for streams of similar hydrographic characteristics, but the evidence of instability is frequent.’
> In adjustment – ‘Channel morphology is not within the consensual range of variance and evidence of instability is wide spread.’ (OMEE, 2001)

2.2 Pfankuch Channel Stability Evaluation

Pfankuch (1975) developed a system to quickly rate channel stability using a numeric rating system and corresponding evaluations of excellent, good, fair, or poor channel stability. However, various stream types exhibit differences in stability which are naturally inherent. As a result, Rosgen (1996) has adjusted the rating values by stream type as exhibited below. This system can be used to describe the potential for erosion and changes to sediment supply due to changes in stream flow and/or watershed condition. A poor stability index rating can be used as a planning tool to warn watershed managers. Once a problem area is identified, actual channel stability can be determined by surveying permanent channel cross-sections and profiles to quantify the rate of vertical and lateral instabilities.

The channel stability rating for the 400 ft project reach of the Tamarack Drain was 114 or ‘poor’. The following characteristics generally describe conditions of the project reach.

Project Reach

1. Sediment Supply – low
2. Bed Stability – moderate
3. Width/Depth Ratio Shifts – moderate to high

A rapid stability rating is useful for the evaluation of a potential reference reach. Although the reference reach was not in a pristine condition, it was stable enough to provide reference dimension planform and profile data. According to a Pfankuch channel stability assessment, the channel stability rating for the reference reach was 80 or ‘good’. A summary of the evaluation and stability rating adjustments by stream type are provided in Tables 2-1.

Table 2-1 Pfankuch Channel Stability Evaluation Summary

		Category	Project Reach Rating	Project Reach (B4c/E4)	Reference Reach Rating	Reference Reach (C4)
UPPER BANKS	1	Landform Slope	fair	6	excellent	2
	2	Mass Wasting	fair	10	excellent	3
	3	Debris Jam Potential	fair	5	good	4
	4	Vegetative Bank Protection	poor	12	good	5
LOWER BANKS	5	Channel Capacity	good	2	good	2
	6	Bank Rock Content	poor	8	poor	8
	7	Obstructions to Flow	fair	6	good	4
	8	Cutting	poor	16	good	7
	9	Deposition	excellent	4	poor	7
BOTTOM	10	Rock Angularity	fair	3	good	2
	11	Brightness	good	2	good	2
	12	Consolidation of Particles	fair	6	fair	7
	13	Bottom Size Distribution	fair	12	good	9
	14	Scouring and Deposition	fair	18	good	14
	15	Aquatic Vegetation	poor	4	poor	4
Average			**poor**	**114**	**good**	**80**

Conversion of Stability Rating to Reach Condition by Stream Type*

Stream Type	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**
GOOD	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60
FAIR	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78
POOR	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+
Stream Type	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**D3**	**D4**	**D5**	**D6**		
GOOD	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98		
FAIR	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125		
POOR	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+		
Stream Type	**DA3**	**DA4**	**DA5**	**DA6**	**E3**	**E4**	**E5**	**E6**				
GOOD	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63				
FAIR	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86				
POOR	87+	87+	87+	87+	87+	97+	97+	87+				
Stream Type	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**
GOOD	60-85	60-85	85-110	85-110	90-115	80-95	40-60	40-60	85-107	85-107	90-112	85-107
FAIR	86-105	86-105	111-125	111-125	116-130	96-110	61-78	61-78	108-120	108-120	113-125	108-120
POOR	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

* Generalized relations; additional Level IV data needed for validation (Source: Rosgen, 1996)

SECTION 3 CHANNEL MATERIALS

3.1 Bed Material

The bed material of the project reach is a mixture of litter, broken concrete, sand, and gravel deposited at depths varying from 0-1.2 ft over fine clayey till (Figure 3-1). The underlying erodible, hardpan bed material effectively controls the rate of channel degradation; therefore, the channel could be considered 'semi-alluvial'. Many glacial streams in southeast Michigan display this characteristic. The sediments in glacial semi-alluvial streams can vary longitudinally and these streams show irregular variation in riffle/pool spacing, irregular meander lengths, long sections with featureless bed topography and bends with riffles, multiple-pools, or no pools (Foster). The pools that do exist are usually shallow and poorly formed. While the bed topography shows semi-regular variations resembling riffles and pools, the Tamarack Drain does not represent the typical riffle-pool channels present in many gravel-bed alluvial streams. Pool spacing is highly variable and closer to $4.5W_{bkf}$ (rather than 5-7 per Leopold).

The bed material of the reference reach is a unimodal mixture of sand and gravel with a median particle size of medium gravel. See Appendix E for particle size distribution curves of two riffle samples and pavement/subpavement materials.

3.1.1 Till (Hardpan) Bed Material

The channel is slightly entrenched into an underlying bed material was a fine clayey till material that, although erodible, restricts the adjustment of stream gradient and the development of a more variable bed topography.

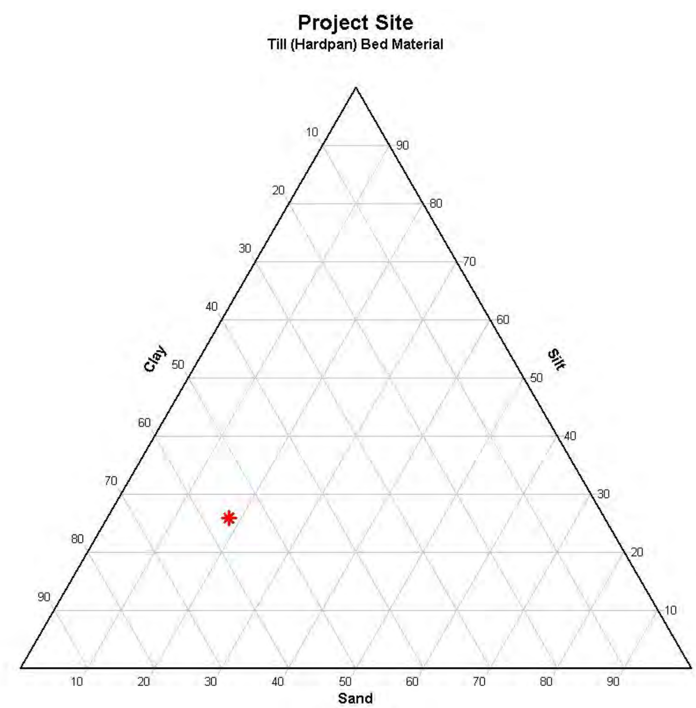


Figure 3-1 Till (Hardpan) Bed Material: fine clayey (18% sand and gravel, 26% silt, and 56% clay)

3.1.2 Surface Bed Material

The bed material of the project reach is a mixture of litter, broken concrete, sand, and gravel. The bed material is naturally variable due to the poorly sorted glacial material, but it varies even more due to riprap and broken concrete from historic structures and litter from highway runoff. The bed deposits are discontinuous and thin and tend to be higher in areas of woody debris and broken concrete. Deposits vary from 0 to 1.2 ft in depth. Figure D-2 shows the longitudinal profile of the hardpan (gray line) below the bed (red line). The stream is imposed by the nature of the deposits rather than the hydraulics of the channel. As described in Section 3.1, the bed material consists of a layer of sediment over a clayey hardpan bed which controls the rate of incision. All grade control structures should be keyed in to this material.

Table 3-1 Bed Particle Material Sizes (mm)

Sample	D16	D35	D50	D84	D95	*i*
1	7.4	9.7	12	20	28	32
2	4.3	6.7	8	13	16	19
3	0.56	3.6	9.8	27	34	43
4	0.38	3.1	5.7	16	22	31
5	0.22	0.35	0.45	1.1	2.3	N/A
6	N/A	N/A	N/A	0.099	0.58	N/A
7	0.3	0.5	0.76	2.1	4.9	est. 10

Sample 1 – reference reach, pavement, pebble count
Sample 2 – reference reach, subpavement, pebble count
Sample 3 – reference reach, riffle 1, bulk sample
Sample 4 – reference reach, riffle 2, bulk sample
Sample 5 – reference reach, lower third of bar, surface, bulk sample
Sample 6 – project reach till (hardpan), bulk sample (sieve and hydrometer)
Sample 7 – existing basin, bed surface, bulk sample

3.2 Streambank Soil Description

Due to the construction of the weirs and the crossing over the three culverts at the basin outlet, there is likely a lot of fill and debris in the project reach. Some of the invasive vegetation along the west side of the stream indicates that the area may have been previously disturbed. However, the soil survey provides a general soil description. Just as the rate of channel incision may have been slowed due to the clayey till, the toe of the banks is a cohesive clayey material which resists erosion. Although the toe material was usually 4-6" of the clayey hardpan, the rest of the streambank soils appeared to be uniform so it was assumed that the material would have similar physical properties. Particle size analysis and hydrometer testing was performed on a composite sample of six subsamples of the bank material.

3.2.1 Oakland County Soil Survey

Sloan-Marlette association – Sloan soils are located in the active wooded floodplain and Marlette soils are on the adjacent side slopes. Soils in the Rouge River Watershed have a higher clay content and slower permeability than in other parts of the County.
Sloan soils (silt loam surface) – The surface layer is dark brown silt loam about 11 inches thick and the subsurface layer is dark gray silt loam about 3 inches thick. The subsoil is grayish brown, mottled, friable silt loam about 22 inches thick. The substratum is gray, mottled, calcareous, stratified silty clay loam and fine sandy loam with thin layers of very dark brown fine sandy loam to a depth of about 60

inches. In some places the soil is mucky. Permeability is moderate or moderately slow. Runoff is slow to ponded. The water table is at or near the surface from November through June.
Erodibility 'Kw' value = 0.28 (High and moderate in subsoils); Hydrologic Soils Group (HSG) = D (NOTE: K values range from 0.10 to 0.43 in Michigan)

Marlette soils (loam surface) – Typically, the surface layer is dark grayish brown loam about 4 inches thick. The subsoil is firm and about 26 inches thick. In the upper part, it is mixed yellowish brown clay loam and pale brown loam and in the lower part it is yellowish brown clay loam. The substratum is pale brown calcareous loam to a depth of about 60 inches. Permeability is moderately slow. Runoff is very rapid (due to the slopes).
Erodibility 'Kw' value = 0.32 (high due to slopes); HSG = B

3.2.2 Streambank Particle Size Analysis

The particle size analysis and hydrometer testing confirm that the bank material is clay loam. The soil survey describes the upper soil (to 14 inches) as silt loam and the subsoil (14 to 36 inches) as silty clay loam, clay loam, or silt loam. The sample was probably representative of the Sloan subsoil.

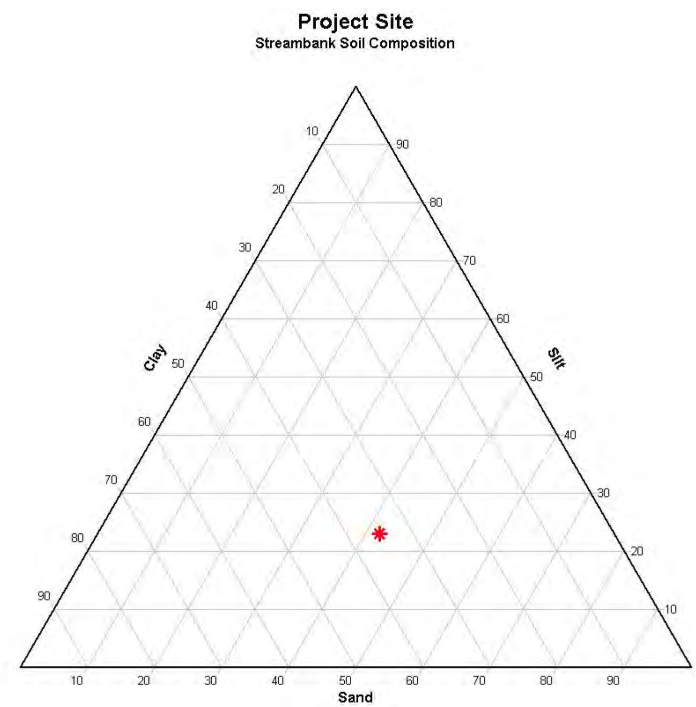


Figure 3-2 Bank Material: Clay loam (42% sand, 23% silt, and 35% clay)

3.2.3 Slope Stability Analysis

None of the lower streambanks exceed the critical bank height (H_c) of the material. For example, the Hc of a slope at an angle of 45^o is 10 feet. This initial analysis of the bare soil is related to gravity and does not consider hydraulic forces, vegetation, or any proposed erosion control materials. Therefore, for a mean bankfull height (Dbkf) of under 2 ft, the bank can be practically vertical from a geotechnical standpoint. Grading the banks at an angle of less than 1:1 will add a factor of safety.

Figure 3-4 can be used to estimate critical bank height (H_c) for bank angle and soil conditions.

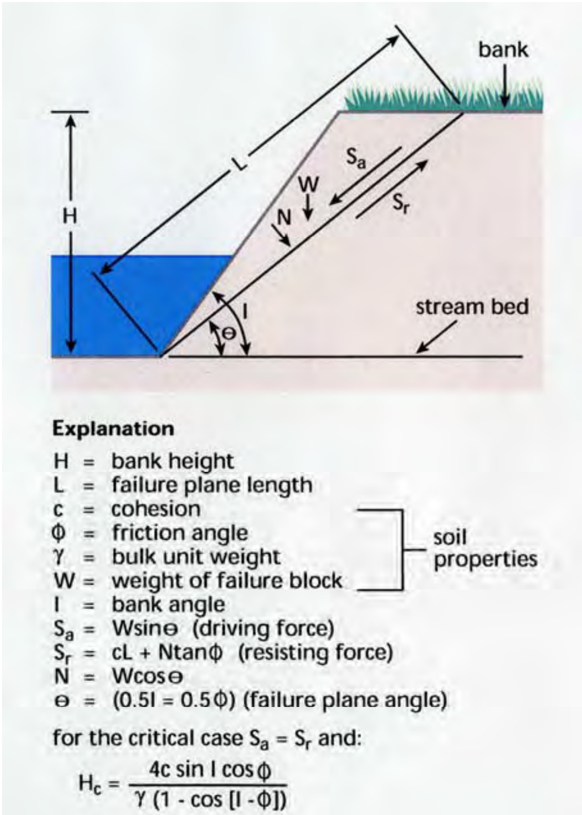


Figure 3-3 Forces acting on a channel bank assuming there is zero pore water pressure. Bank stability analyses relate strength of bank materials to bank height and angles and to moisture conditions. (Source: FISRWG)

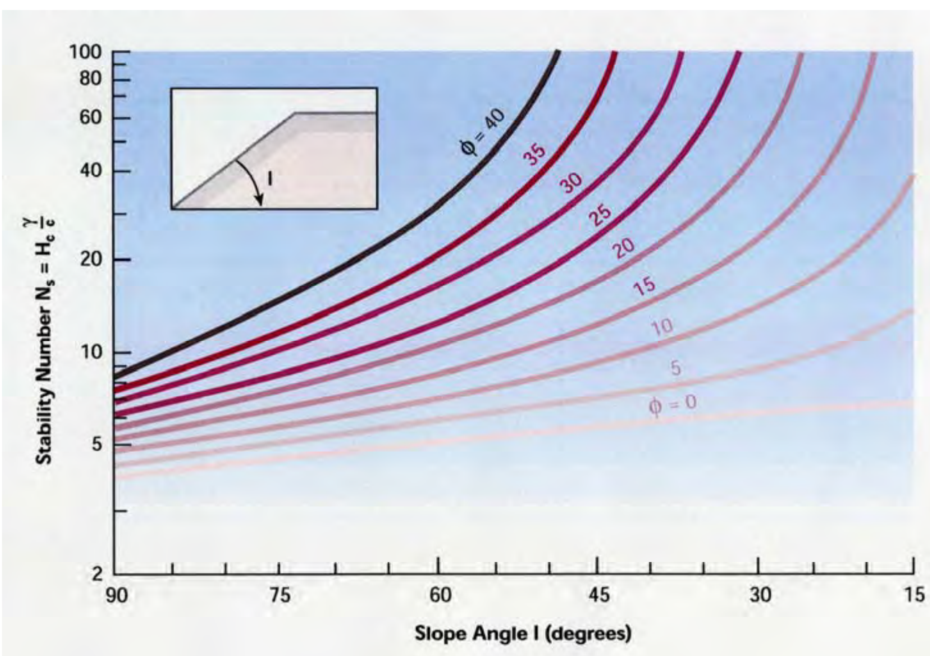


Figure 3-4 Stability number (N_s) as a function of bank angle (i) for a failure surface passing through the bank toe. Critical bank height for worst-case condition can be computed. (Source: Chen, 1975)

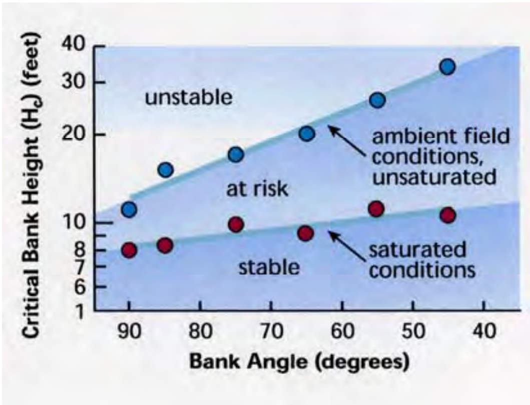


Figure 3-5 Example of a bank stability chart for estimating critical bank height (H_c). Existing bank stability can be assessed, as well as potential stable design heights and slopes. (Source: FISRWG)

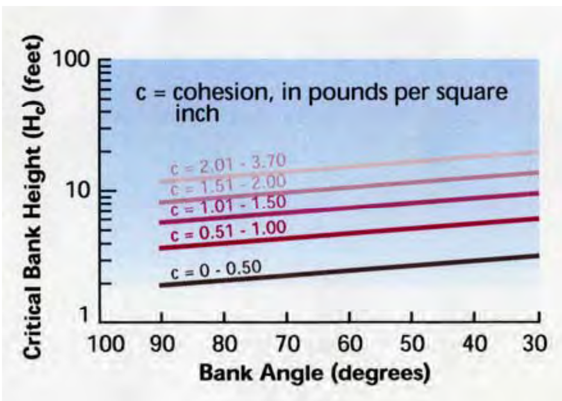


Figure 3-6 Critical bank-slope configurations for various ranges of cohesive strengths under saturated conditions. Specific data on the cohesive strength of bank materials can be collected to determine stable configurations. (Source: FISRWG)

Stability Number (Ns) = Hc * γ/C = Hc *(125/100) = 1.25Hc
Estimated cohesion (C) = 100psf
Estimated Ø = 15^{o}
Estimated unit weight = 125 lb/ft^3

Table 3-1 Project Reach General Geotechnical Stability Analysis

Station	Angle ID	Angle, ^{o}	Ns*	Hc**	Bank Height	Bank Height Exceeds Hc
0+40	A	17	100	80 ft	1.5 ft	No
	B	34	19	15 ft	2.7 ft	No
	C	17	100	80 ft	5.0 ft	No
2+10	A	42	14	11 ft	4.5 ft	No
	B	45	12	10 ft	3.0 ft	No
	C	8	>100	>80 ft	2.0 ft	No
3+20	A	11	>100	>80 ft	1.5 ft	No
	B	51	10	8 ft	2.5 ft	No
	C	45	12	10 ft	3.0 ft	No
	D	21	68	54 ft	3.0 ft	No

* From Figure __ with = 15^o
** Calculated using Ns = 1.25Hc and, therefore, Hc = Ns/1.25

SECTION 4 STREAM GEOMORPHOLOGY

4.1 Rosgen Classification

Table 4.1 Rosgen Classification and Key Geomorphic Parameters

Reach	Detention Basin	Project Reach	Reference Reach
Rosgen Classification	E5	E4 and B4c	C4
Entrenchment Ratio	10.7	2.8	12.3
Width / Depth Ratio	6.4	6.9	9.6
Sinuosity	1.0	1.1	1.47
Slope	0.0875	0.44	0.26

4.2 Velocity

Manning's 'n' of the reference reach was calculated from the relative roughness of the bed material from:

$u/u^* = R^{1/6} / (ng^{0.5})$; n = 0.028
Average Bankfull mean velocity (reference reach) = 3.7 ft/s

The particle size distribution for the design channel was increased slightly which resulted in a value of 'n' = 0.029. Bankfull mean velocity (proposed design) = 3.2 ft/s

4.3 Channel-Forming (Dominant) Discharge

Because the drainage area of the USGS gauge at the Evans Branch was more than twice that of the project reach (DA = 9.49 mi^2), the return interval from the flood frequency curve was not used to estimate the channel-forming discharge. However, the determination of the flood frequency curve provided some useful information:

- The annual peak flows per square mile drainage area at the Evans Branch (54.8 cfs/mi^2) are higher than any of several gauge stations analyzed in the Clinton River and much higher than the Main Rouge at Birmingham (12.8 cfs/mi^2). Therefore, the flows are very flashy. This explains why the estimated channel-forming discharge is so high in the project reach even though the drainage area is so small. Extended detention should be provided to control the effects of altered hydrology for moderate flows along with flood control of larger events.
- A Gumbel plot can be used to quickly estimate the flood frequency curve for discharges below a 5 year return interval (i.e. to estimate the channel-forming discharge), but not for large flood flows (Rosgen). From a Gumbel Plot, Q_2 (discharge with a 2-year return interval) = 520 cfs, $Q_{1.5}$ = 415cfs, and $Q_{1.2}$ = 276 cfs.
- The highest discharge measured was 459 cfs. At that discharge, the velocity was 2.86 ft/s, therefore the bankfull mean velocity of 3.2 ft/s for the proposed channel should be considered conservative. Measurements of W = 59 ft and A = 164 ft^2 are difficult to extrapolate due to the differences in drainage area.

The downstream section of the E5 channel in the existing detention basin had a uniform width and bed material and was unconfined (Wfpa = 110 ft). Therefore, it was thought that the channel in the basin would provide a good estimate of the bankfull channel (although it was not intended to be used as a reference reach). However, the culverts at the basin outlet were set at a negative slope and there was significant deposition upstream of the culverts which created a negative slope for 150 ft. Estimation of the slope just upstream of the deposition provided a discharge that was lower than the project reach or reference channel. The channel upstream of the surveyed reach was unstable. Due to backwater effects of the culverts, there is less confidence in the bankfull discharge calculations in this reach and the values from the reference reach were used instead.

Estimates of bankfull discharge in the project reach were highly variable due to the difficulty in determining the bankfull elevation in an entrenched, unstable channel. The bankfull elevation of the project reach was used to estimate the current velocity, shear stress, and stream power at the bankfull stage and should not be used for design.

SECTION 5 PROPOSED CHANNEL DESIGN

The project reach is relatively confined due to the historic weirs and fill within the floodplain, resulting in high shear stresses during moderate flows. By reducing the velocity, shear stress, and slope of the channel and increasing the width of the floodprone area, the reach will become more stable. Several methods of energy dissipation will have to utilized to offset the effects of the clear water discharge from the basin.

The reach, approximately 600-800 feet long, downstream of the project reach is moderately confined and undergoing varying levels of erosion. Erosion is particularly occurring at the sharp outer bends and where the stream flows up against a hillside. The channel sinuosity is very high at the downstream end of this reach where it transitions into the reference reach area. Extended detention of the 2-yr storm should minimize enlargement of the channel in this reach and allow bank vegetation to establish.

The reference reach area is not pristine, but is relatively stable C4 stream with sand and medium gravel. Sediment from erosion of the project and transition reaches has led to moderate levels of aggradation in the reference reach.

The general form of the proposed project reach will mimic that of the reference reach (i.e., a C4 channel will be created). However, that channel will not be quite as natural in appearance due to the number of structures that will be necessary to dissipate energy. Since the detention basin outflow will essentially have no bedload, threshold methods are appropriate and sediment transport does not need to be considered in the short project reach (Shields).

5.1 Threshold Channel Design

This design procedure uses a threshold-of-motion approach based on a threshold of motion of the bed material and channel banks. Critical shear stress (the value at the threshold of movement) is generally preferred over allowable velocity. Velocity is useful for a quick check of erosion control materials, shear stress should also be evaluated. The following steps were completed:

1. Survey the project reach and reference reach. From the reference reach, determine the bankfull discharge (Q_{bkf}), slope, and dimensions. After extrapolating the Q_{bkf} to the project site by drainage area (78 cfs) and compare to the project reach average Q_{bkf} (74 cfs). A design Q_{bkf} of (70-75) cfs was selected. After entering the proposed cross section, the design discharge was calculated to be 71.3 cfs.
2. Extrapolating the reference reach cross section area to the project site, CSA = 22 ft^2. Assuming a bankfull width of 15 ft and a width:depth ratio of 10, the mean depth is 1.5 ft which gives a CSA of 22.5 ft^2. As a check, the mean velocity (Q/A = V) would be 3.22 ft/s.
3. Based on the geotechnical assessment and the fact that the bank height was only 1.5 ft, an average side slope of 1:1 was used. Using trial and error, a cross section was plotted on the Ohio STREAMS spreadsheet tool until the mean depth was 1.5 ft, CSA was 22.5 ft^2, and the width was 15 ft. The bed particle size distribution was averaged up to round numbers in case bed material was added to the new channel. This increased Manning's 'n' from 0.028 to 0.029. The slope was then lowered slightly (to 0.25%) until the threshold particle size equaled the D50 of the riffle material of the reference reach.
4. Assuming that the sinuosity of the proposed channel is increased from 1.1 to 1.5 (reference reach sinuosity is 1.47), then the channel length will be 600 ft and the valley length 400 ft. The current drop in elevation of 2.26 ft will have to be reduced to 1.5 ft. This could be achieved with an energy dissipater at the basin outlet such as a plunge pool with a grade control structure such as a cross-vane.
5. Check the sediment competence (the ability to move the largest bedload material approximated by the D100 of a subpavement sample) of the proposed channel.
6. Select erosion control materials, bioengineering methods, plant materials, and restoration structures appropriate for the channel type and energy.

5.2 Sediment Entrainment/Competence Calculation (from WARSSS and Andrews)

D50 riffle / D50 subpavement = 10 mm/8 mm = 1.25
Therefore, the ratio of largest bar particle / D50 pavement = 19/12 = 1.58 which is between the values of 1.3 and 3, so critical dimensionless shear stress is calculated by the following equation:

$$\tau_c = 0.038\left(D_i / D_{50}\right)^{-0.887}$$

Where: τ_c = critical dimensionless shear stress

D_i = the largest particle on bar
D_{50} = the medium diameter of bed material on riffle

Di/D50 = 12/9 = 1.58
$\tau_c = 0.038*1.58^{-0.887} = 0.0253$

To calculate depth required to move largest size of bed load using Shields relation:

$$d = \frac{(\tau_c)(D_i)(\gamma_s)}{S}$$

Minimum bankfull mean depth required for entrainment of the largest particle in the subpavement (di):

d = 0.0253*0.06234*1.65/0.0025 = 1.04 ft

Minimum bankfull mean depth required for entrainment of the reference reach riffle D84 is 1.48 ft, which is comparable to the Qbkf (1.5 ft). The interpretations of this analysis indicate that the proposed channel has sufficient shear stress to move the 12 mm particle (reference reach pavement D50) and the reference reach riffle D84 (27mm) at a bankfull depth of 1.5 ft. The available bankfull shear stress could move the D80 of the bed material. If the shear stress is greater than that required to move the D100, then excess bed scour would be anticipated.

In the existing project reach, the required depth (for a steeper slope) to move the 19 mm particle in the subpavement is 0.59 feet, whereas the actual mean bankfull depth of the stream type is approximately 1.7 feet. This indicates that the stream would have excess competence to move the larger sizes. As a result, the prediction would be degradation or channel incision, and field observations confirm the prediction. The increase in sediment size in the project reach is also associated with an increase in bankfull shear stress and stream power (Table 5-1).

Based on D84 (27mm), bankfull water surface slope (S) required:

$S = (\tau_c)(1.65)(Di) / d_{bkf} = 0.0253*1.65*0.08858/1.5 = 0.002465$ ft/ft = 0.0025 ft/ft

Check average shear stress at proposed cross section (NCSRI):

$\tau = \gamma RS = 62.4*1.4*0.0025 = 0.2184$ lb/ft^2 (1.07 kg/m^2)

Compared the Shields diagram, corresponds to a grain diameter of 14 mm which is less than 19 mm, therefore stable. Also, D50 (approximately) = τ (kg/m^2) = 11 mm

Local maximum shear stress in a meandering reach can be estimated by (Chang):

$\tau_{max} = 2.65\,\tau(Rc/W)^{-0.5} = 2.65*0.2184(44/15)^{-0.5} = 0.338$ lb/ft^2

and in straight reaches by $\tau_{max} = 1.5\tau =$ 0.328 lb/ft^2 corresponding to about a 1” particle on the Shield’s curve.

5.2.1 Allowable Velocity Check

The maximum allowable velocity is the greatest mean velocity that will not cause erosion in a natural channel. The velocity can be extremely variable, but can be estimated. The maximum velocity occurs near the surface at a depth of 0.05d to 0.25d and increases significantly along outer bends. The bank material is generally unstratified and the bank material is relatively consistent.

From the Hjulstrom diagram (Knighton), a 10 mm particle size will begin to be entrained at 3 ft/s and will erode at 3.3 ft/s. This matches the proposed velocity of 3.2 ft/s.

As a check, maximum allowable velocity for bioengineering systems with clay loam bank material with matting is 6 ft/s (USDA).

5.3 Erosion Control Materials

A balance needs to be achieved between erosion control (acceptable factor of safety), light penetration (for vegetative growth), and economics.

a. Proposed bank height 1.67 ft.
b. Bank angles approx. 1:1. Cross section developed was 9:10 (H:V).
c. Upper slopes should be less than 1.5:1 (H:V) for vegetative stabilization.
d. Analysis of permissible shear stress indicates that single-net straw erosion control blankets will be stable, even along outer bends; therefore, double-net straw coir ECBs (such as NAG SC150BN) will add to the a factor of safety. Even with a radius of curvature of 35 ft, the shear stress on the bend is only 0.36-0.48 lb/ft^2 and the allowable shear stress for SC150BN is 2.10 lb/ft^2 (FS = 5.8).
e. The allowable shear stress for 6-12" riprap at the toe (D50 = 9 in.) is 3 lb/ft^2 (FS = 6.2).
f. Minimum rock size for cross vanes and steps 0.75 m (2.5 ft). Use two tiers of footer rocks on geotextile fabric and gravel.
g. Stone material for toe protection should be a poorly sorted mix of material to allow for compaction. Minimum stone material size based on velocity and shear stresses is 6 inches and mean diameter should be 12 inches to prevent vandalism in urban areas (USACE); therefore, use 6 to 18 inch stone. Stone should be placed on a gravel toe with poorly sorted gravel used to fill voids. Stone revetment should be placed at a minimum thickness of 1.5*D50 (or 18 inches).
h. If riffles are installed, stone material size should be similar to (g), but riffle crest material should be similar to (f).
i. Where the new bed is excavated into clay hardpan, areas not covered by stone should be covered with a 0.5-1 ft layer of river run gravel and compacted using the design bed material gradation:

% Finer than	Size	Units
D16	2	mm
D35	5	mm
D50	10	mm
D84	30	mm
D95	40	mm

5.6 Clear Water Discharge

Clear water is flow that enters a channel with very little or no sediment load. It is referred to as 'hungry' water because it has full capacity to entrain and transport sediment (Johnson). Clear water is an issue in the Tamarack Drain because the inline detention basin effectively traps out the entire bedload, leaving virtually no sediment discharge available to the stream. As a result, the channel design needs to compensate for this factor by providing greater energy dissipation than would be necessary in a more natural setting. Johnson et al proposed four alternatives:

1. Create a source of sediment at the headwaters – Not an option.
2. Reduce the velocity of flow –
   a. Increase channel roughness (bed topography, woody vegetation, wood, stone)
   b. Increase W/D ratio (reduce hydraulic radius)
   c. Reduce channel slope (increase sinuosity)
3. Provide grade control or armor the bed and banks at strategic locations - Use grade control structures (with footers twice the normal depth) such as Newbury weirs, vortex weirs, cross vanes, step-pools to limit bed degradation. For bank protection, use various forms of bank and toe protection (mix of hard and vegetation) such as crib walls, stone toe, joint plantings, and brush mattresses (high roughness and more woody shrubs).
4. Declare that some enhancement techniques are inappropriate in clear water conditions – do not use coir fiber rolls and rootwads which may be subject to undermining.

5.6 Site Constraints

The main constraint at the project reach is available flood-prone area width. Because much of the area along the west side of the channel consists of fill soils, invasive plant materials, and poor quality trees, some of the west side can be excavated to provide adequate width to increase sinuosity and flood-prone area width. The loamy upper layer of Sloan soils should be retained during excavation and used as topsoil for plantings. Site access and stockpiling areas should be designated on the plans. Where a distinct break in soil materials (from loam to clay) exists along the newly constructed streambank, a gravel filter (Figure 5-1) should be used under the constructed bank to reduce groundwater seepage and the effects of negative pore pressures.

Along the lower slope of the east side, a bench could be constructed to the bankfull elevation (a bankfull bench) and the upper slope graded or filled to a stable angle.

5.6 Groundwater Seepage

Erosion due to groundwater seepage along the interface of the upper loam material and clayey subsoil may be a concern. Significant groundwater seepage was noted at only one location at the lower right bank near the weir at station 3+70 (Figure 3-2). Where this problem is a concern, the geotechnical solution is to utilize a gravel filter drain of ¾” crushed gravel 9” thick between the new bank and submaterial as proposed by Miller (Figure 5-1).

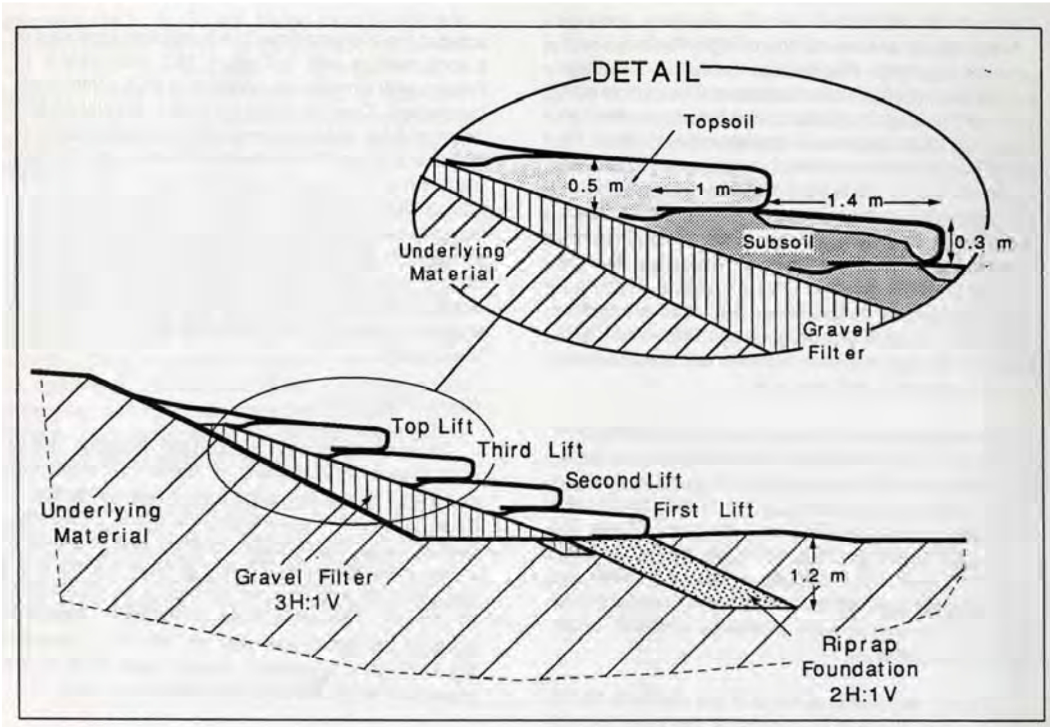
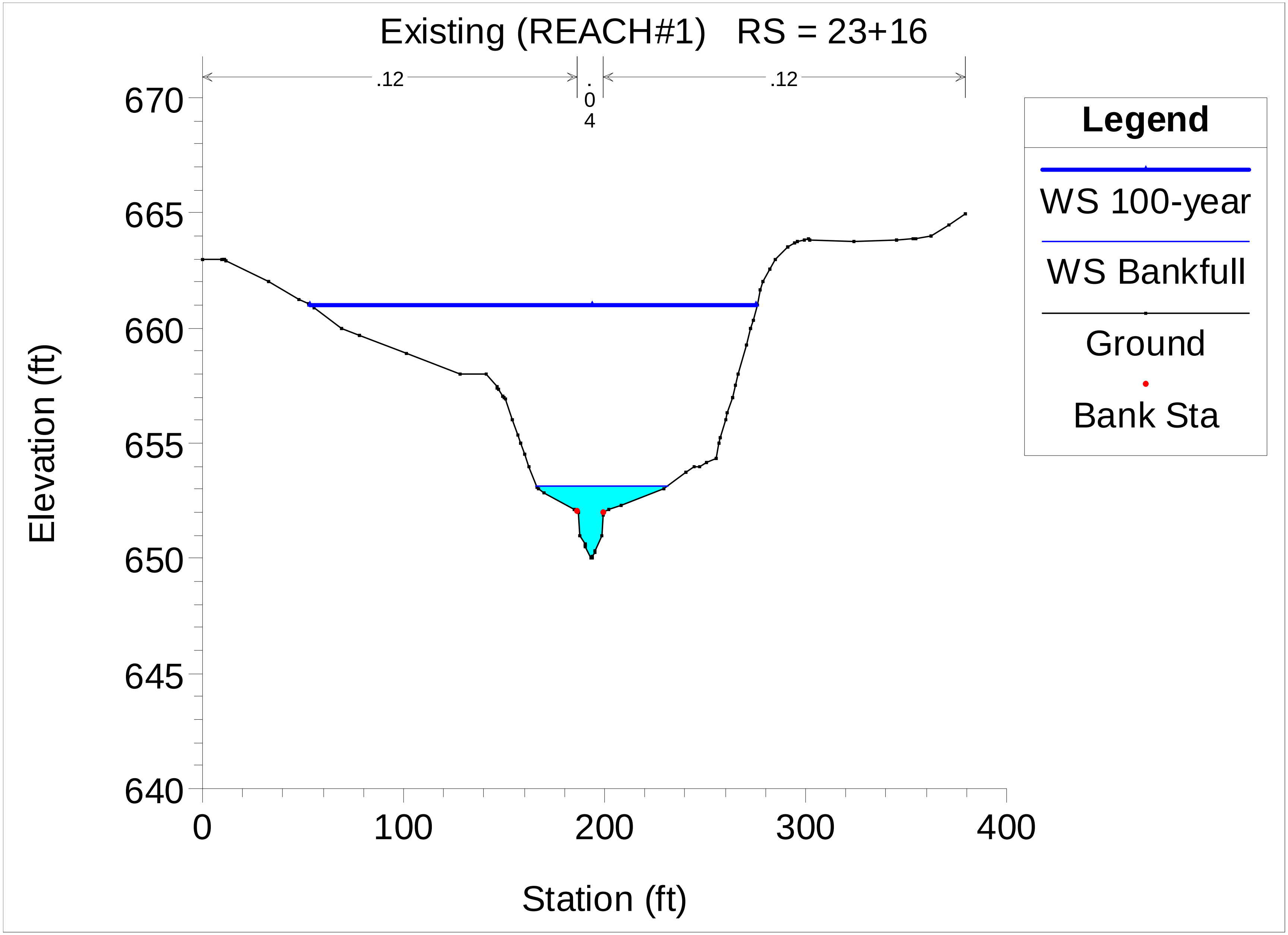


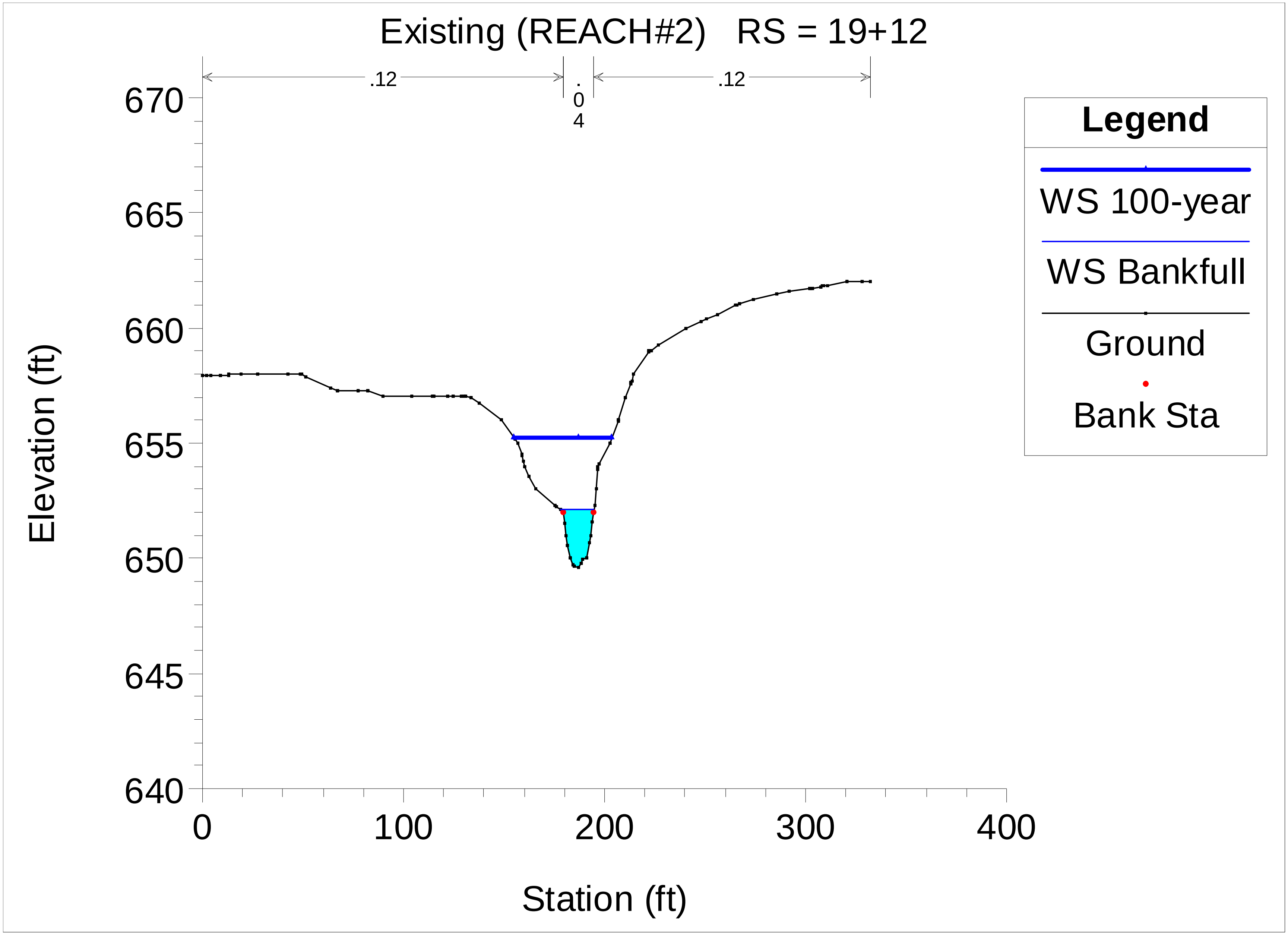
Figure 5-1 Typical Cross-Section of a Re-Constructed Bank with Gravel Filter Drain

Table 5-1 Existing-Condition, Reference and Design Information

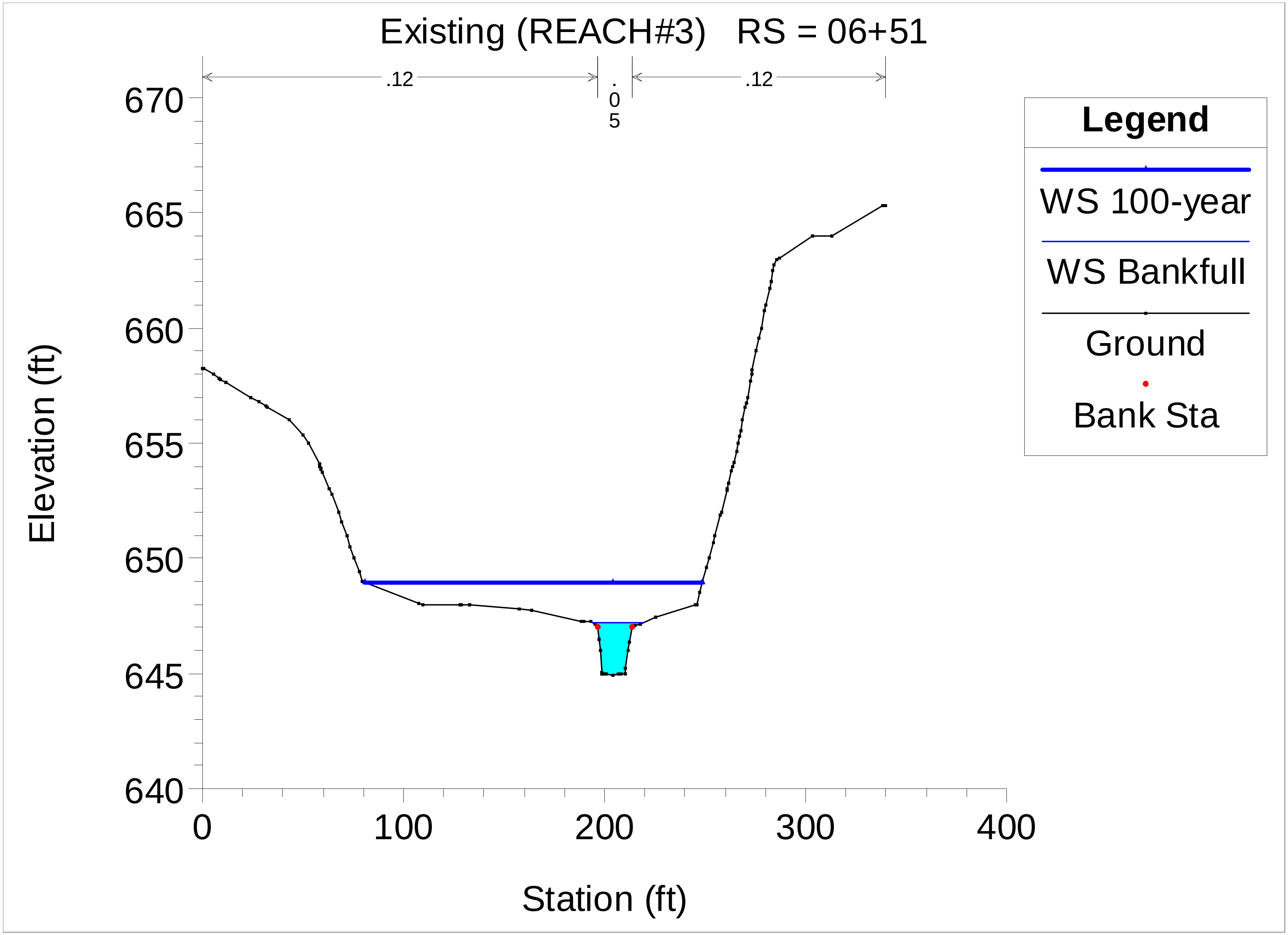
		Existing Detention Basin	**Existing Project Reach**	**Reference Reach**	**Proposed (NCD) Reach**
Parameter, symbol (equation)	**Units**	**Average Value (Range)**	**Average Value (Range)**	**Average Value (Range)**	**Average Value (Range)**
Drainage Area, DA	mi^2	0.89 (570 ac)	0.89	1.1 estimated	0.9
Rosgen Stream Type		E5	E4 (B4c & E4)	C4	C4
Bankfull Width, W_{bkf}	ft	10.3	11.6 (11.2-12.5)	16.3 (15.1-17.6)	15
Bankfull Mean Depth, d_{bkf} (A_{bkf}/W_{bkf})	ft	1.6	1.7 (1.3-2.0)	1.75 (1.7-1.8)	1.5
Width-Depth Ratio (W_{bkf}/d_{bkf})		6.4	6.9 (5.7-8.9)	9.6 (8.6-10.6)	10
Maximum Depth at Bankfull Stage, d_{mbkf}	ft	1.9	2.6 (2.6-2.8)	2.25 (2.2-2.3)	1.75
Max. Depth Ratio (D_{max}/D_{bkf})		1.2	1.5	1.3	1.17
Bank Height Ratio (LBH/d_{mbkf})		1.1	1.0	0.9	1
Bankfull Cross Section Area, A	ft^2	16.7	20.5 (14.1-25.5)	27.9 (26.5-29.2)	22.5
Width Flood-Prone Area, W_{fpa}	ft	110	32.5 (26-41)	202 (180-223)	>60
Entrenchment Ratio, ER (W_{fpa}/W_{bkf})		10.7	2.8 (2.3-3.3)	12.3 (11.9-12.7)	>4
Ratio Riffle:Pool:Run:Glide Length		N/A	39.2:25.5:10.3:25.0	20.4:37.3:21.0:21.3	60:40 (R:P)
Meander Belt Width, W_{blt}	ft	N/A	115	240	150
Meander Width Ratio, MWR (W_{blt}/W_{bkf})		N/A	9.9	14.7	10
Valley Length, L_{val}	ft	N/A	360	900	400??
Channel Length, L	ft	N/A	395	1325	
Sinuosity, K (L_m/L_{val})	ft/ft	1.0	1.10	1.47	1.5
Radius of Curvature, R_c	ft	N/A	N/A	47 (35-58)	44 (40-60)
R_c/W_{bkf}		N/A	N/A	2.9 (2.7-3.1)	2.9
Pool:Pool Spacing **(Spacing/ W_{bkf})**	ft	N/A	106.3 (23-214) **(9.16)**	72.7 (30-129) **(4.46)**	68 **(4.5)**
Riffle Length, L_{rif}	ft	N/A	51 (17-94)	15.3 (6-25)	25?
Hydraulic Radius, R	ft	1.3	1.4 (1.1-1.7)	1.55 (1.5-1.6)	1.4
Wetted Perimeter, Wp	ft	12.9	13.8 (12.8-14.6)	18.2 (16.6-19.7)	16.5
Shear Velocity, u*	ft/s	0.19	0.44 (0.37-0.48)	0.355 (0.35-0.36)	0.33
Avg. Shear Stress, τ (γRS)	lb/ft^2	0.07	0.38 (0.27-0.45)	0.25 (0.24-0.26)	0.21
Unit Stream Power, ω (τ/u)	lb/ft/s	0.27	1.67 (1.12-2.2)	1.00 (0.957-1.05)	0.74
Slope, S	%	0.0875	0.44 (0.39-0.47)	0.26	0.25
Relative Roughness ($d_{bkf}/D84$)	ft/ft	234.5	19.7 (14.2-23)	17.4 (16.9-17.8)	15.3
Friction Factor (u/u*)		16.3	10.3 (9.8-10.7)	10.35 (10.3-10.4)	9.6
Manning's 'n' value		0.017	0.034 (0.027-0.04)	0.028	0.029
Bankfull Mean Velocity	ft/s	3.1	3.6 (3.4-3.9)	3.7 (3.6-3.8)	3.2
Bankfull Discharge (calculated)	ft^3/s	51.7	74.2 (51.5-86.2)	100 (97.4-102.8)	71.3 (52-80)
D16	mm	0.3	N/A	0.5	2
D35	mm	0.5	N/A	4	5
D50	mm	0.76	N/A	7.7	10
D84	mm (ft)	2.1 (0.00689)	N/A	27 (0.0886)	30 (0.0984)
D95	mm	4.9	N/A	39	40

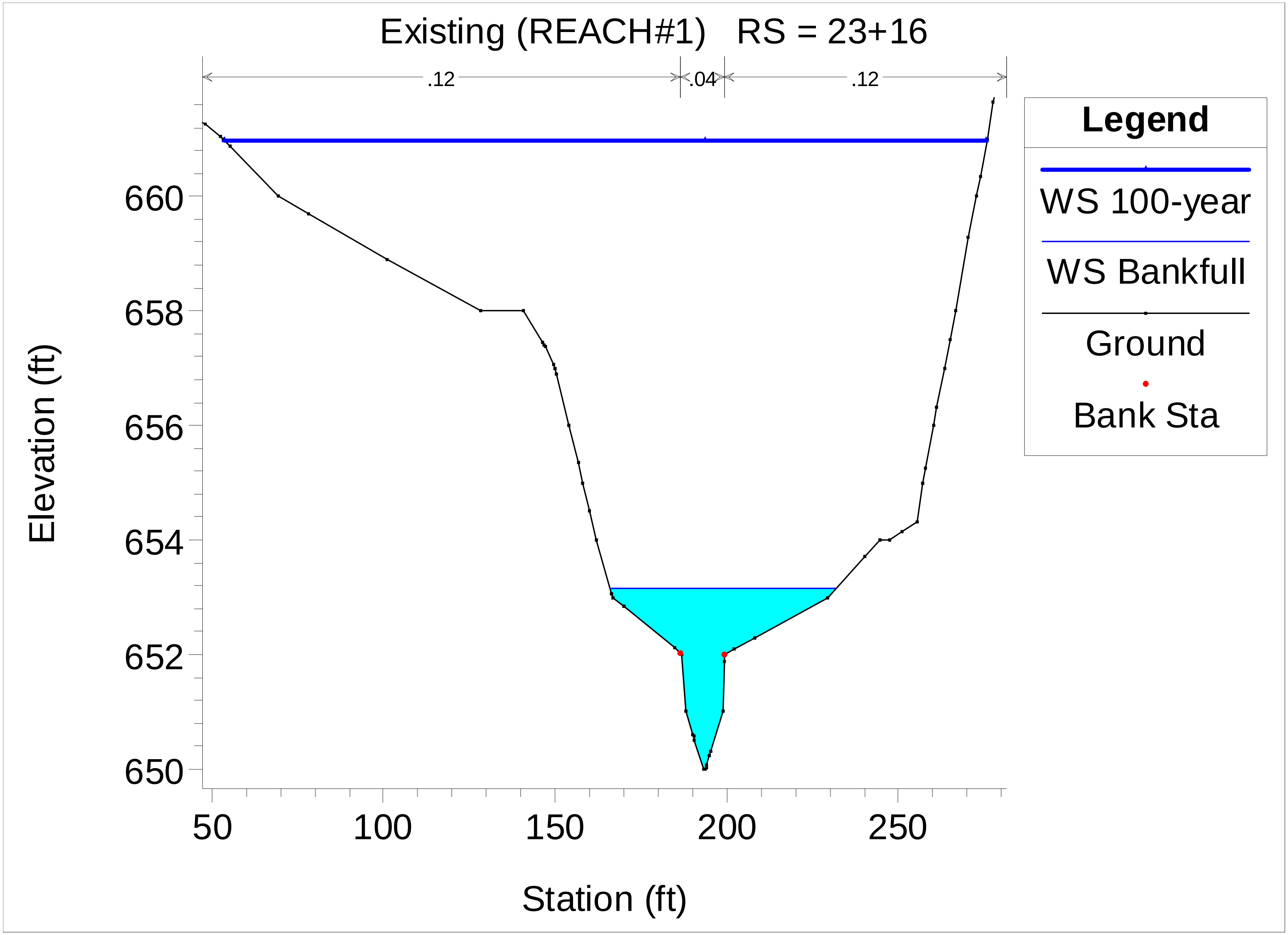
Appendix J


Existing (REACH#1) RS = 23+16
.12
.04
.12
Elevation (ft)
670
665
660
655
650
645
640
0
100
200
300
400
Station (ft)
Legend
WS 100-year
WS Bankfull
Ground
Bank Sta

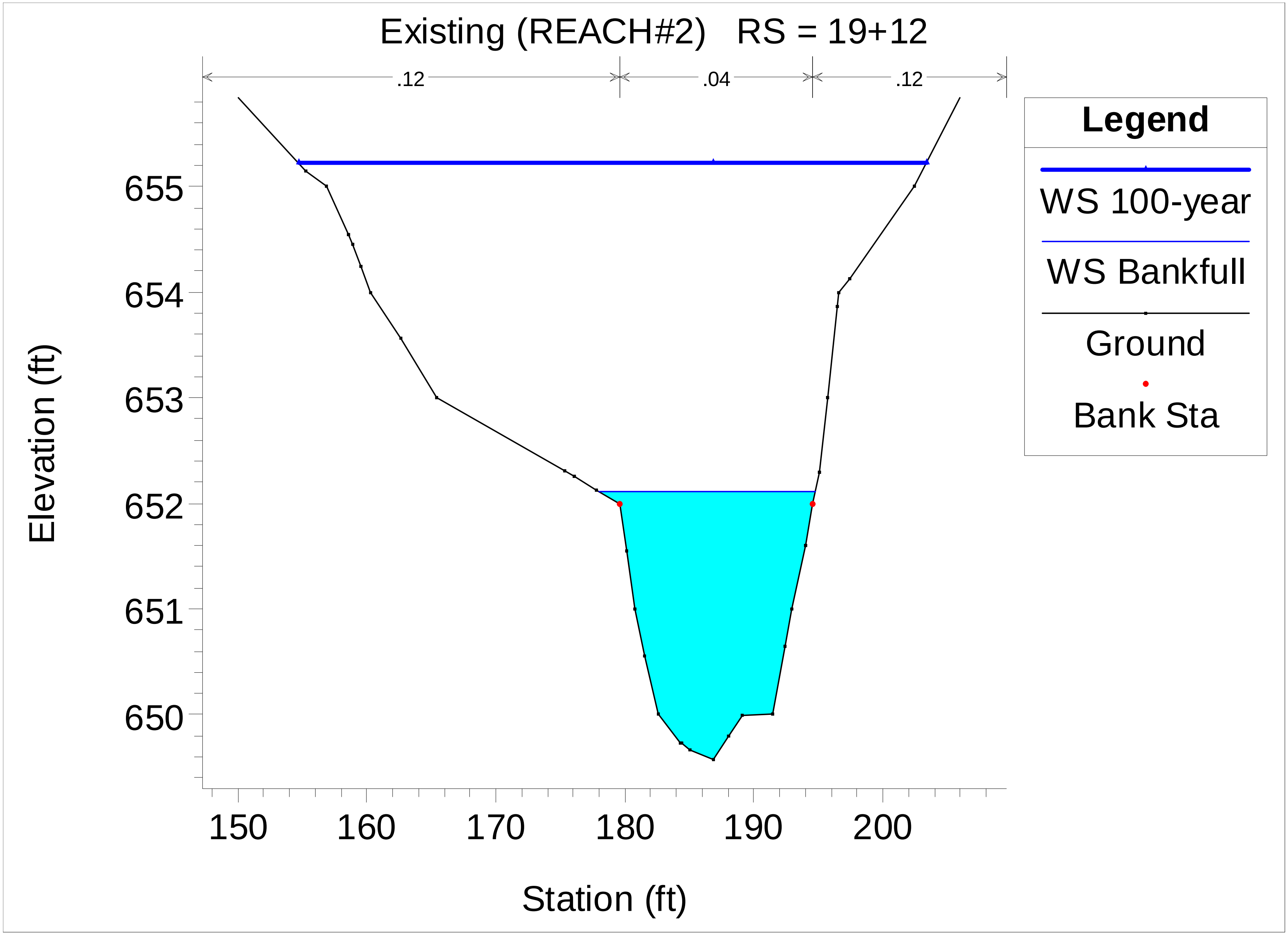


Existing (REACH#2) RS = 19+12
.12
.04
.12
Elevation (ft)
670
665
660
655
650
645
640
0
100
200
300
400
Station (ft)
Legend
WS 100-year
WS Bankfull
Ground
Bank Sta

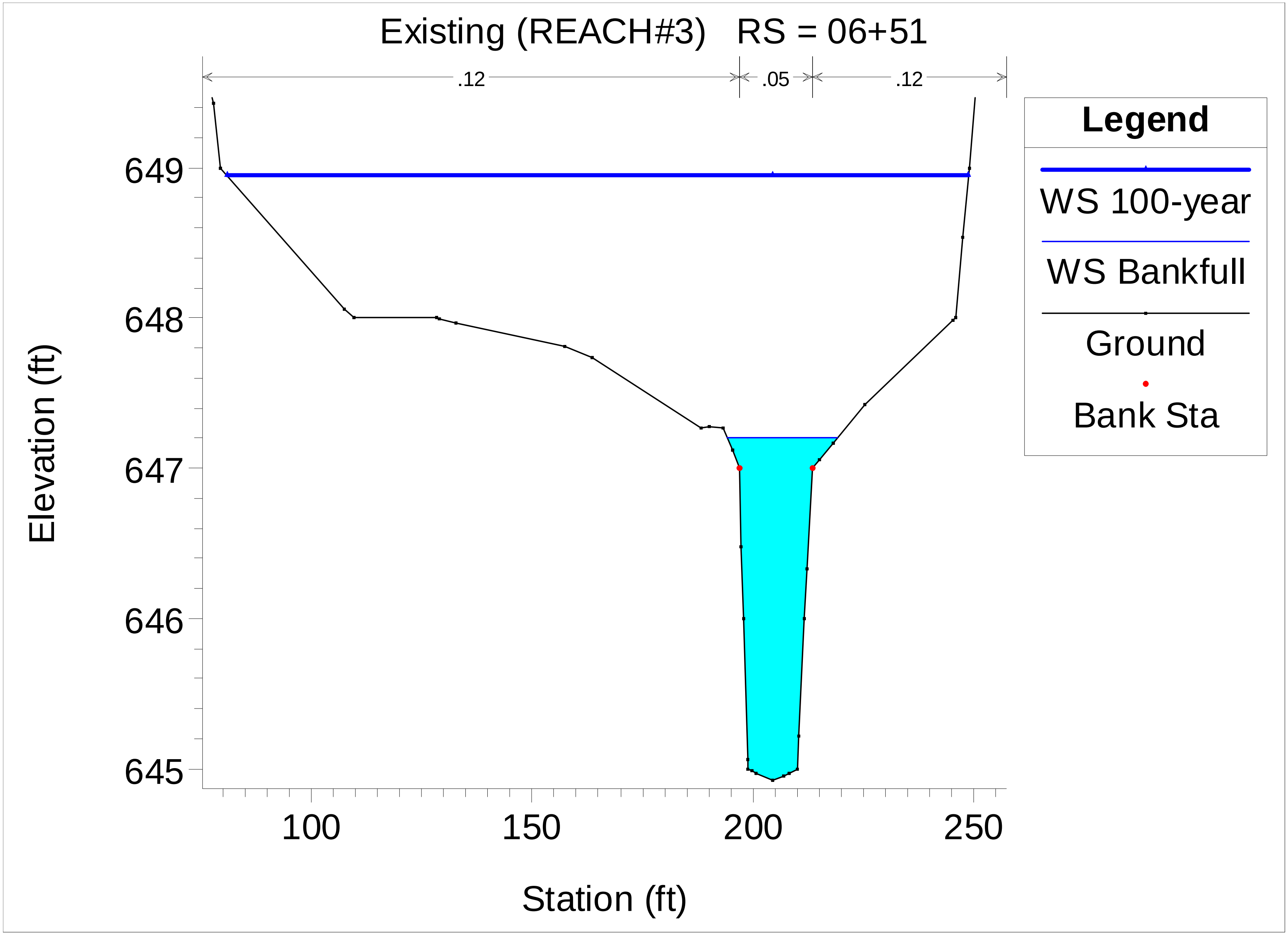

Existing (REACH#3) RS = 06+51
.12
.05
.12
Legend
WS 100-year
WS Bankfull
Ground
Bank Sta
Elevation (ft)
670
665
660
655
650
645
640
0
100
200
300
400
Station (ft)

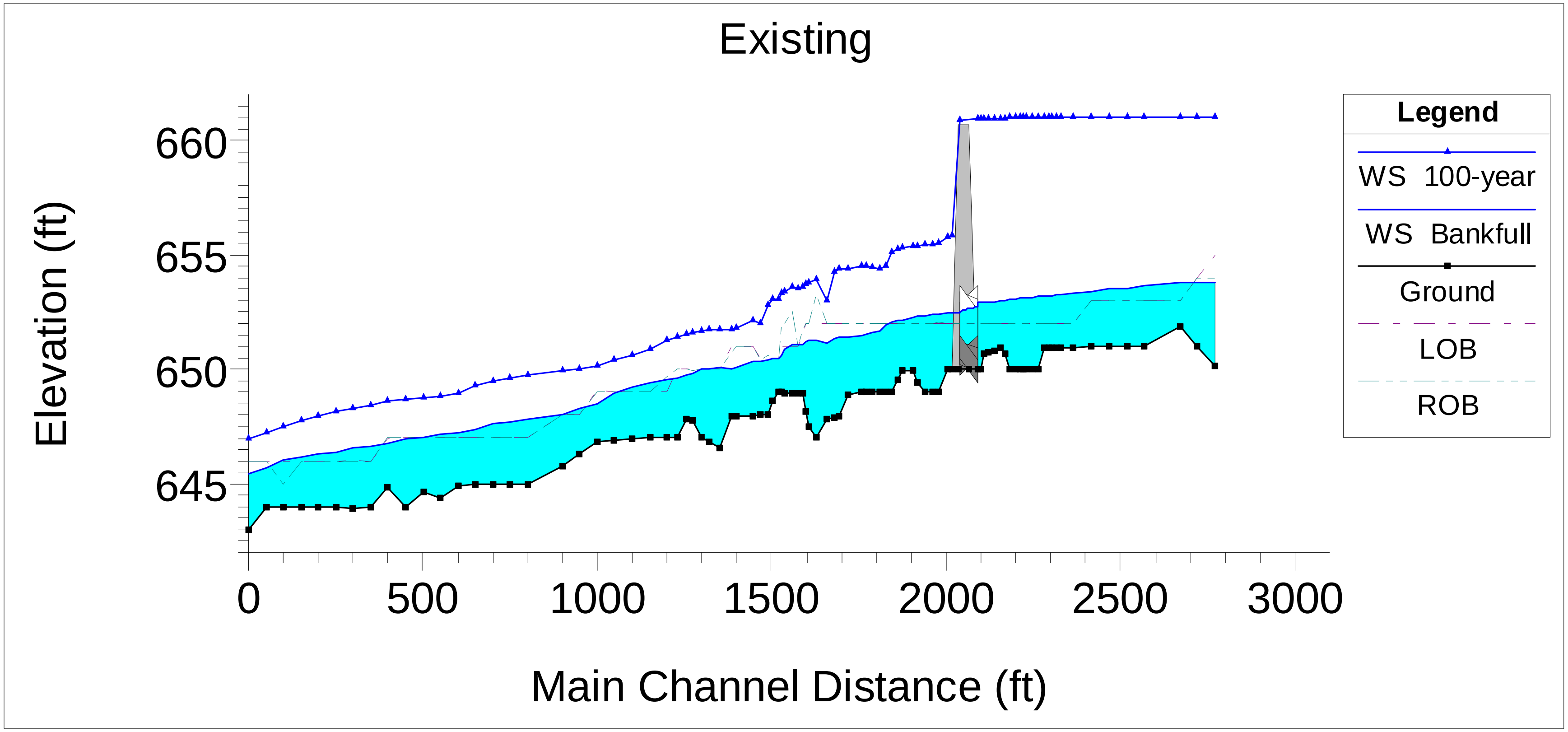


Existing (REACH#1) RS = 23+16
.12
.04
.12
Legend
WS 100-year
WS Bankfull
Ground
Bank Sta
Elevation (ft)
660
658
656
654
652
650
50
100
150
200
250
Station (ft)



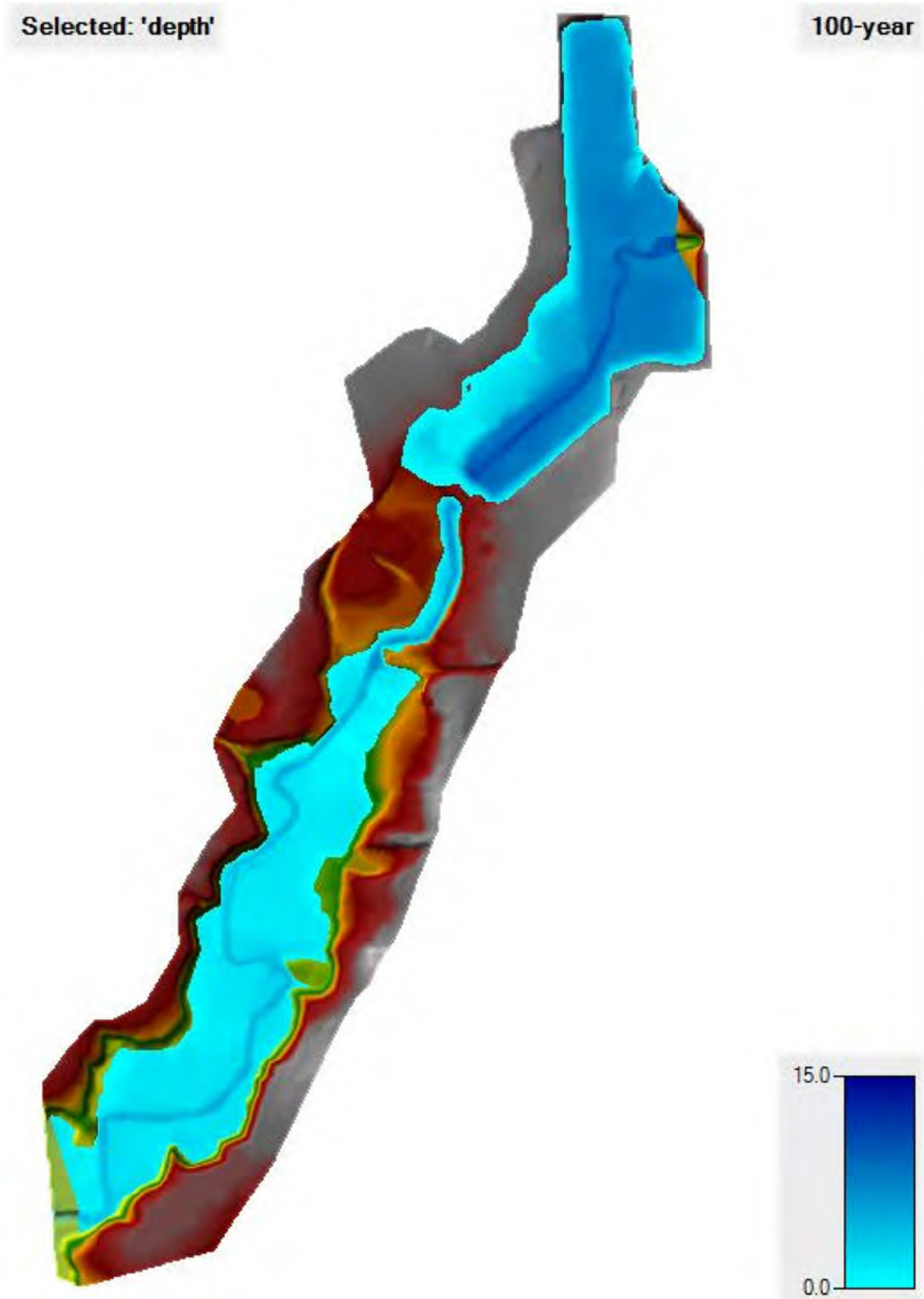
Existing (REACH#2) RS = 19+12
.12
.04
.12
Legend
WS 100-year
WS Bankfull
Ground
Bank Sta
655
654
653
652
651
650
Elevation (ft)
150
160
170
180
190
200
Station (ft)


Existing (REACH#3) RS = 06+51
.12
.05
.12
Legend
WS 100-year
WS Bankfull
Ground
Bank Sta
Elevation (ft)
649
648
647
646
645
100
150
200
250
Station (ft)

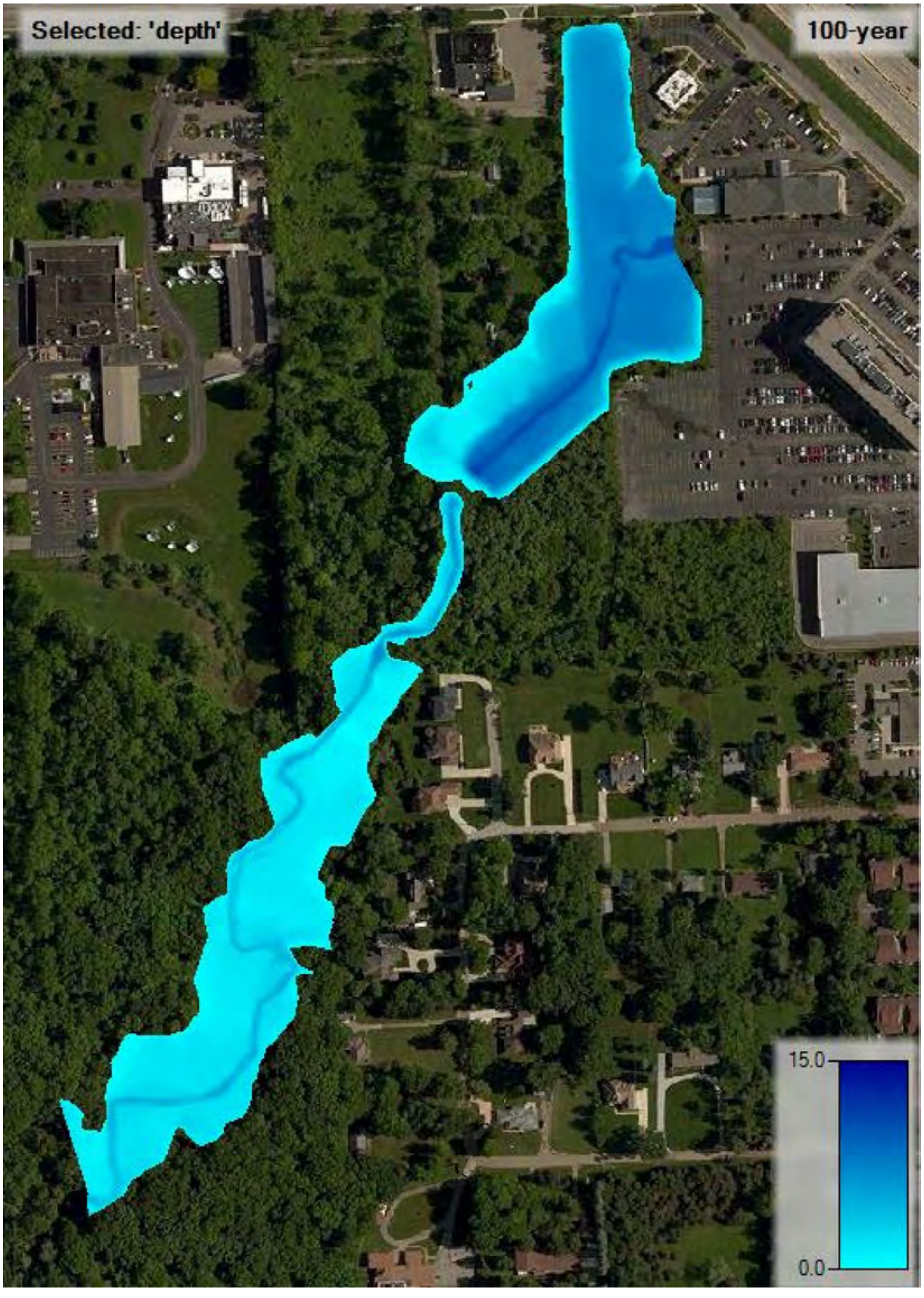


Existing
Elevation (ft)
660
655
650
645
0
500
1000
1500
2000
2500
3000
Main Channel Distance (ft)
Legend
WS 100-year
WS Bankfull
Ground
LOB
ROB


2821.16
2620.82
2570.99
2466.39
2415.96
2282.79
2347.83
2219.67
2191.58
2160.12
2106.84
2067.36
2028.75
1989.51
1956.48
1896.38
1808.17
1711.26
1678.95
1638.6
1589.85
1539.73
1495.79
1451.14
1401.51
1351.48
1281.1
1201.59
1151.61
1101.33
1051.46
1001.58
951.64
701.54
Ex HECRAS Export
651.4
451.51
351.48
301.2
251.35



Selected: 'depth'
100-year
15.0
0.0



Selected: 'depth'
100-year
15.0
0.0

Existing Bankfull HEC-RAS Output

River Sta	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Vel Left (ft/s)	Vel Right (ft/s)	Flow Area (sq ft)	Top Width (ft)	Shear Chan (lb/sq ft)	Shear LOB (lb/sq ft)	Shear ROB (lb/sq ft)	Froude # Chl
2821.2	80	650.16	653.80	653.81	0.00011	0.76			105.38	35.68	0.02			0.08
2771.2	80	651.00	653.78	653.80	0.00050	1.34	0.10	0.16	126.37	219.17	0.06	0.01	0.01	0.16
2721.1	80	651.84	653.76	653.77	0.00052	1.21	0.19	0.20	217.12	337.92	0.06	0.02	0.02	0.16
2620.8	80	651.00	653.68	653.71	0.00076	1.58	0.16	0.25	124.84	179.82	0.09	0.02	0.03	0.19
2571.0	80	651.00	653.54	653.64	0.00238	2.73	0.25	0.37	65.55	109.57	0.27	0.04	0.07	0.34
2520.8	80	651.00	653.49	653.55	0.00110	1.87	0.24	0.18	57.54	66.28	0.13	0.03	0.02	0.23
2466.4	80	651.00	653.40	653.47	0.00154	2.15	0.16	0.16	38.68	27.44	0.17	0.02	0.02	0.27
2416.0	80	650.97	653.31	653.39	0.00164	2.46	0.41	0.16	49.20	42.44	0.21	0.08	0.02	0.29
2379.7	80	650.95	653.26	653.33	0.00148	2.32	0.37	0.25	50.30	46.13	0.19	0.06	0.03	0.28
2368.0	80	650.95	653.24	653.31	0.00155	2.37	0.37	0.30	51.32	48.85	0.20	0.06	0.05	0.28
2356.5	80	650.94	653.22	653.30	0.00156	2.36	0.37	0.34	53.13	50.66	0.20	0.06	0.06	0.28
2347.8	80	650.94	653.20	653.28	0.00157	2.37	0.36	0.37	55.46	53.28	0.20	0.06	0.06	0.28
2333.9	80	650.93	653.17	653.26	0.00177	2.47	0.39	0.36	56.07	59.06	0.22	0.07	0.06	0.30
2315.7	80	650.00	653.16	653.22	0.00114	2.17	0.31	0.30	64.72	65.66	0.16	0.04	0.04	0.24
2296.8	80	650.00	653.14	653.20	0.00114	2.22	0.30	0.29	67.54	72.60	0.17	0.04	0.04	0.24
2282.8	80	650.00	653.12	653.18	0.00108	2.17	0.29	0.29	71.11	78.78	0.16	0.04	0.04	0.24
2272.8	80	650.00	653.11	653.17	0.00106	2.14	0.29	0.28	73.84	83.12	0.16	0.04	0.04	0.24
2262.5	80	650.00	653.10	653.16	0.00104	2.09	0.28	0.27	74.01	84.60	0.15	0.04	0.04	0.23
2253.1	80	650.00	653.09	653.15	0.00109	2.15	0.29	0.24	68.65	85.18	0.16	0.04	0.03	0.24
2235.8	80	650.00	653.06	653.13	0.00118	2.18	0.29	0.20	62.42	85.16	0.16	0.04	0.02	0.25
2219.7	80	650.66	653.01	653.10	0.00186	2.50	0.34	0.19	51.43	85.23	0.23	0.06	0.02	0.31
2209.2	80	650.91	652.98	653.08	0.00234	2.69	0.37	0.33	46.96	63.68	0.27	0.07	0.05	0.34
2191.6	80	650.82	652.95	653.03	0.00211	2.55	0.34	0.35	56.40	73.58	0.24	0.06	0.06	0.32
2172.3	80	650.72	652.93	652.99	0.00150	2.20	0.31	0.30	64.11	79.69	0.18	0.05	0.05	0.27
2160.1	80	650.66	652.94	652.97	0.00078	1.51	0.22	0.26	80.05	78.44	0.09	0.02	0.03	0.20
2152.9	80	650.00	652.94	652.96	0.00043	1.24	0.14	0.19	88.13	73.98	0.05	0.01	0.02	0.15
2144.2	80	650.00	652.94	652.96	0.00029	1.08	0.12	0.12	89.24	68.41	0.04	0.01	0.01	0.13
2106.8	Culvert													
2067.4	80	650.00	652.49	652.54	0.00084	1.71	0.13	0.14	47.29	24.24	0.11	0.01	0.01	0.21

2056.2	80	650.00	652.43	652.52	0.00209	2.39	0.20	0.22	34.74	25.09	0.22	0.03	0.03	0.32
2028.8	80	649.00	652.39	652.47	0.00151	2.36	0.15	0.13	34.16	16.11	0.20	0.02	0.01	0.27
2012.0	80	649.00	652.37	652.45	0.00116	2.17	0.13	0.13	37.10	16.10	0.16	0.01	0.01	0.24
1989.5	80	649.00	652.35	652.42	0.00101	2.05	0.11	0.12	39.28	16.63	0.14	0.01	0.01	0.22
1970.1	80	649.43	652.32	652.39	0.00136	2.23	0.11	0.13	36.08	16.71	0.18	0.01	0.01	0.26
1956.5	80	649.92	652.26	652.37	0.00222	2.60	0.16	0.13	31.06	17.47	0.25	0.02	0.01	0.32
1926.6	80	649.97	652.16	652.29	0.00299	2.87	0.13	0.10	28.13	18.02	0.31	0.02	0.01	0.37
1912.2	80	649.57	652.11	652.25	0.00305	2.91	0.10	0.09	27.57	16.74	0.32	0.01	0.01	0.38
1896.4	80	649.00	652.08	652.20	0.00256	2.81	0.07	0.05	28.52	14.69	0.29	0.01		0.35
1879.7	80	649.00	651.91	652.13	0.00525	3.76			21.30	10.94	0.54			0.47
1860.0	80	648.99	651.70	651.99	0.00874	4.35			18.38	11.50	0.77			0.61
1841.1	80	648.99	651.58	651.82	0.00742	3.92			20.41	13.63	0.63			0.56
1822.4	80	648.99	651.51	651.68	0.00550	3.39			23.63	16.17	0.47			0.49
1808.2	80	648.99	651.47	651.61	0.00391	2.97			26.91	17.37	0.35			0.42
1772.3	80	648.89	651.38	651.48	0.00260	2.63			30.42	17.38	0.27			0.35
1746.7	80	647.94	651.38	651.43	0.00087	1.88			42.62	16.28	0.12			0.20
1729.6	80	647.88	651.33	651.41	0.00154	2.23			35.85	16.40	0.18			0.27
1711.3	80	647.82	651.14	651.35	0.00526	3.65			21.90	11.88	0.52			0.47
1679.0	80	647.00	651.27	651.28	0.00009	0.75		0.05	107.83	34.34	0.02		0.00	0.07
1658.7	80	647.52	651.24	651.27	0.00045	1.42			56.39	20.85	0.07			0.15
1647.2	80	648.15	651.19	651.26	0.00145	2.10			38.07	18.90	0.16			0.26
1638.6	80	648.95	651.09	651.23	0.00423	3.08			25.98	16.86	0.38			0.44
1627.3	80	648.96	651.05	651.19	0.00397	3.03	0.06	0.06	26.46	18.43	0.36	0.01		0.43
1610.9	80	648.97	651.05	651.12	0.00187	2.21	0.04		36.16	22.74	0.19	0.00		0.30
1589.9	80	648.98	650.85	651.05	0.00641	3.57			22.39	16.25	0.53			0.54
1581.1	80	648.99	650.64	650.96	0.01177	4.56			17.55	13.79	0.88			0.71
1570.6	80	648.99	650.46	650.82	0.01377	4.81			16.64	13.37	1.00			0.76
1556.0	80	648.60	650.45	650.65	0.00599	3.57			22.44	15.02	0.52			0.51
1539.7	80	648.00	650.43	650.56	0.00306	2.84			28.16	15.53	0.31			0.37
1517.3	80	648.00	650.38	650.49	0.00261	2.72			29.41	14.35	0.28			0.34
1495.8	80	647.99	650.32	650.43	0.00263	2.73			29.33	14.79	0.28			0.34
1451.1	80	647.95	650.07	650.26	0.00601	3.48			23.00	15.09	0.50			0.50
1435.6	80	647.94	650.05	650.17	0.00348	2.77			28.83	19.29	0.31			0.40
1401.5	80	646.59	650.07	650.10	0.00054	1.51	0.03	0.04	55.01	57.44	0.08	0.00	0.00	0.17

1373.9	80	646.82	650.02	650.08	0.00177	1.91	0.02	0.04	42.54	65.95	0.21		0.00	0.24
1351.5	84.6	647.00	650.00	650.04	0.00124	1.62			52.16	25.46	0.15			0.20
1325.6	84.6	647.78	649.83	649.97	0.00551	2.95			28.64	16.52	0.53			0.40
1305.2	84.6	647.82	649.73	649.86	0.00541	2.86			29.61	18.08	0.50			0.39
1281.1	84.6	647.00	649.64	649.74	0.00398	2.55			33.20	19.62	0.39			0.35
1251.6	84.6	647.00	649.55	649.64	0.00273	2.46	0.25	0.08	37.42	30.04	0.34	0.04	0.01	0.29
1201.6	84.6	647.00	649.41	649.50	0.00287	2.34	0.13	0.24	42.05	49.37	0.32	0.02	0.04	0.30
1151.6	84.6	646.94	649.23	649.32	0.00439	2.71	0.23	0.49	66.91	109.32	0.44	0.04	0.13	0.35
1101.3	84.6	646.89	648.96	649.06	0.00600	2.47		0.14	34.23	29.78	0.42		0.02	0.40
1051.5	84.6	646.84	648.48	648.66	0.01069	3.44			24.58	19.86	0.79			0.55
1001.6	84.6	646.30	648.26	648.33	0.00373	2.34	0.17	0.44	69.20	112.81	0.34	0.02	0.10	0.33
951.6	84.6	645.78	648.03	648.12	0.00447	2.68	0.04	0.39	62.36	127.63	0.44	0.00	0.09	0.36
851.3	84.6	645.00	647.84	647.87	0.00137	1.47	0.24	0.19	61.17	45.56	0.13	0.03	0.02	0.20
801.3	84.6	645.00	647.71	647.78	0.00225	2.32	0.41	0.24	64.72	72.08	0.30	0.08	0.04	0.27
751.5	84.6	645.00	647.61	647.68	0.00189	2.08	0.26	0.24	53.62	63.67	0.24	0.04	0.04	0.25
701.5	84.6	644.96	647.39	647.53	0.00471	2.98	0.28	0.30	33.25	40.34	0.52	0.06	0.06	0.38
651.4	84.6	644.92	647.20	647.31	0.00377	2.67	0.16	0.16	32.48	24.87	0.42	0.02	0.02	0.34
601.9	84.6	644.37	647.14	647.18	0.00139	1.71	0.11	0.08	52.47	52.99	0.17	0.01	0.01	0.21
551.8	84.6	644.65	647.01	647.09	0.00286	2.14	0.04	0.03	41.12	145.90	0.28	0.00	0.00	0.30
501.6	84.6	644.00	646.95	646.98	0.00129	1.49			56.80	33.18	0.13			0.20
451.5	84.6	644.86	646.75	646.86	0.00555	2.58		0.12	34.39	63.79	0.44		0.02	0.40
401.6	84.6	643.97	646.66	646.72	0.00144	1.85	0.20	0.23	55.05	57.87	0.19	0.02	0.03	0.22
351.5	84.6	643.91	646.54	646.62	0.00238	2.28	0.25	0.27	47.75	57.72	0.29	0.04	0.05	0.27
301.2	84.6	644.00	646.39	646.48	0.00332	2.43	0.24	0.26	49.74	96.25	0.35	0.04	0.04	0.32
251.4	84.6	644.00	646.29	646.35	0.00178	1.96	0.11	0.16	59.42	124.45	0.22	0.01	0.02	0.24
201.4	84.6	644.00	646.14	646.22	0.00383	2.42	0.13	0.35	52.33	85.60	0.36	0.02	0.08	0.34
151.3	84.6	644.00	646.02	646.08	0.00208	1.99	0.03	0.53	58.16	51.83	0.23	0.00	0.12	0.25
101.6	84.6	644.00	645.72	645.88	0.00861	3.19	0.16		26.88	27.99	0.67	0.03		0.49
51.7	84.6	643.00	645.47	645.57	0.00431	2.59			32.62	41.21	0.41			0.36

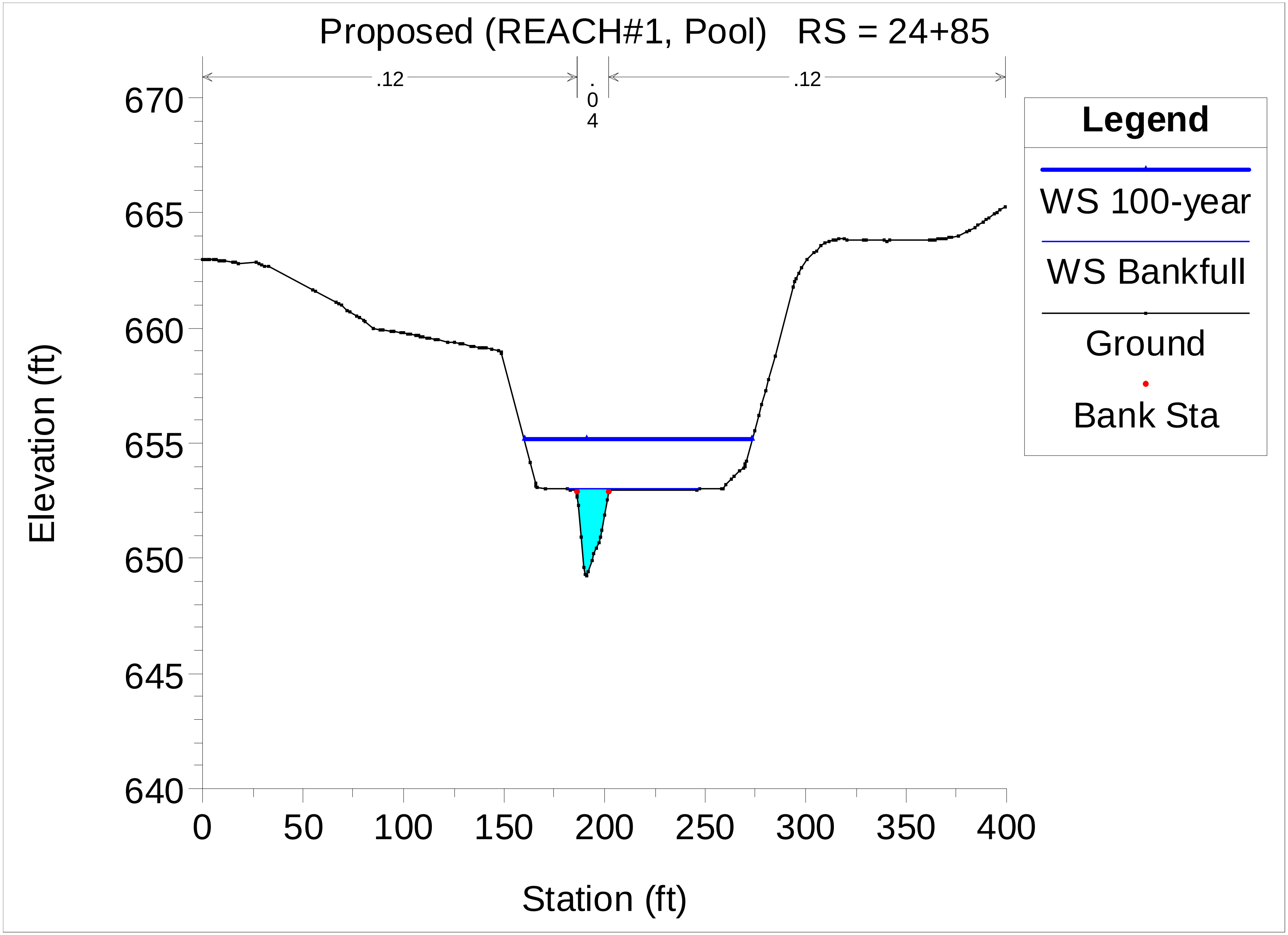
Existing 100-year HEC-RAS Output

River Sta	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Vel Left (ft/s)	Vel Right (ft/s)	Flow Area (sq ft)	Top Width (ft)	Shear Chan (lb/sq ft)	Shear LOB (lb/sq ft)	Shear ROB (lb/sq ft)	Froude # Chl
2821.2	460	650.16	661.01	661.01	0.00001	0.58	0.14	0.14	2146.73	359.66	0.01	0.00	0.00	0.03
2771.2	460	651.00	661.01	661.01	0.00000	0.31	0.09	0.09	4784.87	705.80	0.00	0.00	0.00	0.02
2721.1	460	651.84	661.01	661.01	0.00000	0.30	0.08	0.09	4876.47	698.82	0.00	0.00	0.00	0.02
2620.8	460	651.00	661.01	661.01	0.00002	0.70	0.18	0.20	1918.63	276.62	0.01	0.01	0.01	0.04
2571.0	460	651.00	661.01	661.01	0.00004	0.99	0.22	0.29	1481.90	251.27	0.02	0.01	0.02	0.06
2520.8	460	651.00	661.00	661.01	0.00004	1.04	0.23	0.27	1255.87	226.54	0.02	0.01	0.02	0.06
2466.4	460	651.00	660.99	661.00	0.00006	1.23	0.27	0.27	1048.95	199.95	0.03	0.02	0.02	0.07
2416.0	460	650.97	660.99	661.00	0.00007	1.37	0.28	0.30	1098.58	217.99	0.04	0.02	0.02	0.08
2379.7	460	650.95	660.99	661.00	0.00006	1.29	0.26	0.32	1110.70	209.96	0.04	0.02	0.02	0.07
2368.0	460	650.95	660.99	661.00	0.00006	1.30	0.25	0.33	1114.40	211.61	0.04	0.02	0.02	0.07
2356.5	460	650.94	660.99	661.00	0.00006	1.32	0.24	0.33	1105.50	218.69	0.04	0.02	0.02	0.07
2347.8	460	650.94	660.98	661.00	0.00006	1.32	0.24	0.34	1108.75	218.83	0.04	0.02	0.03	0.07
2333.9	460	650.93	660.98	660.99	0.00007	1.32	0.24	0.35	1108.57	219.23	0.04	0.02	0.03	0.07
2315.7	460	650.00	660.98	660.99	0.00006	1.33	0.23	0.35	1104.10	222.01	0.04	0.01	0.03	0.07
2296.8	460	650.00	660.98	660.99	0.00007	1.34	0.23	0.35	1126.85	227.67	0.04	0.01	0.03	0.07
2282.8	460	650.00	660.98	660.99	0.00006	1.31	0.23	0.35	1144.93	224.45	0.04	0.01	0.03	0.07
2272.8	460	650.00	660.98	660.99	0.00006	1.30	0.23	0.34	1135.42	230.34	0.04	0.01	0.03	0.07
2262.5	460	650.00	660.98	660.99	0.00006	1.28	0.23	0.34	1129.81	223.66	0.03	0.01	0.02	0.07
2253.1	460	650.00	660.98	660.99	0.00006	1.34	0.21	0.35	1095.22	225.11	0.04	0.01	0.03	0.07
2235.8	460	650.00	660.97	660.99	0.00006	1.32	0.23	0.34	1069.90	207.07	0.04	0.01	0.03	0.07
2219.7	460	650.66	660.97	660.99	0.00007	1.37	0.22	0.36	1018.46	204.10	0.04	0.01	0.03	0.08
2209.2	460	650.91	660.97	660.98	0.00007	1.38	0.23	0.37	1021.17	207.66	0.04	0.01	0.03	0.08
2191.6	460	650.82	660.97	660.98	0.00007	1.36	0.20	0.37	1059.62	238.14	0.04	0.01	0.03	0.08
2172.3	460	650.72	660.97	660.98	0.00006	1.29	0.19	0.34	1085.48	240.67	0.04	0.01	0.03	0.07
2160.1	460	650.66	660.97	660.98	0.00004	1.07	0.14	0.28	1086.82	239.41	0.02	0.01	0.02	0.06
2152.9	460	650.00	660.97	660.98	0.00004	1.01	0.13	0.26	1097.24	239.27	0.02	0.01	0.01	0.06
2144.2	460	650.00	660.97	660.98	0.00003	0.97	0.13	0.24	1110.79	238.32	0.02	0.00	0.01	0.05
2106.8	Culvert													
2067.4	460	650.00	655.85	656.05	0.00109	3.64	0.60	0.59	164.58	45.97	0.35	0.12	0.12	0.27

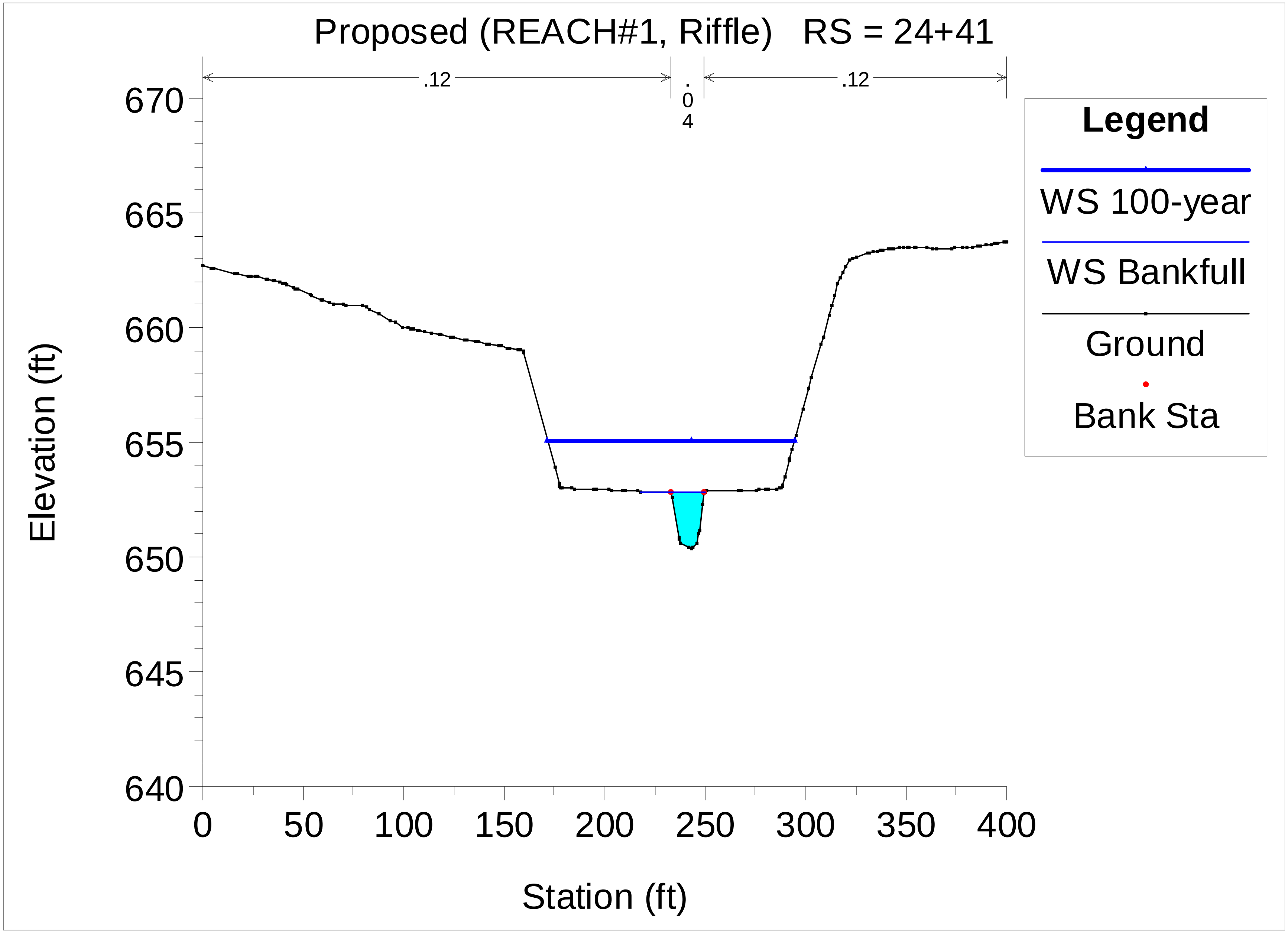
2056.2	460	650.00	655.78	656.03	0.00155	4.21	0.75	0.77	158.62	49.17	0.47	0.19	0.19	0.33
2028.8	460	649.00	655.51	655.95	0.00261	5.46	0.88	0.81	109.81	33.01	0.80	0.27	0.24	0.41
2012.0	460	649.00	655.48	655.90	0.00244	5.37	0.72	0.78	110.35	34.36	0.76	0.19	0.22	0.40
1989.5	460	649.00	655.45	655.84	0.00222	5.12	0.72	0.80	115.53	33.95	0.69	0.19	0.22	0.38
1970.1	460	649.43	655.41	655.79	0.00233	5.14	0.80	0.78	119.33	37.55	0.71	0.22	0.22	0.39
1956.5	460	649.92	655.37	655.76	0.00263	5.29	0.96	0.74	127.67	43.58	0.76	0.31	0.21	0.41
1926.6	460	649.97	655.31	655.67	0.00255	5.17	1.02	0.68	144.48	50.95	0.73	0.33	0.18	0.41
1912.2	460	649.57	655.22	655.63	0.00284	5.44	1.04	0.64	133.10	48.60	0.81	0.35	0.17	0.43
1896.4	460	649.00	655.10	655.57	0.00330	5.83	1.04	0.60	122.22	48.16	0.93	0.36	0.16	0.46
1879.7	460	649.00	654.54	655.44	0.00783	8.06	1.38	0.76	89.93	41.64	1.88	0.69	0.28	0.67
1860.0	460	648.99	654.38	655.28	0.00836	8.00	1.33	0.81	86.44	41.30	1.89	0.67	0.31	0.69
1841.1	460	648.99	654.47	655.06	0.00509	6.40	1.06	0.84	101.24	43.43	1.19	0.42	0.29	0.56
1822.4	460	648.99	654.51	654.93	0.00341	5.37	0.84	0.69	111.14	43.18	0.83	0.27	0.20	0.46
1808.2	460	648.99	654.50	654.87	0.00278	4.95	0.78	0.61	118.49	43.65	0.70	0.23	0.16	0.42
1772.3	460	648.89	654.38	654.77	0.00275	5.06	0.68	0.57	105.44	34.79	0.72	0.18	0.14	0.42
1746.7	460	647.94	654.36	654.69	0.00214	4.69	0.58	0.38	114.49	41.83	0.60	0.14	0.07	0.36
1729.6	460	647.88	654.26	654.64	0.00277	5.06	0.73	0.52	118.04	52.79	0.72	0.21	0.12	0.40
1711.3	460	647.82	652.96	654.43	0.01756	9.74	0.90	0.96	49.23	18.95	3.05	0.45	0.49	0.95
1679.0	460	647.00	653.89	653.97	0.00045	2.30	0.21	0.29	287.87	124.81	0.14	0.02	0.03	0.17
1658.7	460	647.52	653.78	653.94	0.00127	3.46	0.43	0.47	231.50	132.52	0.33	0.08	0.09	0.28
1647.2	460	648.15	653.70	653.92	0.00217	4.08	0.63	0.52	211.37	140.83	0.49	0.16	0.12	0.36
1638.6	460	648.95	653.60	653.89	0.00317	4.79	0.85	0.53	196.25	142.06	0.69	0.27	0.13	0.44
1627.3	460	648.96	653.53	653.85	0.00324	5.16	0.93	0.47	200.53	145.82	0.77	0.31	0.11	0.45
1610.9	460	648.97	653.57	653.77	0.00193	3.95	0.73	0.44	242.94	153.74	0.45	0.19	0.09	0.35
1589.9	460	648.98	653.40	653.70	0.00349	5.03	0.91	0.63	207.77	144.31	0.75	0.30	0.18	0.46
1581.1	460	648.99	653.34	653.66	0.00409	5.34	1.08	0.67	200.34	135.09	0.86	0.41	0.20	0.50
1570.6	460	648.99	653.09	653.59	0.00562	6.53	1.29	0.70	165.11	120.63	1.26	0.57	0.23	0.59
1556.0	460	648.60	653.07	653.48	0.00411	5.79	1.13	0.70	173.39	115.25	0.97	0.43	0.21	0.50
1539.7	460	648.00	652.80	653.38	0.00519	6.41	0.60	0.73	123.84	97.91	1.20	0.18	0.24	0.55
1517.3	460	648.00	652.03	653.16	0.01184	8.54	0.88	0.24	60.08	84.95	2.27	0.39	0.06	0.79
1495.8	460	647.99	652.10	652.82	0.00858	7.22	0.57	0.86	115.12	104.82	1.63	0.19	0.35	0.67
1451.1	460	647.95	651.80	652.36	0.00982	6.88	0.94	0.99	161.69	171.54	1.57	0.41	0.44	0.69
1435.6	460	647.94	651.74	652.03	0.00527	4.86	0.47	0.78	200.44	194.56	0.80	0.13	0.27	0.54
1401.5	460	646.59	651.74	651.90	0.00168	3.73	0.44	0.58	319.75	219.56	0.40	0.08	0.13	0.32

1373.9	460	646.82	651.72	651.82	0.00236	3.33	0.72	0.74	353.23	225.14	0.52	0.19	0.20	0.30
1351.5	466.5	647.00	651.68	651.77	0.00198	3.06	0.60	0.67	362.47	230.16	0.43	0.14	0.17	0.28
1325.6	466.5	647.78	651.59	651.70	0.00359	3.77	0.88	0.90	334.58	225.34	0.69	0.29	0.30	0.36
1305.2	466.5	647.82	651.51	651.63	0.00354	3.72	0.89	0.88	325.84	217.34	0.67	0.30	0.29	0.36
1281.1	466.5	647.00	651.42	651.55	0.00340	3.63	0.84	0.89	303.79	195.71	0.64	0.27	0.29	0.36
1251.6	466.5	647.00	651.25	651.43	0.00422	4.43	1.05	0.91	269.38	178.69	0.92	0.39	0.32	0.39
1201.6	466.5	647.00	650.85	651.16	0.00671	5.25	0.59	1.12	185.70	126.16	1.33	0.19	0.49	0.51
1151.6	466.5	646.94	650.62	650.78	0.00628	4.71	1.01	1.27	256.26	159.52	1.11	0.41	0.58	0.46
1101.3	466.5	646.89	650.41	650.52	0.00383	3.37	0.59	0.88	314.37	224.85	0.59	0.16	0.29	0.37
1051.5	466.5	646.84	650.15	650.29	0.00504	3.97	0.53	0.97	288.97	220.64	0.81	0.15	0.36	0.43
1001.6	466.5	646.30	650.04	650.10	0.00235	3.10	0.66	0.79	422.14	269.56	0.46	0.17	0.22	0.30
951.6	466.5	645.78	649.93	649.99	0.00206	3.01	0.71	0.84	423.42	229.30	0.43	0.18	0.24	0.28
851.3	466.5	645.00	649.73	649.81	0.00155	2.60	0.65	0.39	353.54	190.32	0.32	0.15	0.07	0.24
801.3	466.5	645.00	649.61	649.70	0.00238	3.55	0.87	0.51	369.09	198.20	0.57	0.26	0.11	0.30
751.5	466.5	645.00	649.49	649.58	0.00213	3.34	0.74	0.80	371.84	217.08	0.50	0.19	0.22	0.29
701.5	466.5	644.96	649.29	649.44	0.00377	4.24	0.79	1.10	306.17	212.09	0.83	0.25	0.41	0.38
651.4	466.5	644.92	648.95	649.21	0.00549	4.96	0.94	1.12	228.21	167.71	1.16	0.36	0.46	0.46
601.9	466.5	644.37	648.83	648.98	0.00280	3.65	0.78	0.72	265.90	160.05	0.62	0.23	0.20	0.33
551.8	466.5	644.65	648.75	648.84	0.00235	3.14	0.82	0.83	336.28	182.56	0.47	0.23	0.24	0.30
501.6	466.5	644.00	648.67	648.73	0.00147	2.51	0.62	0.65	396.45	217.77	0.30	0.14	0.15	0.24
451.5	466.5	644.86	648.60	648.65	0.00179	2.58	0.69	0.75	439.02	250.19	0.33	0.17	0.19	0.26
401.6	466.5	643.97	648.42	648.54	0.00234	3.49	0.71	0.74	336.41	213.81	0.55	0.19	0.20	0.31
351.5	466.5	643.91	648.28	648.41	0.00315	3.85	0.72	0.90	330.04	223.57	0.69	0.21	0.29	0.34
301.2	466.5	644.00	648.17	648.25	0.00243	3.30	0.59	0.91	347.44	184.12	0.51	0.15	0.28	0.31
251.4	466.5	644.00	647.98	648.11	0.00281	3.62	0.49	0.98	278.88	137.80	0.61	0.11	0.32	0.33
201.4	466.5	644.00	647.74	647.92	0.00480	4.31	0.73	1.29	228.94	137.99	0.91	0.23	0.55	0.43
151.3	466.5	644.00	647.47	647.67	0.00498	4.48	0.87	1.40	232.26	204.09	0.97	0.31	0.63	0.43
101.6	466.5	644.00	647.22	647.38	0.00598	4.23	0.99	0.46	274.78	228.04	0.93	0.39	0.13	0.46
51.7	466.5	643.00	646.98	647.10	0.00430	3.69	0.88	0.76	309.71	240.51	0.70	0.30	0.24	0.39

Appendix K



Proposed (REACH#1, Pool) RS = 24+85
.12
.04
.12
Elevation (ft)
670
665
660
655
650
645
640
0
50
100
150
200
250
300
350
400
Station (ft)
Legend
WS 100-year
WS Bankfull
Ground
Bank Sta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.04
.12
Legend
WS 100-year
WS Bankfull
Ground
Bank Sta
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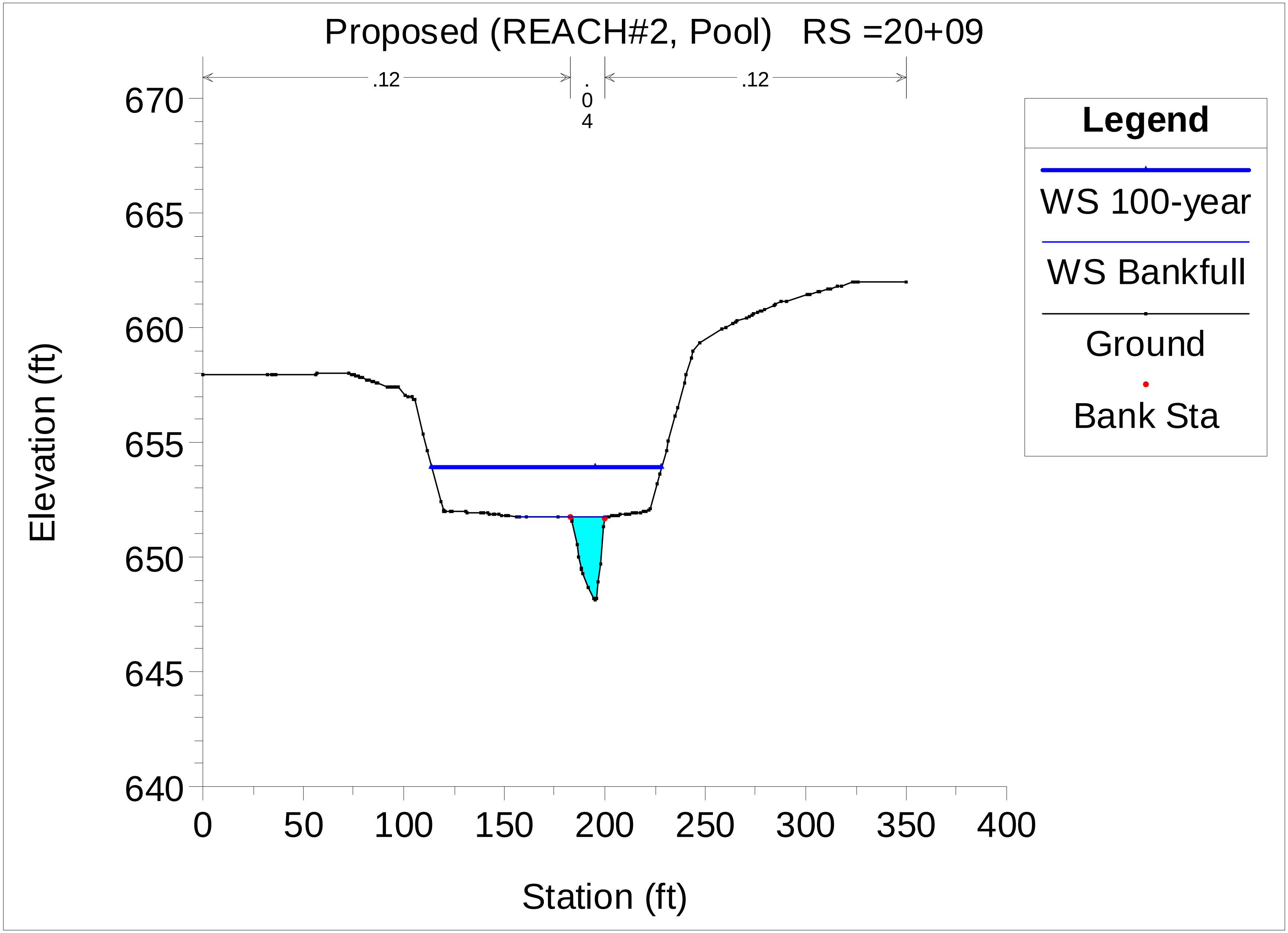
665
660
655
650
645
640
Elevation (ft)
0
50
100
150
200
250
300
350
400
Station (ft)



Proposed (REACH#2, Pool) RS =20+09
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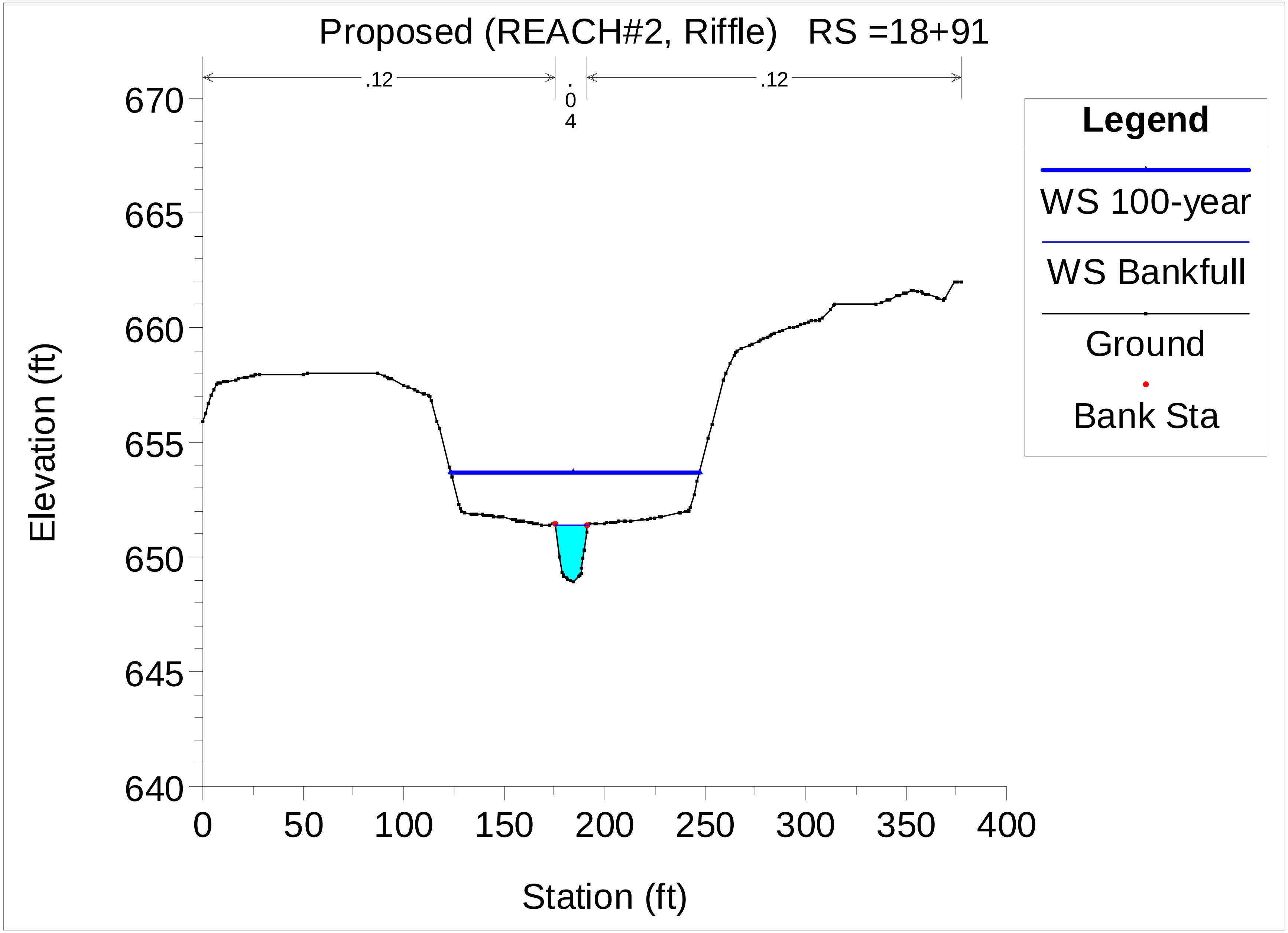
.04
.12
Elevation (ft)
670
665
660
655
650
645
640
0
50
100
150
200
250
300
350
400
Station (ft)
Legend
WS 100-year
WS Bankfull
Ground
Bank Sta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.04
.12
Elevation (ft)
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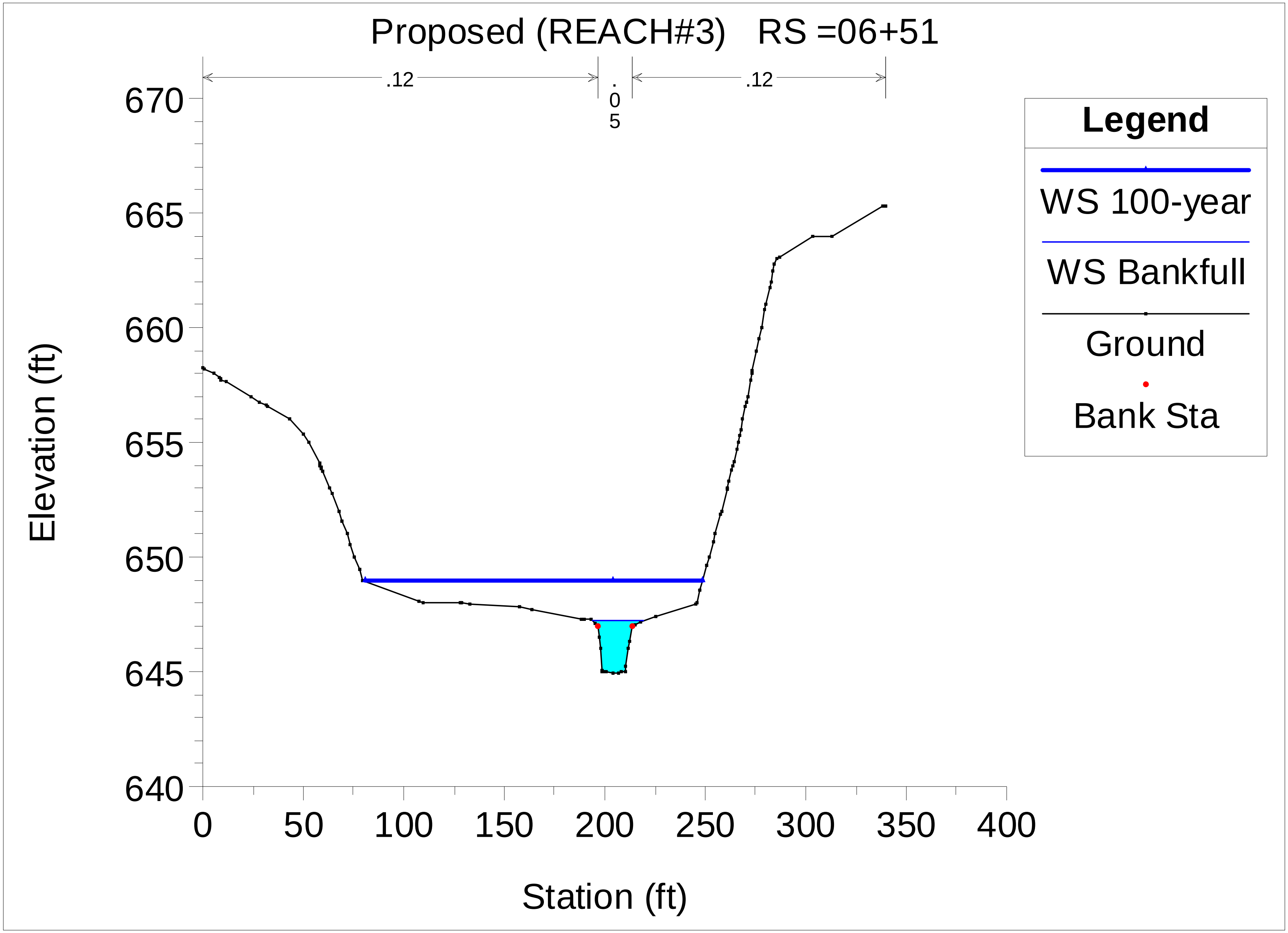
665
660
655
650
645
640
0
50
100
150
200
250
300
350
400
Station (ft)
Legend
WS 100-year
WS Bankfull
Ground
Bank Sta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.05
.12
Elevation (ft)
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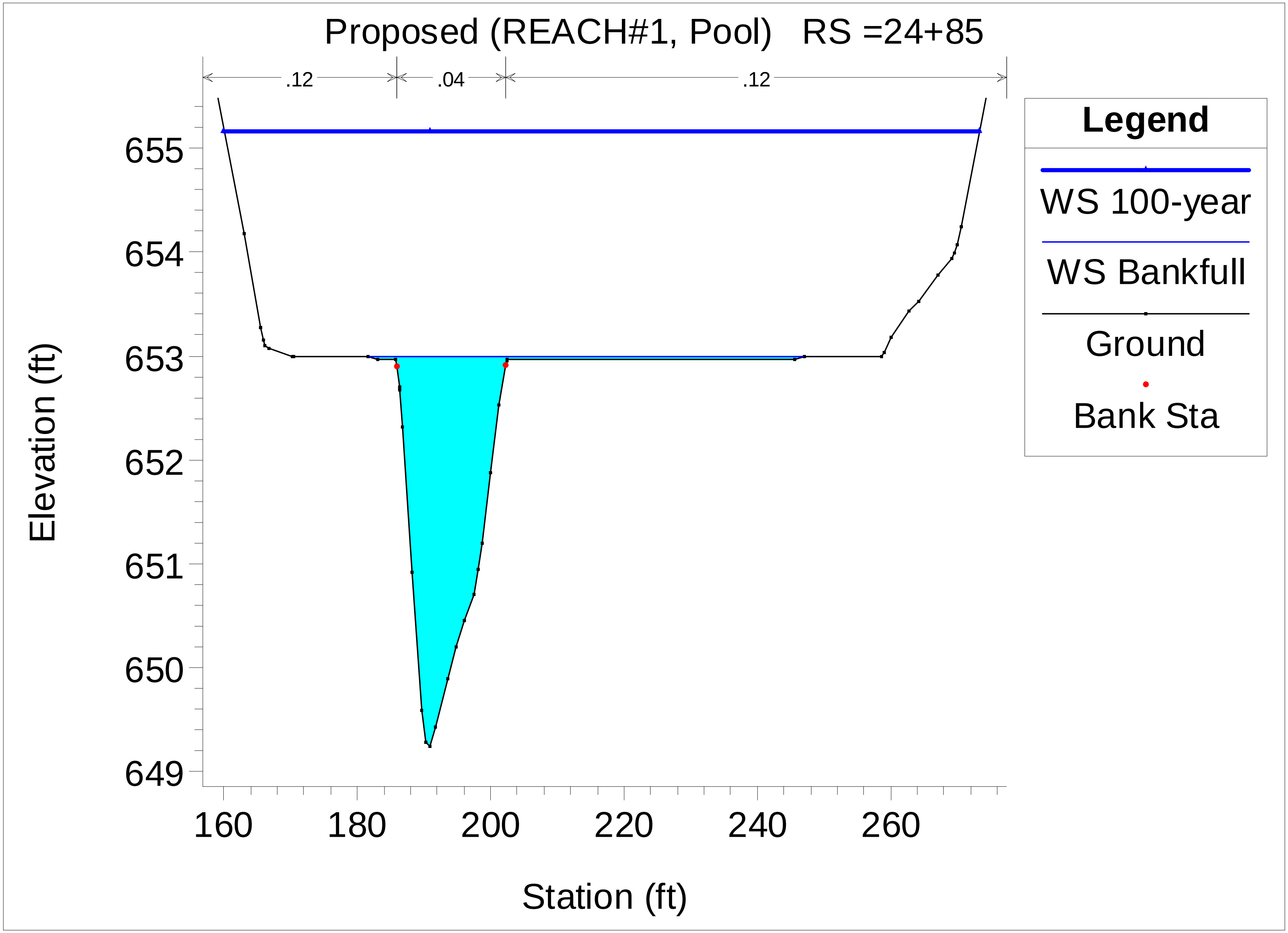
665
660
655
650
645
640
0
50
100
150
200
250
300
350
400
Station (ft)
Legend
WS 100-year
WS Bankfull
Ground
Bank Sta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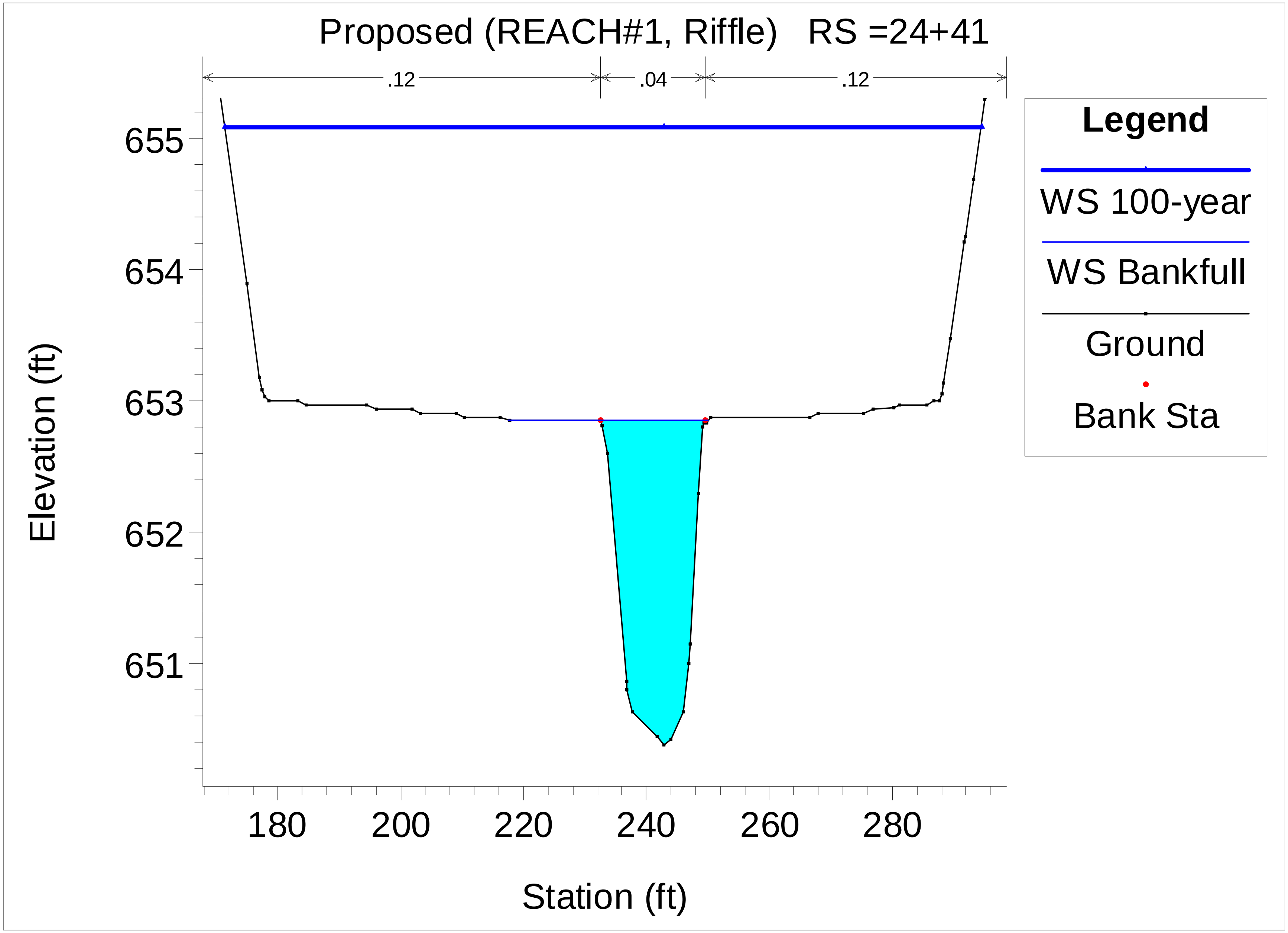
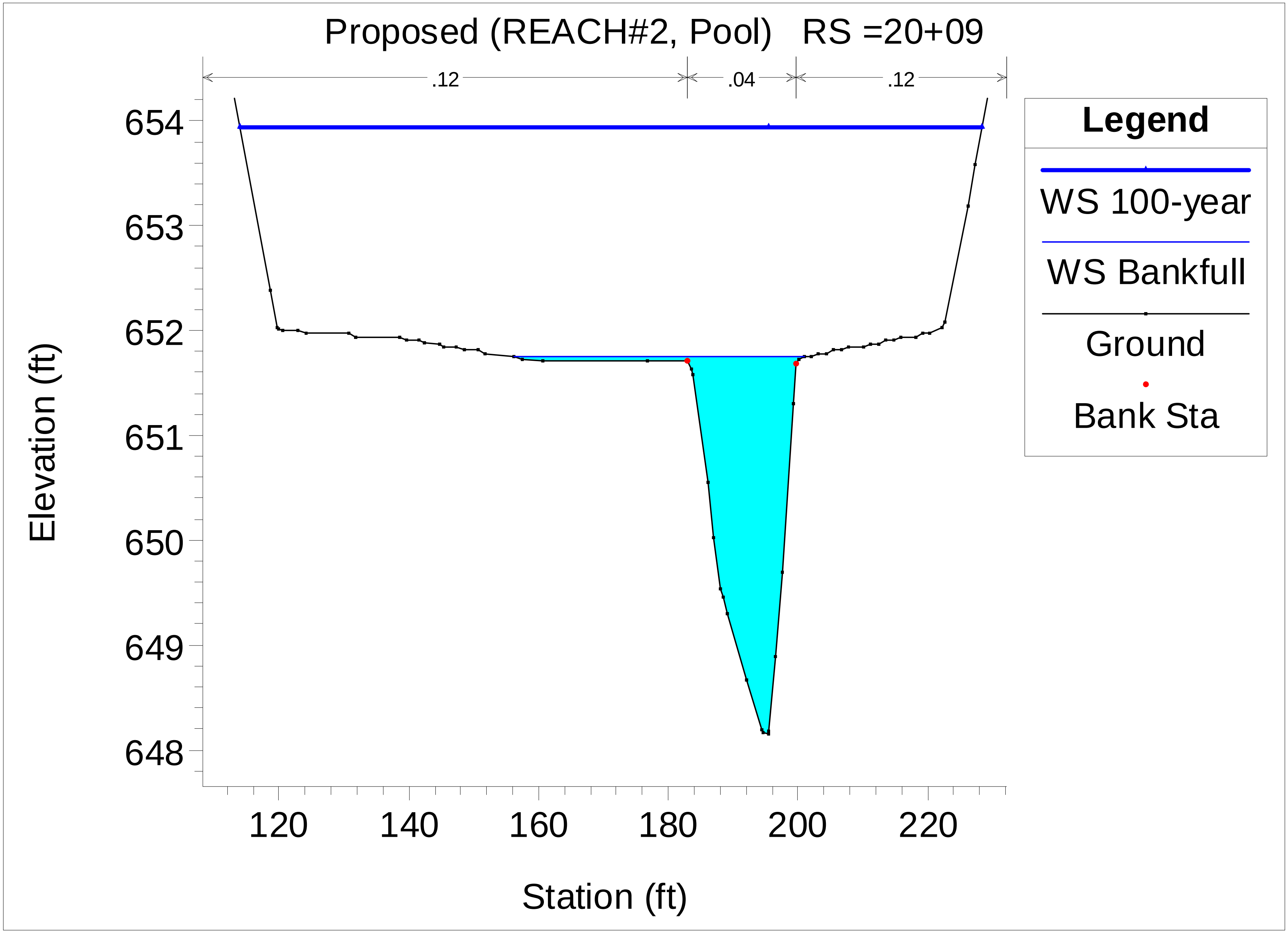
.04
.12
Elevation (ft)
655
654
653
652
651
650
649
160
180
200
220
240
260
Station (ft)
Legend
WS 100-year
WS Bankfull
Ground
Bank Sta



Proposed (REACH#1, Riffle) RS =24+41
.12
.04
.12
Legend
WS 100-year
WS Bankfull
Ground
Bank Sta
655
654
653
652
651
Elevation (ft)
180
200
220
240
260
280
Station (ft)



Proposed (REACH#2, Pool) RS =20+09
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.04
.12
Legend
WS 100-year
WS Bankfull
Ground
Bank Sta
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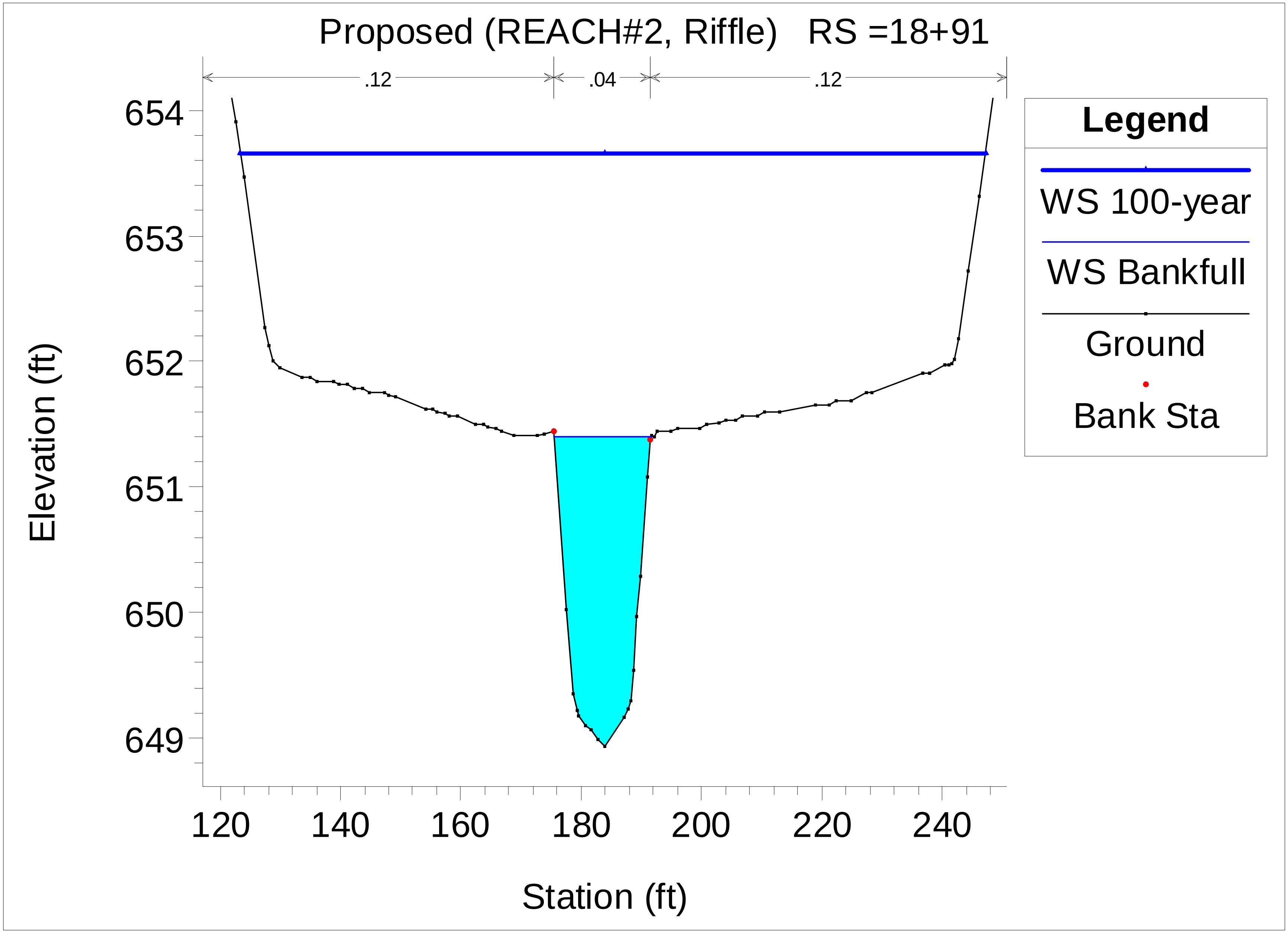
653
652
651
650
649
648
Elevation (ft)
120
140
160
180
200
220
Station (ft)



Proposed (REACH#2, Riffle) RS =18+91
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.04
.12
654
653
652
651
650
649
120
140
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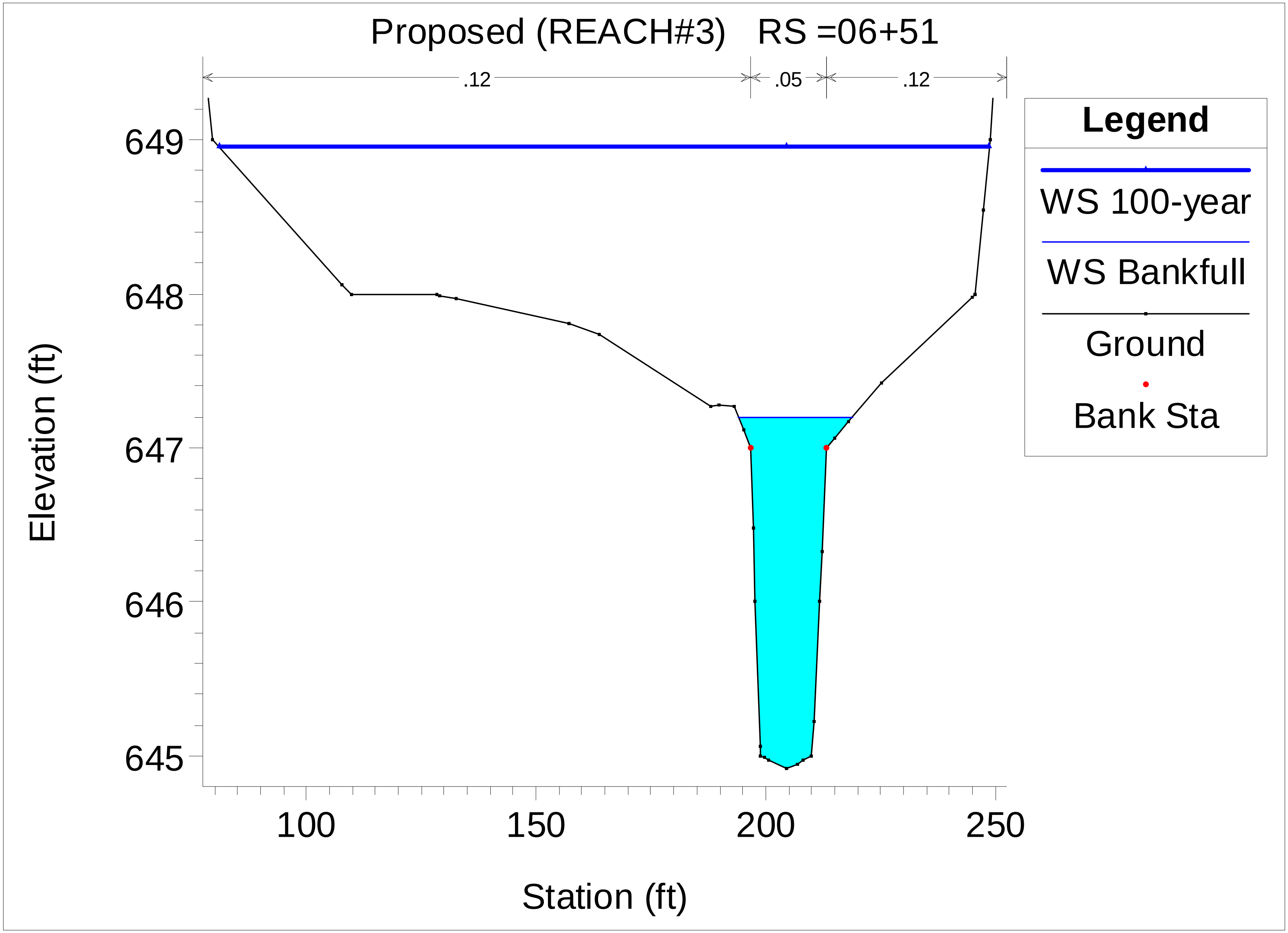
180
200
220
240
Elevation (ft)
Station (ft)
Legend
WS 100-year
WS Bankfull
Ground
Bank Sta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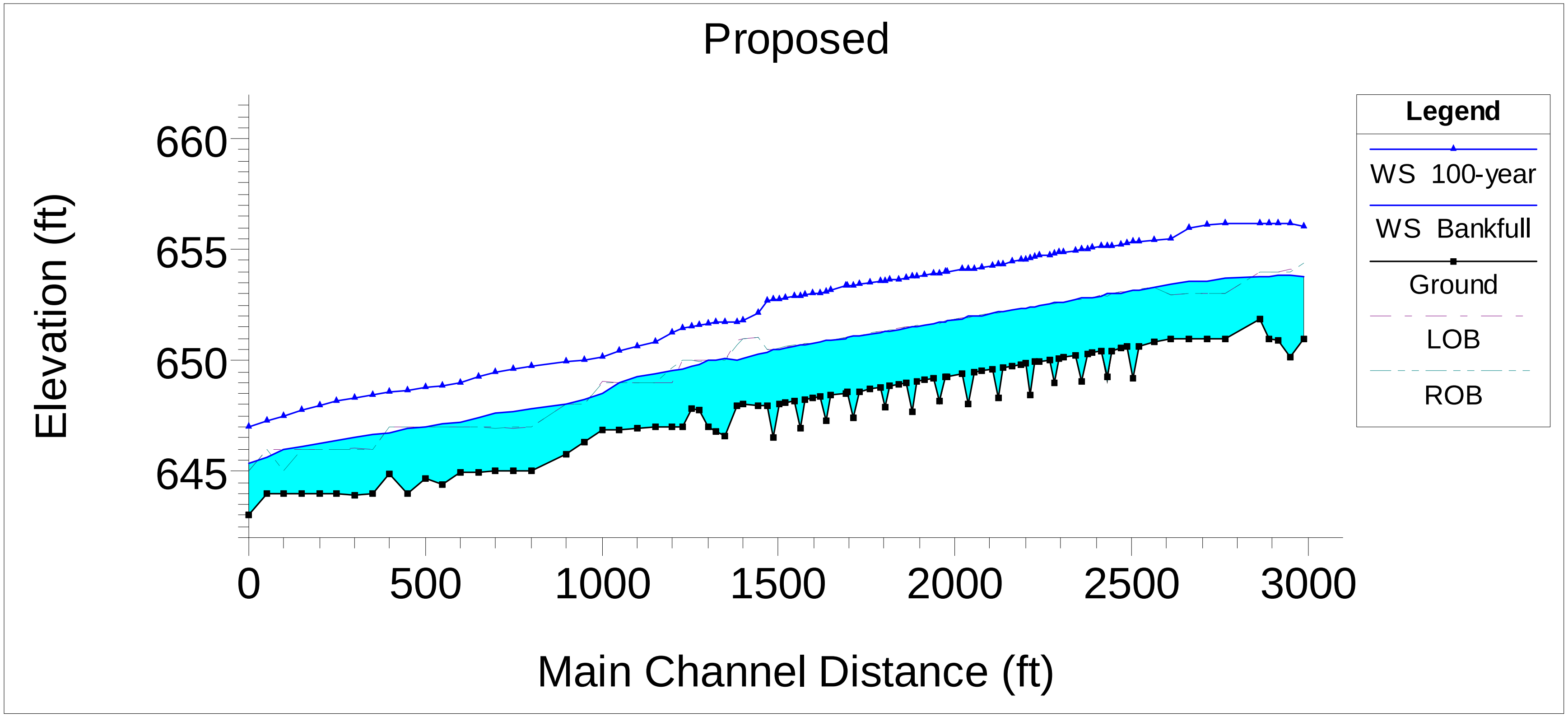
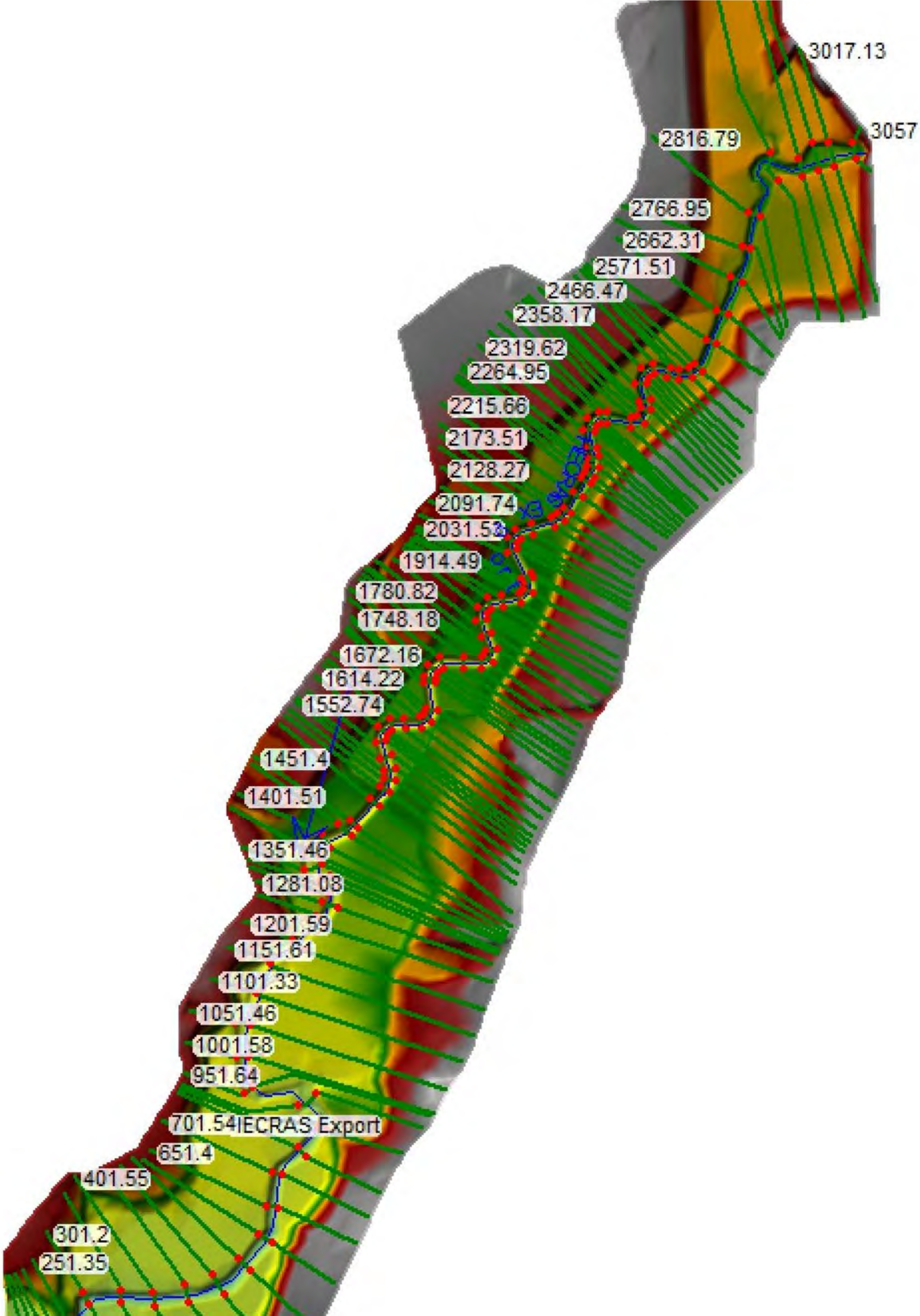
.12
.05
.12
Legend
WS 100-year
WS Bankfull
Ground
Bank Sta
Elevation (ft)
649
648
647
646
645
100
150
200
250
Station (ft)



Proposed
Elevation (ft)
660
655
650
645
0
500
1000
1500
2000
2500
3000
Main Channel Distance (ft)
Legend
WS 100-year
WS Bankfull
Ground
LOB
ROB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2215.66
2173.51
2128.27
2091.74
2031.53
1914.49
1780.82
1748.18
1672.16
1614.22
1552.74
1451.4
1401.51
1351.46
1281.08
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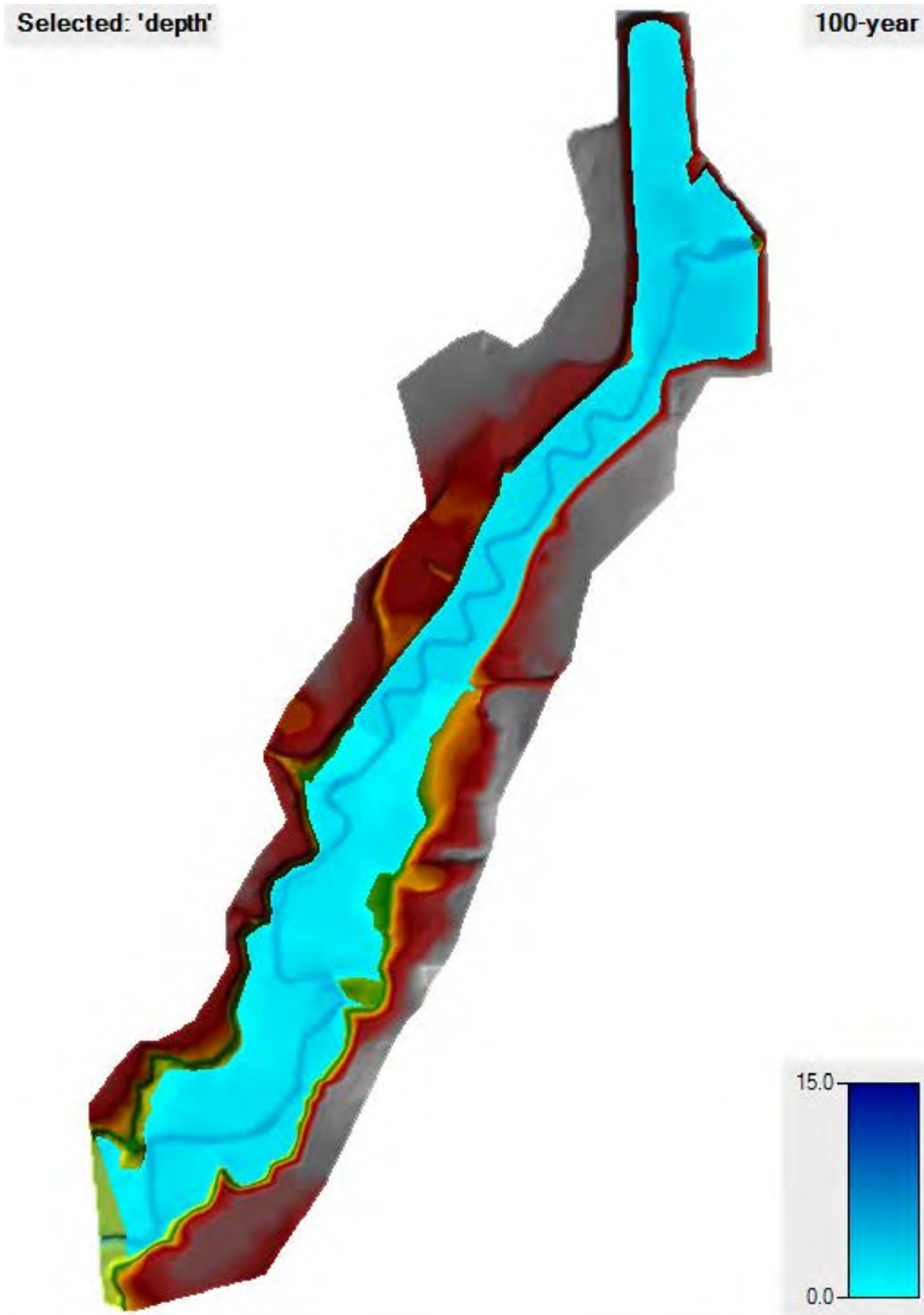
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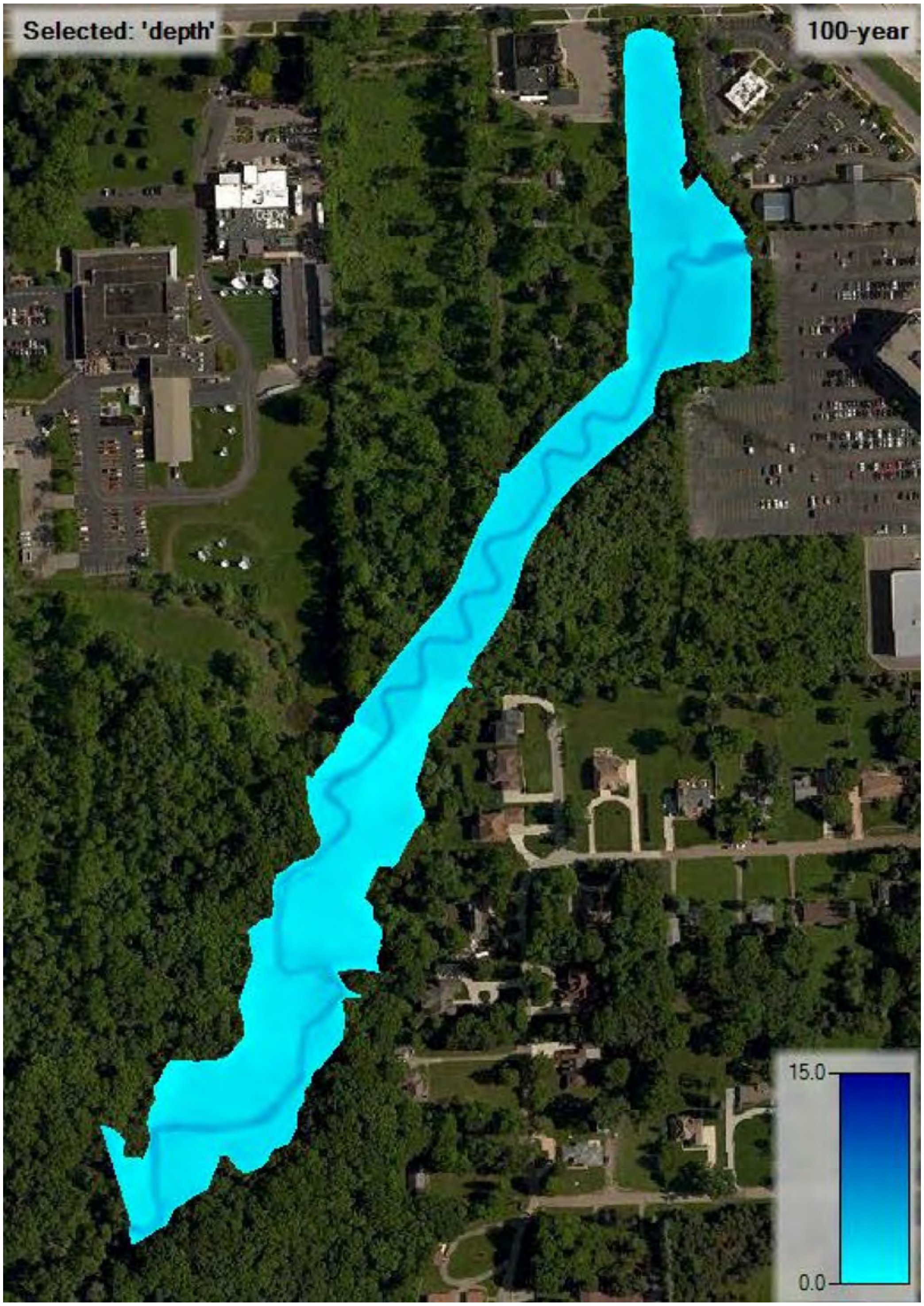

Selected: 'depth'
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0.0

Proposed Bankfull HEC-RAS Output

River Sta	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Vel Left (ft/s)	Vel Right (ft/s)	Flow Area (sq ft)	Top Width (ft)	Shear Chan (lb/sq ft)	Shear LOB (lb/sq ft)	Shear ROB (lb/sq ft)	Froude # Chl
3057.0	80	651.00	653.81	653.85	0.00071	1.55			51.72	25.17	0.09			0.19
3017.1	80	650.15	653.82	653.83	0.00011	0.76			105.91	35.38	0.02			0.08
2992.0	80	650.92	653.82	653.82	0.00013	0.76	0.02	0.06	126.33	148.29	0.02	0.00	0.00	0.09
2967.1	80	651.00	653.79	653.82	0.00048	1.32	0.10	0.16	130.44	223.22	0.06	0.01	0.01	0.15
2917.1	80	651.84	653.79	653.80	0.00049	0.86	0.19	0.20	228.71	341.91	0.03	0.02	0.02	0.15
2816.8	80	651.00	653.71	653.74	0.00069	1.53	0.16	0.25	131.06	183.74	0.08	0.01	0.03	0.19
2767.0	80	651.00	653.59	653.68	0.00210	2.61	0.25	0.37	71.03	113.41	0.25	0.04	0.07	0.32
2716.8	80	651.00	653.55	653.59	0.00100	1.81	0.24	0.18	61.10	68.79	0.12	0.03	0.02	0.22
2662.3	80	650.99	653.46	653.53	0.00137	2.16	0.22	0.17	39.69	27.99	0.17	0.03	0.02	0.26
2615.2	80	650.81	653.30	653.43	0.00321	2.89			27.65	15.96	0.32			0.39
2571.5	80	650.65	653.18	653.30	0.00275	2.74			29.18	16.01	0.29			0.36
2556.9	80	649.18	653.18	653.26	0.00135	2.17	0.04	0.02	37.31	32.33	0.17	0.00		0.25
2538.2	80	650.61	653.10	653.22	0.00270	2.72	0.01		29.36	17.08	0.28			0.35
2522.2	80	650.57	653.06	653.17	0.00274	2.75			29.10	15.96	0.29			0.36
2498.6	80	650.42	652.99	653.11	0.00265	2.71			29.50	15.99	0.28			0.35
2485.1	80	649.02	653.00	653.07	0.00141	2.20	0.02	0.03	37.17	79.93	0.17	0.00	0.00	0.26
2466.5	80	650.42	652.92	653.03	0.00265	2.71			29.56	16.09	0.28			0.35
2441.3	80	650.36	652.85	652.97	0.00275	2.75			29.09	15.96	0.29			0.36
2427.3	80	650.28	652.81	652.93	0.00274	2.74			29.20	16.01	0.29			0.36
2410.8	80	649.08	652.81	652.88	0.00145	2.22	0.04	0.03	36.87	52.31	0.18	0.00	0.00	0.26
2395.0	80	650.23	652.74	652.85	0.00261	2.68	0.02		29.84	24.31	0.27	0.00		0.35
2358.2	80	650.14	652.64	652.75	0.00269	2.73			29.33	16.00	0.28			0.36
2347.6	80	650.05	652.61	652.72	0.00252	2.66		0.01	30.09	18.46	0.27			0.34
2333.2	80	649.01	652.61	652.69	0.00149	2.25	0.03	0.04	36.19	43.31	0.18	0.00	0.00	0.27
2319.6	80	650.04	652.54	652.66	0.00264	2.71		0.01	29.57	21.58	0.28			0.35
2293.1	80	649.97	652.47	652.59	0.00268	2.73			29.33	16.11	0.28			0.36
2277.6	80	649.93	652.43	652.54	0.00271	2.73			29.29	16.01	0.28			0.36
2265.0	80	648.45	652.43	652.51	0.00139	2.19	0.04	0.03	36.70	22.78	0.17	0.00	0.00	0.26
2251.6	80	649.86	652.36	652.48	0.00271	2.73			29.29	16.03	0.28			0.36

2240.9	80	649.84	652.33	652.45	0.00275	2.75			29.12	15.98	0.29			0.36
2215.7	80	649.77	652.26	652.38	0.00274	2.74			29.19	15.99	0.29			0.36
2186.7	80	649.70	652.18	652.30	0.00272	2.73			29.26	16.01	0.28			0.36
2173.5	80	648.28	652.19	652.26	0.00143	2.22	0.03	0.03	36.13	18.34	0.18	0.00		0.26
2160.1	80	649.62	652.12	652.23	0.00273	2.74			29.19	15.93	0.29			0.36
2128.3	80	649.55	652.03	652.15	0.00273	2.74			29.16	35.57	0.29			0.36
2105.8	80	649.48	651.97	652.08	0.00280	2.76			29.00	16.00	0.29			0.36
2091.7	80	648.06	651.97	652.04	0.00142	2.20	0.02	0.04	37.72	79.22	0.17	0.00	0.00	0.26
2074.5	80	649.40	651.89	652.01	0.00276	2.75			29.08	15.95	0.29			0.36
2031.5	80	649.29	651.77	651.89	0.00272	2.74			29.19	15.95	0.29			0.36
2025.3	80	649.28	651.75	651.87	0.00277	2.75			29.07	15.96	0.29			0.36
2008.9	80	648.00	651.75	651.83	0.00148	2.24	0.03	0.01	36.30	45.69	0.18	0.00		0.27
1991.1	80	649.19	651.67	651.79	0.00274	2.73			29.26	16.08	0.29			0.36
1965.3	80	649.12	651.60	651.72	0.00279	2.76			28.94	15.95	0.29			0.36
1945.6	80	649.07	651.54	651.66	0.00282	2.77			28.92	16.01	0.29			0.36
1931.2	80	647.68	651.55	651.62	0.00141	2.20	0.02	0.03	36.72	39.28	0.17		0.00	0.26
1914.5	80	648.99	651.47	651.59	0.00280	2.76			28.96	15.91	0.29			0.36
1890.8	80	648.93	651.40	651.52	0.00278	2.76			28.94	15.92	0.29			0.36
1867.5	80	648.87	651.34	651.45	0.00281	2.76			28.95	16.01	0.29			0.36
1852.8	80	647.87	651.33	651.41	0.00171	2.35			34.06	16.12	0.20			0.28
1839.8	80	648.79	651.27	651.38	0.00276	2.73			29.27	16.27	0.29			0.36
1812.7	80	648.72	651.19	651.31	0.00283	2.78			28.77	15.90	0.29			0.36
1780.8	80	648.56	651.10	651.22	0.00276	2.75			29.12	15.97	0.29			0.36
1764.9	80	647.38	651.10	651.17	0.00149	2.25			35.56	16.06	0.18			0.27
1748.2	80	648.55	651.02	651.14	0.00279	2.75			29.07	16.04	0.29			0.36
1740.8	80	648.54	651.00	651.12	0.00280	2.77			28.92	15.93	0.29			0.36
1700.5	80	648.42	650.88	651.00	0.00281	2.76			28.96	16.02	0.29			0.36
1685.3	80	647.28	650.88	650.96	0.00167	2.33			34.36	16.08	0.20			0.28
1672.2	80	648.35	650.81	650.93	0.00283	2.77			28.88	15.94	0.29			0.36
1650.4	80	648.30	650.75	650.87	0.00283	2.78			28.76	15.91	0.30			0.36
1628.9	80	648.22	650.69	650.81	0.00283	2.77			28.85	15.96	0.29			0.36
1614.2	80	646.96	650.69	650.76	0.00150	2.26			35.44	15.96	0.18			0.27
1597.3	80	648.16	650.61	650.73	0.00285	2.77			28.87	15.92	0.29			0.36
1573.7	80	648.10	650.53	650.66	0.00295	2.82			28.35	15.81	0.30			0.37

1552.7	80	648.02	650.47	650.60	0.00305	2.85			28.12	15.80	0.31			0.38
1537.8	80	646.55	650.47	650.55	0.00150	2.25			35.49	15.89	0.18			0.27
1520.8	80	647.96	650.38	650.51	0.00308	2.86			27.96	15.70	0.31			0.38
1495.8	80	647.99	650.31	650.43	0.00274	2.78			28.73	14.70	0.29			0.35
1451.4	80	648.00	650.06	650.26	0.00572	3.56			22.48	14.86	0.51			0.51
1435.5	80	647.94	650.05	650.16	0.00339	2.75			29.14	19.54	0.30			0.40
1401.5	80	646.59	650.07	650.10	0.00054	1.51	0.03	0.04	54.99	57.43	0.08	0.00	0.00	0.17
1373.9	80	646.82	650.02	650.08	0.00177	1.91	0.02	0.04	42.53	65.93	0.21		0.00	0.24
1351.5	84.6	647.00	650.00	650.04	0.00124	1.62			52.16	25.46	0.15			0.20
1325.5	84.6	647.78	649.83	649.97	0.00550	2.95			28.64	16.52	0.53			0.40
1305.1	84.6	647.82	649.73	649.86	0.00541	2.86			29.61	18.08	0.50			0.39
1281.1	84.6	647.00	649.64	649.74	0.00398	2.55			33.20	19.62	0.39			0.35
1251.6	84.6	647.00	649.55	649.64	0.00273	2.46	0.25	0.08	37.42	30.04	0.34	0.04	0.01	0.29
1201.6	84.6	647.00	649.41	649.50	0.00287	2.34	0.13	0.24	42.05	49.37	0.32	0.02	0.04	0.30
1151.6	84.6	646.94	649.23	649.32	0.00439	2.71	0.23	0.49	66.91	109.32	0.44	0.04	0.13	0.35
1101.3	84.6	646.89	648.96	649.06	0.00600	2.47		0.14	34.23	29.78	0.42		0.02	0.40
1051.5	84.6	646.84	648.48	648.66	0.01069	3.44			24.58	19.86	0.79			0.55
1001.6	84.6	646.30	648.26	648.33	0.00373	2.34	0.17	0.44	69.19	112.81	0.34	0.02	0.10	0.33
951.6	84.6	645.78	648.03	648.12	0.00448	2.68	0.04	0.39	62.32	127.60	0.44	0.00	0.09	0.36
851.3	84.6	645.00	647.84	647.87	0.00137	1.47	0.24	0.19	61.15	45.55	0.13	0.03	0.02	0.20
801.3	84.6	645.00	647.71	647.78	0.00224	2.33	0.41	0.25	64.64	72.05	0.30	0.08	0.04	0.27
751.5	84.6	645.00	647.61	647.68	0.00188	2.08	0.25	0.24	53.49	63.49	0.24	0.04	0.04	0.25
701.5	84.6	644.96	647.39	647.53	0.00472	2.99	0.28	0.30	33.20	40.25	0.52	0.06	0.06	0.38
651.4	84.6	644.92	647.20	647.31	0.00378	2.67	0.16	0.16	32.45	24.82	0.42	0.02	0.02	0.34
601.6	84.6	644.39	647.14	647.18	0.00141	1.72	0.11	0.08	52.25	52.97	0.17	0.01	0.01	0.21
551.8	84.6	644.65	647.01	647.08	0.00289	2.14	0.03	0.03	40.56	141.11	0.28	0.00	0.00	0.30
501.6	84.6	644.00	646.94	646.98	0.00129	1.49			56.66	33.11	0.13			0.20
451.5	84.6	644.86	646.75	646.85	0.00564	2.60		0.11	33.98	61.94	0.44		0.01	0.40
401.6	84.6	643.97	646.66	646.71	0.00146	1.85	0.20	0.23	54.61	57.37	0.19	0.02	0.03	0.22
351.5	84.6	643.91	646.53	646.61	0.00242	2.29	0.25	0.27	47.20	57.03	0.30	0.04	0.05	0.27
301.2	84.6	644.00	646.38	646.47	0.00343	2.46	0.24	0.26	48.36	92.10	0.36	0.04	0.05	0.33
251.4	84.6	644.00	646.28	646.33	0.00186	1.99	0.11	0.15	57.08	124.40	0.22	0.01	0.02	0.24
201.4	84.6	644.00	646.11	646.20	0.00419	2.50	0.11	0.35	49.65	85.29	0.39	0.01	0.07	0.35
151.3	84.6	644.00	645.98	646.04	0.00225	2.05		0.54	56.39	41.99	0.25		0.12	0.26

101.6	84.6	644.00	645.64	645.82	0.01009	3.40	0.06		24.88	20.72	0.77			0.53
51.7	84.6	643.00	645.37	645.49	0.00430	2.80	0.22	0.26	30.67	35.96	0.46	0.04	0.05	0.37

Proposed 100-year HEC-RAS Output

River Sta	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Vel Left (ft/s)	Vel Right (ft/s)	Flow Area (sq ft)	Top Width (ft)	Shear Chan (lb/sq ft)	Shear LOB (lb/sq ft)	Shear ROB (lb/sq ft)	Froude # Chl
3057.0	460	651.00	656.07	656.30	0.00183	3.98	0.62	0.55	137.31	47.46	0.45	0.14	0.12	0.34
3017.1	460	650.15	656.19	656.22	0.00025	1.68	0.30	0.30	642.89	269.74	0.08	0.03	0.03	0.13
2992.0	460	650.92	656.20	656.21	0.00014	1.20	0.22	0.24	1136.74	524.92	0.04	0.01	0.02	0.10
2967.1	460	651.00	656.20	656.20	0.00013	1.07	0.23	0.27	1483.70	627.33	0.03	0.02	0.02	0.09
2917.1	460	651.84	656.20	656.20	0.00010	0.82	0.20	0.25	1613.57	647.73	0.02	0.01	0.02	0.08
2816.8	460	651.00	656.16	656.18	0.00042	2.00	0.46	0.52	676.43	236.66	0.11	0.06	0.08	0.16
2767.0	460	651.00	656.09	656.15	0.00100	3.03	0.66	0.76	466.09	176.87	0.26	0.14	0.17	0.25
2716.8	460	651.00	655.96	656.08	0.00126	3.41	0.65	0.76	302.17	124.25	0.33	0.14	0.18	0.28
2662.3	460	650.99	655.51	655.94	0.00380	5.63	0.69	1.09	134.59	70.62	0.91	0.20	0.41	0.48
2615.2	460	650.81	655.44	655.73	0.00342	5.08	1.01	0.93	206.41	107.08	0.76	0.35	0.31	0.46
2571.5	460	650.65	655.36	655.57	0.00272	4.59	0.95	0.87	239.65	116.68	0.62	0.30	0.27	0.41
2556.9	460	649.18	655.33	655.53	0.00222	4.33	0.87	0.79	248.53	116.26	0.54	0.25	0.22	0.36
2538.2	460	650.61	655.27	655.48	0.00265	4.55	0.94	0.89	245.61	119.64	0.61	0.30	0.27	0.40
2522.2	460	650.57	655.24	655.44	0.00256	4.48	0.90	0.93	253.61	123.29	0.59	0.27	0.29	0.40
2498.6	460	650.42	655.18	655.38	0.00252	4.45	0.87	0.96	249.76	116.37	0.58	0.26	0.30	0.39
2485.1	460	649.02	655.17	655.34	0.00200	4.11	0.84	0.88	264.21	113.30	0.49	0.23	0.25	0.34
2466.5	460	650.42	655.14	655.29	0.00210	4.08	0.89	0.92	277.67	119.92	0.49	0.26	0.27	0.36
2441.3	460	650.36	655.08	655.24	0.00207	4.07	0.91	0.89	282.84	123.09	0.48	0.26	0.26	0.36
2427.3	460	650.28	655.04	655.20	0.00220	4.18	0.94	0.89	269.28	117.38	0.51	0.28	0.26	0.37
2410.8	460	649.08	655.00	655.17	0.00193	4.05	0.89	0.81	267.49	113.19	0.47	0.25	0.22	0.34
2395.0	460	650.23	654.97	655.13	0.00216	4.15	0.94	0.88	268.52	116.24	0.50	0.28	0.25	0.36
2358.2	460	650.14	654.88	655.05	0.00220	4.21	0.91	0.92	267.93	117.79	0.51	0.27	0.27	0.37
2347.6	460	650.05	654.85	655.03	0.00226	4.26	0.89	0.93	258.85	114.14	0.53	0.26	0.28	0.37
2333.2	460	649.01	654.81	654.99	0.00209	4.23	0.83	0.90	252.37	109.17	0.51	0.23	0.26	0.36

2319.6	460	650.04	654.77	654.96	0.00238	4.36	0.90	0.95	252.17	112.27	0.55	0.27	0.29	0.38
2293.1	460	649.97	654.71	654.90	0.00238	4.38	0.92	0.92	255.38	116.61	0.56	0.28	0.28	0.38
2277.6	460	649.93	654.67	654.86	0.00243	4.41	0.93	0.91	253.07	117.01	0.57	0.28	0.27	0.39
2265.0	460	648.45	654.63	654.83	0.00216	4.29	0.87	0.83	248.07	112.68	0.53	0.25	0.23	0.36
2251.6	460	649.86	654.56	654.79	0.00277	4.67	0.96	0.90	231.37	110.70	0.64	0.31	0.28	0.41
2240.9	460	649.84	654.53	654.76	0.00285	4.73	0.93	0.90	232.58	117.25	0.65	0.30	0.28	0.42
2215.7	460	649.77	654.46	654.69	0.00284	4.72	0.95	0.82	234.03	118.75	0.65	0.30	0.25	0.42
2186.7	460	649.70	654.34	654.60	0.00314	4.93	0.98	0.90	214.46	107.09	0.71	0.33	0.29	0.44
2173.5	460	648.28	654.31	654.55	0.00258	4.64	0.89	0.84	223.20	108.46	0.62	0.27	0.25	0.39
2160.1	460	649.62	654.25	654.52	0.00316	4.93	0.97	0.94	217.15	110.68	0.72	0.32	0.31	0.44
2128.3	460	649.55	654.20	654.41	0.00266	4.56	0.89	0.99	242.12	114.80	0.61	0.27	0.32	0.40
2105.8	460	649.48	654.15	654.34	0.00250	4.41	0.85	1.00	247.73	110.88	0.57	0.25	0.32	0.39
2091.7	460	648.06	654.13	654.30	0.00203	4.13	0.81	0.91	258.02	108.78	0.49	0.22	0.26	0.35
2074.5	460	649.40	654.09	654.26	0.00225	4.20	0.89	0.95	266.92	116.17	0.52	0.26	0.29	0.37
2031.5	460	649.29	653.99	654.16	0.00224	4.21	0.93	0.91	268.08	118.60	0.52	0.28	0.27	0.37
2025.3	460	649.28	653.98	654.15	0.00224	4.21	0.93	0.90	268.23	118.67	0.52	0.28	0.27	0.37
2008.9	460	648.00	653.94	654.11	0.00200	4.12	0.88	0.83	264.24	114.45	0.49	0.25	0.23	0.35
1991.1	460	649.19	653.90	654.07	0.00220	4.17	0.92	0.89	272.54	121.73	0.51	0.27	0.26	0.37
1965.3	460	649.12	653.83	654.01	0.00228	4.26	0.90	0.92	267.12	121.63	0.53	0.27	0.28	0.37
1945.6	460	649.07	653.79	653.96	0.00228	4.25	0.87	0.93	265.56	119.96	0.53	0.26	0.28	0.37
1931.2	460	647.68	653.75	653.93	0.00201	4.14	0.78	0.87	260.73	114.62	0.49	0.21	0.25	0.35
1914.5	460	648.99	653.72	653.89	0.00228	4.25	0.88	0.92	266.92	121.15	0.53	0.26	0.28	0.37
1890.8	460	648.93	653.66	653.84	0.00225	4.26	0.89	0.90	269.03	123.80	0.53	0.26	0.27	0.37
1867.5	460	648.87	653.61	653.78	0.00222	4.22	0.91	0.86	270.46	123.41	0.52	0.27	0.25	0.37
1852.8	460	647.87	653.57	653.75	0.00207	4.19	0.88	0.81	262.89	117.86	0.50	0.25	0.22	0.35
1839.8	460	648.79	653.54	653.71	0.00217	4.17	0.90	0.84	273.32	124.93	0.51	0.27	0.24	0.36
1812.7	460	648.72	653.48	653.65	0.00217	4.19	0.89	0.87	276.67	127.82	0.51	0.26	0.25	0.37
1780.8	460	648.56	653.42	653.58	0.00204	4.07	0.78	0.89	283.77	128.08	0.48	0.21	0.26	0.35
1764.9	460	647.38	653.40	653.55	0.00171	3.87	0.69	0.83	293.42	127.54	0.43	0.17	0.22	0.32
1748.2	460	648.55	653.38	653.51	0.00180	3.85	0.79	0.83	311.40	139.96	0.43	0.21	0.22	0.33
1740.8	460	648.54	653.35	653.50	0.00188	3.94	0.85	0.78	314.68	153.68	0.45	0.23	0.21	0.34
1700.5	460	648.42	653.18	653.40	0.00260	4.58	1.03	0.61	244.94	137.11	0.61	0.34	0.15	0.40
1685.3	460	647.28	653.11	653.36	0.00254	4.63	1.01	0.40	222.41	136.01	0.62	0.32	0.08	0.39
1672.2	460	648.35	653.06	653.32	0.00297	4.84	1.08	0.50	224.18	143.67	0.69	0.37	0.12	0.42

1650.4	460	648.30	653.02	653.24	0.00266	4.63	1.00	0.71	254.18	147.84	0.62	0.33	0.20	0.40
1628.9	460	648.22	652.96	653.18	0.00266	4.58	0.95	0.78	255.44	147.96	0.61	0.30	0.22	0.40
1614.2	460	646.96	652.91	653.14	0.00245	4.57	0.84	0.75	247.44	141.79	0.60	0.25	0.21	0.38
1597.3	460	648.16	652.87	653.09	0.00275	4.65	0.96	0.79	254.14	148.05	0.63	0.31	0.23	0.41
1573.7	460	648.10	652.79	653.03	0.00283	4.74	1.01	0.68	249.22	153.93	0.66	0.33	0.19	0.42
1552.7	460	648.02	652.75	652.96	0.00267	4.59	1.00	0.59	257.93	159.95	0.62	0.33	0.15	0.40
1537.8	460	646.55	652.73	652.92	0.00213	4.26	0.91	0.50	270.27	160.60	0.52	0.27	0.11	0.36
1520.8	460	647.96	652.66	652.87	0.00265	4.57	1.01	0.48	256.04	165.61	0.61	0.33	0.11	0.40
1495.8	460	647.99	652.12	652.73	0.00775	6.78	0.61	0.84	144.91	169.37	1.44	0.20	0.33	0.64
1451.4	460	648.00	651.79	652.34	0.00899	6.79	0.78	0.94	173.68	200.65	1.50	0.31	0.40	0.70
1435.5	460	647.94	651.74	652.03	0.00499	4.84	0.47	0.77	210.89	213.99	0.78	0.12	0.26	0.53
1401.5	460	646.59	651.74	651.90	0.00167	3.72	0.40	0.58	324.41	230.33	0.40	0.07	0.13	0.32
1373.9	460	646.82	651.72	651.82	0.00236	3.33	0.72	0.74	353.23	225.14	0.52	0.19	0.20	0.30
1351.5	466.5	647.00	651.68	651.77	0.00198	3.06	0.60	0.67	362.47	230.16	0.43	0.14	0.17	0.28
1325.5	466.5	647.78	651.59	651.70	0.00359	3.76	0.88	0.90	334.65	225.35	0.69	0.29	0.30	0.36
1305.1	466.5	647.82	651.51	651.63	0.00354	3.72	0.89	0.88	325.84	217.34	0.67	0.30	0.29	0.36
1281.1	466.5	647.00	651.42	651.55	0.00340	3.63	0.84	0.89	303.79	195.71	0.64	0.27	0.29	0.36
1251.6	466.5	647.00	651.25	651.43	0.00422	4.43	1.05	0.91	269.38	178.69	0.92	0.39	0.32	0.39
1201.6	466.5	647.00	650.85	651.16	0.00671	5.25	0.59	1.12	185.71	126.16	1.33	0.19	0.49	0.51
1151.6	466.5	646.94	650.62	650.78	0.00628	4.71	1.01	1.27	256.28	159.52	1.11	0.41	0.58	0.46
1101.3	466.5	646.89	650.41	650.52	0.00383	3.37	0.59	0.88	314.43	224.86	0.59	0.16	0.29	0.37
1051.5	466.5	646.84	650.16	650.29	0.00504	3.97	0.53	0.97	289.09	220.64	0.81	0.15	0.36	0.43
1001.6	466.5	646.30	650.04	650.10	0.00235	3.10	0.66	0.79	422.32	269.57	0.46	0.17	0.22	0.30
951.6	466.5	645.78	649.93	649.99	0.00206	3.01	0.71	0.84	423.59	229.35	0.43	0.18	0.23	0.28
851.3	466.5	645.00	649.73	649.81	0.00155	2.60	0.65	0.39	353.73	190.33	0.32	0.15	0.07	0.24
801.3	466.5	645.00	649.61	649.70	0.00238	3.56	0.87	0.51	369.21	198.27	0.57	0.26	0.12	0.30
751.5	466.5	645.00	649.49	649.58	0.00214	3.35	0.74	0.80	371.70	217.07	0.51	0.19	0.22	0.29
701.5	466.5	644.96	649.29	649.44	0.00377	4.24	0.79	1.10	306.14	212.08	0.83	0.25	0.41	0.38
651.4	466.5	644.92	648.95	649.21	0.00548	4.96	0.94	1.12	228.39	167.75	1.16	0.35	0.46	0.46
601.6	466.5	644.39	648.83	648.98	0.00279	3.64	0.78	0.72	266.12	160.06	0.62	0.23	0.20	0.33
551.8	466.5	644.65	648.75	648.84	0.00234	3.14	0.82	0.83	336.51	182.58	0.47	0.23	0.24	0.30
501.6	466.5	644.00	648.67	648.74	0.00146	2.51	0.62	0.65	396.76	217.78	0.30	0.14	0.15	0.24
451.5	466.5	644.86	648.60	648.65	0.00178	2.57	0.69	0.75	439.45	250.20	0.33	0.17	0.19	0.26
401.6	466.5	643.97	648.43	648.54	0.00233	3.49	0.71	0.74	336.89	213.84	0.55	0.19	0.20	0.31

351.5	466.5	643.91	648.28	648.41	0.00313	3.84	0.72	0.90	330.69	223.66	0.69	0.21	0.29	0.34
301.2	466.5	644.00	648.17	648.25	0.00242	3.30	0.59	0.91	348.07	184.17	0.51	0.15	0.28	0.31
251.4	466.5	644.00	647.99	648.11	0.00279	3.61	0.49	0.98	279.50	137.82	0.61	0.11	0.32	0.33
201.4	466.5	644.00	647.75	647.93	0.00475	4.30	0.73	1.29	229.88	138.09	0.90	0.23	0.55	0.42
151.3	466.5	644.00	647.49	647.68	0.00489	4.45	0.87	1.39	234.26	204.67	0.96	0.31	0.62	0.43
101.6	466.5	644.00	647.25	647.40	0.00566	4.15	0.98	0.46	280.61	228.14	0.89	0.38	0.12	0.45
51.7	466.5	643.00	646.98	647.14	0.00430	4.28	0.88	0.85	310.41	240.52	0.87	0.30	0.29	0.41

APPENDIX J
Michigan Department of Transportation Construction Permit – Tamarack Creek

Michigan Department of Transportation

INDIVIDUAL CONSTRUCTION PERMIT

For Operations within State Highway Right-of-Way

Issued To:
City of Southfield

25501 CLARA LN
SOUTHFIELD MI 48034-2391

Contact:
Leigh Schultz
248-796-4812(O) 248-860-0824(Cell)
lschultz@cityofsouthfield.com

Permit Number: 63081-069595-20-061720
Permit Type: Individual Application
Permit Fee:
Effective Date: Jun 17, 2020 **to** Jun 17, 2021
Bond Numbers:
Liability Insurance Expiration Date:

Contractor:

Environmental Consulting & Technology, Inc. - Ann Arbor,
2200 Commonwealth Blvd, Suite 300
Ann Arbor MI 48105

Contact:

Shelby Dix

248-796-4812(O) 443-504-2912(Cell)
sdix@ectinc.com

63081-069595-20-061720 Issued To:City of Southfield

THIS PERMIT IS VALID ONLY FOR THE FOLLOWING PROPOSED OPERATIONS:

PURPOSE:

This application is being submitted in order to permit habitat restoration work being completed on MDOT property and within MDOT easements. This work is part of a larger effort funded by the U.S. EPA to restore Tamarack Creek in Southfield, MI and help in the removal of the Beneficial Use Impairments (BUIs). These impairments have caused the Rouge River Watershed to be designated as an Area of Concern (AOC). Several activities are being proposed on MDOT property and within MDOT ROWs to enhance habitat in and adjacent to Tamarack Creek, including invasive species management, naturalization of the straightened channels, creation of floodplain, management of invasive species, and planting of native grasses, forbs, shrubs, and trees. These proposed activities will improve and enhance hydrological storage capacity, channel stability, wildlife habitat, instream habitat for fish and macroinvertebrates, and flood conveyance capacity. The proposed work on MDOT property and within MDOT easements is described in detail below:

1. Enhanced stormwater basin: Currently, the 2.3-acre stormwater basin at the upstream end of Tamarack Creek is in poor condition, with invasive Phragmites and non-native cattails filling most of the basin. These Phragmites, along with 1 foot of soil will be removed from the basin area and disposed of at a Type II Landfill (3756 cubic yards total). To restore the basin, 1 foot of clean fill and topsoil will be placed in the basin and planted with native wetland plants. See Sheet 13 on the Permit Drawings.

2. Removal and replacement of existing fence as needed for grading: Up to 700 linear feet of fencing will be removed and replaced to allow for grading in the existing 100-year floodplain. See Sheet 13 and 14 on the Permit Drawings.

3. Permanent access: Access will be established at the toe-of slope along the west side of the stream so construction equipment can access the stream to complete stream improvements, totaling 372 linear feet on MDOT property and easements. In the future, this access route will be used to conduct routine inspections and any maintenance work required. See Sheet 14 on the Permit Drawings.

4. Expanded floodplain and wetland creation: Within MDOT property and easements, a net volume of 1272 cubic yards of soil will be removed to expand the floodplain in narrow portions of the creek and create additional wetlands. See Sheet 14 on the Permit Drawings.

5. Channel realignment and habitat improvements: 372 linear feet of stream channel will be realigned through excavation of a new channel and placement of fill into the existing channel. Four habitat structures will be installed to protect against erosion and provide habitat for fish and macroinvertebrates. See Sheet 14 on the Permit Drawings.

6. Removal of a road crossing with three elliptical concrete culverts: The existing stream crossing will be removed to naturalize the stream, improve conveyance capacity, and improve channel hydraulics during storm events. This will also lower the floodplain elevation, which will remove land from the 100-year floodplain upstream of the crossing. The crossing will be replaced with an at-grade stream crossing. 175 cubic yards of soil will be removed and replaced with gravel to establish the at-grade stream crossing. See Sheet 14 on the Permit Drawings.

STATE ROUTE: M-10 **CITY OF:** Southfield **COUNTY:** Oakland County

NEAREST INTERSECTION:	**SIDE OF ROAD:**	**DISTANCE TO (in feet) NEAREST INTERSECTION:**	**DIRECTION TO NEAREST INTERECTION:**
W 10 Mile Rd & Northweste	S	300.00	East

CONTROL SECTION:	**MILE POINT FROM:**	**MILE POINT TO:**	**LOCATION:** LEFT	MEDIAN	RIGHT	TRANSVERSE
63081	2.470	2.470	X			

REQUISITION NUMBER:	**WORK ORDER NUMBER:**	**MDOT JOB NUMBER:**	**ORG JOB NUMBER:**

63081-069595-20-061720 Issued To:City of Southfield

This permit is incomplete without "General Conditions and Supplemental Specifications"

I certify that I accept the following:

1. I am the legal owner of this property or facility, the owner's authorized representative, or have statutory authority to work within state highway Right-of-Way.
2. Commencement of work set forth in the permit application constitutes acceptance of the permit as issued.
3. Failure to object, ***within ten (10) days*** to the permit as issued constitutes acceptance of the permit as issued.
4. If this permit is accepted by either of the above methods, I will comply with the provisions of the permit.
5. I agree that Advance Notice for Permitted Activities for shall be submitted **5 days prior** to the commencement of the proposed work.

   I agree that Advance Notice for Permitted Utility Tree Trimming and Tree Removal Activities shall be submitted **15 days prior** to the commencement of the proposed work for an annual permit.

CAUTION

Work shall NOT begin until the Advance Notice has been approved.

Failure to submit the advance notice may result in a Stop Work Order.

City of Southfield	**Stacey Gough** **MDOT**	June 17, 2020 **Approved Date**
TSC Contact Info	**Oakland TSC**	**(248) 451-0001**

THE STANDARD ATTACHMENTS, ATTACHMENTS AND SPECIAL CONDITIONS MARKED BELOW ARE A PART OF THIS PERMIT.

STANDARD ATTACHMENTS:

1 Special Conditions For Underground Construction (2205C)
2 General Conditions for Permit (General Conditions)
3 ENVIRONMENTAL REQUIREMENTS FORACTIVITIES WITHIN MDOT RIGHT-OF-WAY (2486)
4 The Northern Long Ear and Indiana Bat Advisory (Bat Advisory)
5 Historical and Archaeological Discoveries During Construction Operations (Const. Advisory Historical/Archae
6 Special Conditions For Tree Removal, Tree Trimming & Herbicide Application (2240)
7 Regulated Eastern Massasauga Rattlesnake Habitat Advisory 10-30-19 (Eastern Massasauga Rattlesnake A

63081-069595-20-061720 Issued To:City of Southfield

ADDITIONAL ATTACHMENTS:

1 MDOT Property Map 04.10.20.pdf
2 Tamarack Permit Drawings 1.pdf
3 Tamarack Permit Drawings 2.pdf
4 Tamarack - Basis of Design Report.pdf
5 Tamarack Wetland Memo rev021020.pdf
6 MDOT_Form_2484_TamarackCreek_2020-6-8.pdf
7 MDOT_Form_2484_TamarackCreek_2020-6-8.pdf
8 Culvert_Sizing_Drainage_Area_Map.pdf
9 Copy of Culvert_Sizing_NOAA_Atlas_14_All_Depth_English_PDS.pdf
10 Copy of Culvert_Sizing_Rational_and_DetentionOutflow_Calcs.pdf
11 TR55_Hydrologic_Soil_Groups.pdf
12 TR55_Pond and Swamp Adjustment.pdf
13 TR55_RCN.pdf
14 TR55_Tamarack_TOC_FLOW_PATH_Final.pdf
15 TR55_Tamarack_TOC_FLOW_PATH_USGS_Contours.pdf
16 TR55_TOC.pdf
17 69595supplementalspecs.pdf

AMENDMENT ATTACHMENTS:

SPECIAL CONDITIONS:

1 The Department of Transportation does not, by issuance of this permit, assume any liability claims or maintenance costs resulting from the wetland & drainage work facility placed by this permit. The Department reserves the right to require removal of all or any portion of this facility as needed for highway maintenance or construction purposes without replacement or reimbursement of any costs incurred by the permitted or other party. The permitted will defend, indemnify and hold harmless the Department for any claims whatsoever resulting from the construction or the removal of the authorized by this permit.

2 All disturbed areas within the right of way shall be top-soiled, seeded and mulched to match existing areas per current MDOT standards and specifications.

APPENDIX K
Michigan Department of Environment, Great Lakes and Energy (EGLE) Construction Permits

Appendix K1 – EGLE Permit Tamarack Creek
Appendix K2 – EGLE Permit Johnson Creek

EGLE

MICHIGAN DEPARTMENT OF ENVIRONMENT, GREAT LAKES, AND ENERGY
WATER RESOURCES DIVISION
PERMIT

Issued To:

City of Southfield, Attn: Brandy Siedlaczek
26000 Evergreen Road
Southfield, MI 48076

Permit No:	**WRP026823 v.1**
Submission No.:	**HNQ-4757-9EWHW**
Site Name:	**63-Tamarack Creek-Southfield**
Issued:	**December 17, 2020**
Revised:	
Expires:	**December 17, 2025**

This permit is being issued by the Michigan Department of Environment, Great Lakes, and Energy (EGLE), Water Resources Division, under the provisions of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA); specifically:

- ☒ **Part 301, Inland Lakes and Streams**
- ☒ **Part 303, Wetlands Protection**
- ☐ **Part 315, Dam Safety**
- ☐ **Part 31, Water Resources Protection (Floodplain Regulatory Authority)**
- ☐ **Part 323, Shorelands Protection and Management**
- ☐ **Part 325, Great Lakes Submerged Lands**
- ☐ **Part 353, Sand Dunes Protection and Management**

Permission is hereby granted, based on permittee assurance of adherence to State of Michigan requirements and permit conditions, to:

Authorized Activity:

Remove an in-stream triple-culvert stream crossing, an in-stream culvert, concrete rubble, and bridge abutments from Tamarack Creek. Remove drain tiles and 900 linear feet of chain link fence from wetland. Excavate 1,129 cubic yards and fill 944 cubic yards to relocate 955 linear feet of the Tamarack Creek into 1,130 linear feet of new channel and construct a floodplain bench. Eliminate 0.11 acres of wetland associated with construction impacts related to the stream relocation and construct 0.23 acres of new wetland along the banks of the new stream, employ bioengineering and live stake planting along 1,600 linear feet of the stream. Place 8 riffles, 8 whole tree revetments, 5 scour pools with logs, and 1 root wad revetment in the stream.
Construct a temporary at-grade crossing across the stream to be removed at the conclusion construction activities. Construct an 1,890-foot-long maintenance path partially through wetland, and place a 20-foot long, 24-inch diameter culvert in a tributary stream.
Excavate 3,756 cubic yards from a detention pond constructed in upland for the purposes of invasive species control then fill with 3,756 cubic yards of clean fill and reseed with a wetland seed mix.

All work shall be in accordance with the approved attached drawings and the specific terms and conditions of this permit.

EGLE-WRD
WRP026823 v1.0
Approved
Issued On:12/17/2020
Expires On:12/17/2025

Waterbody Affected: Tamarack Creek
Property Location: Oakland County, City of Southfield, Town/Range/Section 01N10E27, Property Tax No. 24-27-226-021, 24-27-201-005, 24-27-226-003, 24-27-226-004, 24-27-226-005, 24-27-226-006, 24-27-226-008, 24-27-276- 013

Authority granted by this permit is subject to the following limitations:

A. Initiation of any work on the permitted project confirms the permittee's acceptance and agreement to comply with all terms and conditions of this permit.
B. The permittee, in exercising the authority granted by this permit, shall not cause unlawful pollution as defined by Part 31 of the NREPA.
C. This permit shall be kept at the site of the work and available for inspection at all times during the duration of the project or until its date of expiration.
D. All work shall be completed in accordance with the approved plans and specifications submitted with the application and/or plans and specifications attached to this permit.
E. No attempt shall be made by the permittee to forbid the full and free use by the public of public waters at or adjacent to the structure or work approved.
F. It is made a requirement of this permit that the permittee give notice to public utilities in accordance with 2013 PA 174 (Act 174) and comply with each of the requirements of Act 174.
G. This permit does not convey property rights in either real estate or material, nor does it authorize any injury to private property or invasion of public or private rights, nor does it waive the necessity of seeking federal assent, all local permits, or complying with other state statutes.
H. This permit does not prejudice or limit the right of a riparian owner or other person to institute proceedings in any circuit court of this state when necessary to protect his rights.
I. Permittee shall notify EGLE within one week after the completion of the activity authorized by this permit by completing and forwarding the attached preaddressed postcard to the office addressed thereon.
J. This permit shall not be assigned or transferred without the written approval of EGLE.
K. Failure to comply with conditions of this permit may subject the permittee to revocation of permit and criminal and/or civil action as cited by the specific state act, federal act, and/or rule under which this permit is granted.
L. All dredged or excavated materials shall be disposed of in an upland site (outside of floodplains, unless exempt under Part 31 of the NREPA, and wetlands).
M. In issuing this permit, EGLE has relied on the information and data that the permittee has provided in connection with the submitted application for permit. If, subsequent to the issuance of a permit, such information and data prove to be false, incomplete, or inaccurate, EGLE may modify, revoke, or suspend the permit, in whole or in part, in accordance with the new information.
N. The permittee shall indemnify and hold harmless the State of Michigan and its departments, agencies, officials, employees, agents, and representatives for any and all claims or causes of action arising from acts or omissions of the permittee, or employees, agents, or representative of the permittee, undertaken in connection with this permit. The permittee's obligation to indemnify the State of Michigan applies only if the state: (1) provides the permittee or its designated representative written notice of the claim or cause of action within 30 days after it is received by the state, and (2) consents to the permittee's participation in the proceeding on the claim or cause of action. It does not apply to contested case proceedings under the Administrative Procedures Act, 1969 PA 306, as amended, challenging the permit. This permit shall not be construed as an indemnity by the State of Michigan for the benefit of the permittee or any other person.
O. Noncompliance with these terms and conditions and/or the initiation of other regulated activities not specifically authorized shall be cause for the modification, suspension, or revocation of this permit, in whole or in part. Further, EGLE may initiate criminal and/or civil proceedings as may be deemed necessary to correct project deficiencies, protect natural resource values, and secure compliance with statutes.
P. If any change or deviation from the permitted activity becomes necessary, the permittee shall request, in writing, a revision of the permitted activity from EGLE. Such revision request shall include complete documentation supporting the modification and revised plans detailing the proposed modification. Proposed modifications must be approved, in writing, by EGLE prior to being implemented.
Q. This permit may be transferred to another person upon written approval of EGLE. The permittee must submit a written request to EGLE to transfer the permit to the new owner. The new owner must also submit a written request to EGLE to accept transfer. The new owner must agree, in writing, to accept all conditions of the permit.

EGLE-WRD
WRP026823 v1.0
Approved
Issued On:12/17/2020
Expires On:12/17/2025

A single letter signed by both parties that includes all the above information may be provided to EGLE. EGLE will review the request and, if approved, will provide written notification to the new owner.

R. Prior to initiating permitted construction, the permittee is required to provide a copy of the permit to the contractor(s) for review. The property owner, contractor(s), and any agent involved in exercising the permit are held responsible to ensure that the project is constructed in accordance with all drawings and specifications. The contractor is required to provide a copy of the permit to all subcontractors doing work authorized by the permit.

S. Construction must be undertaken and completed during the dry period of the wetland. If the area does not dry out, construction shall be done on equipment mats to prevent compaction of the soil.

T. Authority granted by this permit does not waive permit requirements under Part 91, Soil Erosion and Sedimentation Control, of the NREPA, or the need to acquire applicable permits from the County Enforcing Agent (CEA).

U. Authority granted by this permit does not waive permit requirements under the authority of Part 305, Natural Rivers, of the NREPA. A Natural Rivers Zoning Permit may be required for construction, land alteration, streambank stabilization, or vegetation removal along or near a natural river.

V. The permittee is cautioned that grade changes resulting in increased runoff onto adjacent property is subject to civil damage litigation.

W. Unless specifically stated in this permit, construction pads, haul roads, temporary structures, or other structural appurtenances to be placed in a wetland or on bottomland of the water body are not authorized and shall not be constructed unless authorized by a separate permit or permit revision granted in accordance with the applicable law.

X. For projects with potential impacts to fish spawning or migration, no work shall occur within fish spawning or migration timelines (i.e., windows) unless otherwise approved in writing by the Michigan Department of Natural Resources, Fisheries Division.

Y. Work to be done under authority of this permit is further subject to the following special instructions and specifications:

1. Authority granted by this permit does not waive permit or program requirements under Part 91 of the NREPA or the need to acquire applicable permits from the CEA. To locate the Soil Erosion Program Administrator for your county, visit www.mi.gov/eglestormwater and select "Soil Erosion and Sedimentation Control Program" under "Related Links."

2. The authority to conduct the activity as authorized by this permit is granted solely under the provisions of the governing act as identified above. This permit does not convey, provide, or otherwise imply approval of any other governing act, ordinance, or regulation, nor does it waive the permittee's obligation to acquire any local, county, state, or federal approval or authorization necessary to conduct the activity.

3. No fill, excess soil, or other material shall be placed in any wetland, floodplain, or surface water area not specifically authorized by this permit, its plans, and specifications.

4. This permit does not authorize or sanction work that has been completed in violation of applicable federal, state, or local statutes.

5. The permit placard shall be kept posted at the work site in a prominent location at all times for the duration of the project or until permit expiration.

6. This permit is being issued for the maximum time allowed and no extensions of this permit will be granted. Initiation of the construction work authorized by this permit indicates the permittee's acceptance of this condition. The permit, when signed by EGLE, will be for a five-year period beginning on the date of issuance. If the project is not completed by the expiration date, a new permit must be sought.

7. During removal or repair of existing structures, every precaution shall be taken to prevent debris from entering any watercourse. Any debris reaching the watercourse during the removal and/or reconstruction of the structure shall be immediately retrieved from the water. All material shall be disposed of in an acceptable manner consistent with local, state, and federal regulations.

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8. The use of explosives for removal of the structure over the waterbody, including any abutments or piers, is prohibited.

9. The temporary bridge shall span the bankfull width of the stream with the lowest bottom of beam elevation at or above the natural ground elevations on each bank. The approach fill shall slope to natural ground elevations within ten (10) feet of either end of the structure.

10. The fill for temporary bridge approaches shall consist of clean rock or washed gravel. The use of pit-run gravel is NOT authorized by this permit.

11. This permit is for one installation of a temporary bridge over a stream. The structure may not be removed and reinstalled at a later date, unless authorized under another permit.

12. The structure shall be removed immediately upon completion of the project activity or by the expiration date of this permit, whichever is earlier. The area shall be restored to the condition and configuration indicated in the approved attached plans upon removal of the temporary structure.

13. Culvert installations authorized by this permit shall be installed to align with the center line of the existing stream at both the inlet and outlet ends and must be buried below the stream bed to provide a natural channel substrate through the structure as shown on the approved plans.

14. No work shall be done in the stream during periods of above-normal flows except as necessary to prevent erosion.

15. If the project, or any portion of the project, is stopped and lies incomplete for any length of time (other than that encountered in a normal work week) every precaution shall be taken to protect the incomplete work from erosion, including the placement of temporary gravel bag riprap, temporary seed and mulch, or other acceptable temporary protection.

16. All other exposed slopes, ditches, and other raw areas draining directly to the stream may be protected with riprap, sod and/or seed and mulch as may be necessary to provide effective erosion protection. The placement of riprap shall be limited to the minimum necessary to ensure proper stabilization of the side slopes and fill in the immediate vicinity of the structure.

17. The permittee is responsible for acquiring all necessary easements or rights-of-way before commencing any work authorized by this permit. All construction operations relating to or part of this project shall be confined to the existing right-of-way limits or other acquired easements.

18. Under Appendix G of the Michigan Building Code 2009, a local building permit is required for development located in flood hazard areas.

19. The project is located within a community that participates in the National Flood Insurance Program (NFIP). As a participant in the NFIP, the community must comply with the Michigan Building Code (including Appendix G and listed supporting materials); the Michigan Residential Code; and Title 44 of the Code of Federal Regulations, Part 60, Criteria for Land Management and Use. The community is also responsible to ensure that its floodplain maps and studies are maintained to show changes to flood elevations and flood delineations as described in 44 CFR, Part 65, Identification and Mapping of Special Hazard Areas.

20. Prior to the start of construction, all adjacent non-work wetland areas shall be protected by properly trenched sedimentation barrier to prevent sediment from entering the wetland. Orange construction fencing shall be installed as needed to prohibit construction personnel and equipment from entering or performing work in these areas. Fence shall be maintained daily throughout the construction process. Upon project completion, the accumulated materials shall be removed and disposed of at an upland site, the sedimentation barrier shall then be removed in its entirety and the area restored to its original configuration and cover.

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21. The local unit of government in which this project site is located has a wetland ordinance. Authority granted by this permit does not waive permit requirements or the need to obtain a separate permit from the local unit of government.

22. All slurry resulting from any dewatering operation shall be discharged through a filter bag or pumped to a sump located away from wetlands and surface waters and allowed to filter through natural upland vegetation, gravel filters, or other engineered devices for a sufficient distance and/or period of time necessary to remove sediment or suspended particles. The discharge of slurry water resulting from the hydrodemolition of concrete is not allowed to enter a lake, stream, or wetland.

23. Prior to the initiation of any permitted construction activities, a sedimentation barrier shall be constructed immediately down gradient of the construction site. Sedimentation barriers shall be specifically designed to handle the sediment type, load, water depth, and flow conditions of each construction site throughout the anticipated time of construction and unstable site conditions. The sedimentation barrier shall be maintained in good working order throughout the duration of the project. Upon project completion, the accumulated materials shall be removed and disposed of at an upland (non-wetland, non-floodplain) site and stabilized with seed and mulch. The sedimentation barrier shall then be removed in its entirety and the area restored to its original configuration and cover.

24. All raw areas in uplands resulting from the permitted construction activity shall be effectively stabilized with sod and/or seed and mulch (or other technology specified by this permit or project plans) in a sufficient quantity and manner to prevent erosion and any potential siltation to surface waters or wetlands. Temporary stabilization measures shall be installed before or upon commencement of the permitted activity, and shall be maintained until permanent measures are in place. Permanent measures shall be in place within five (5) days of achieving final grade.

25. No in-stream work may occur between April 15 and June 15 of any calendar year that this permit is active without the use of silt curtains to segregate defined work zones, with progression of work within one zone at a time. If such work occurs the permittee shall contact EGLE 48 hours prior to the commencement of construction activities and submit a plan drawing indicating silt curtain layout and the segregation of work areas.

26. The permittee shall both: inspect in-stream work areas prior to the commencement of construction activities to determine if mussels are present in the work area, and contact EGLE to indicate if mussels were found, at minimum 48 hours before work is planned to commence. If mussels are found, work is not authorized until further guidance is sent by EGLE and/or the Michigan Department of Natural Resources (DNR)

27. All work shall be in accordance with the attached approved drawings and the specific terms and conditions of this permit.

Issued By: Robert Primeau

Robert Primeau
Warren District Office
Water Resources Division
586-256-7274

cc: Southfield City Clerk Southfield - MEA
Oakland County Drain Commissioner
Oakland County Water Resources Commission
Sara Thomas, DNR
Andy Hartz, EGLE
Alice Bailey, ETC
Stacy Gough, MDOT

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MICHIGAN DEPARTMENT OF ENVIRONMENT, GREAT LAKES, AND ENERGY
WATER RESOURCES DIVISION
PERMIT

Issued To:

Patrick Sullivan, City of Northville
215 W. Main Street
Northville, MI 48167

Permit No:	**WRP021007 v.1**
Submission No.:	**HNP-Y4RN-V3TNE**
Site Name:	**82-641 Fairbrook Street-Northville**
Issued:	**February 17, 2020**
Revised:	
Expires:	**February 17, 2025**

This permit is being issued by the Michigan Department of Environment, Great Lakes, and Energy (EGLE), Water Resources Division, under the provisions of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA); specifically:

- ☒ **Part 301, Inland Lakes and Streams**
- ☐ **Part 323, Shorelands Protection and Management**
- ☐ **Part 303, Wetlands Protection**
- ☐ **Part 325, Great Lakes Submerged Lands**
- ☐ **Part 315, Dam Safety**
- ☐ **Part 353, Sand Dunes Protection and Management**
- ☒ **Part 31, Water Resources Protection (Floodplain Regulatory Authority)**

Permission is hereby granted, based on permittee assurance of adherence to State of Michigan requirements and permit conditions, to:

Authorized Activity:

Remove 1,130 linear feet of existing concrete wall from the banks of Johnson Creek to naturalize the stream channel; excavate 1,833 cubic yards of soil to create a 13 foot wide floodplain bench; install 682 cubic yards of mechanically stabilized soil lifts with live stakes for stream bank stabilization and habitat creation; dredge approximately 3,560 cubic yards of accumulated sediment from adjacent Fish Hatchery Pond and construct a step pool from pond to stream to enhance fish passage; install 338 linear feet of interlocking sheet pile wall to stabilize the pond edge; place 20 cubic yards of angular limestone rip-rap to control scour at the existing pedestrian bridge, remove a 5 cubic yard point bar and 117 cubic yards of woody debris from the stream and construct 4 rock vane structures to control erosion.

All work shall be completed in accordance with the attached plans and the terms and conditions of this permit.

Waterbody Affected:	Johnson Creek
Property Location:	Wayne County, Northville Township, Town/Range/Section 01S08E03, Property Tax No. 77033990001000

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Authority granted by this permit is subject to the following limitations:

A. Initiation of any work on the permitted project confirms the permittee's acceptance and agreement to comply with all terms and conditions of this permit.
B. The permittee, in exercising the authority granted by this permit, shall not cause unlawful pollution as defined by Part 31 of the NREPA.
C. This permit shall be kept at the site of the work and available for inspection at all times during the duration of the project or until its date of expiration.
D. All work shall be completed in accordance with the approved plans and specifications submitted with the application and/or plans and specifications attached to this permit.
E. No attempt shall be made by the permittee to forbid the full and free use by the public of public waters at or adjacent to the structure or work approved.
F. It is made a requirement of this permit that the permittee give notice to public utilities in accordance with 2013 PA 174 (Act 174) and comply with each of the requirements of Act 174.
G. This permit does not convey property rights in either real estate or material, nor does it authorize any injury to private property or invasion of public or private rights, nor does it waive the necessity of seeking federal assent, all local permits, or complying with other state statutes.
H. This permit does not prejudice or limit the right of a riparian owner or other person to institute proceedings in any circuit court of this state when necessary to protect his rights.
I. Permittee shall notify EGLE within one week after the completion of the activity authorized by this permit by completing and forwarding the attached preaddressed postcard to the office addressed thereon.
J. This permit shall not be assigned or transferred without the written approval of EGLE.
K. Failure to comply with conditions of this permit may subject the permittee to revocation of permit and criminal and/or civil action as cited by the specific state act, federal act, and/or rule under which this permit is granted.
L. All dredged or excavated materials shall be disposed of in an upland site (outside of floodplains, unless exempt under Part 31 of the NREPA, and wetlands).
M. In issuing this permit, EGLE has relied on the information and data that the permittee has provided in connection with the submitted application for permit. If, subsequent to the issuance of a permit, such information and data prove to be false, incomplete, or inaccurate, EGLE may modify, revoke, or suspend the permit, in whole or in part, in accordance with the new information.
N. The permittee shall indemnify and hold harmless the State of Michigan and its departments, agencies, officials, employees, agents, and representatives for any and all claims or causes of action arising from acts or omissions of the permittee, or employees, agents, or representative of the permittee, undertaken in connection with this permit. The permittee's obligation to indemnify the State of Michigan applies only if the state: (1) provides the permittee or its designated representative written notice of the claim or cause of action within 30 days after it is received by the state, and (2) consents to the permittee's participation in the proceeding on the claim or cause of action. It does not apply to contested case proceedings under the Administrative Procedures Act, 1969 PA 306, as amended, challenging the permit. This permit shall not be construed as an indemnity by the State of Michigan for the benefit of the permittee or any other person.
O. Noncompliance with these terms and conditions and/or the initiation of other regulated activities not specifically authorized shall be cause for the modification, suspension, or revocation of this permit, in whole or in part. Further, EGLE may initiate criminal and/or civil proceedings as may be deemed necessary to correct project deficiencies, protect natural resource values, and secure compliance with statutes.
P. If any change or deviation from the permitted activity becomes necessary, the permittee shall request, in writing, a revision of the permitted activity from EGLE. Such revision request shall include complete documentation supporting the modification and revised plans detailing the proposed modification. Proposed modifications must be approved, in writing, by EGLE prior to being implemented.
Q. This permit may be transferred to another person upon written approval of EGLE. The permittee must submit a written request to EGLE to transfer the permit to the new owner. The new owner must also submit a written request to EGLE to accept transfer. The new owner must agree, in writing, to accept all conditions of the permit. A single letter signed by both parties that includes all the above information may be provided to EGLE. EGLE will review the request and, if approved, will provide written notification to the new owner.
R. Prior to initiating permitted construction, the permittee is required to provide a copy of the permit to the contractor(s) for review. The property owner, contractor(s), and any agent involved in exercising the permit are held responsible to ensure that the project is constructed in accordance with all drawings and specifications. The contractor is required to provide a copy of the permit to all subcontractors doing work authorized by the permit.

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S. Construction must be undertaken and completed during the dry period of the wetland. If the area does not dry out, construction shall be done on equipment mats to prevent compaction of the soil.

T. Authority granted by this permit does not waive permit requirements under Part 91, Soil Erosion and Sedimentation Control, of the NREPA, or the need to acquire applicable permits from the County Enforcing Agent (CEA).

U. Authority granted by this permit does not waive permit requirements under the authority of Part 305, Natural Rivers, of the NREPA. A Natural Rivers Zoning Permit may be required for construction, land alteration, streambank stabilization, or vegetation removal along or near a natural river.

V. The permittee is cautioned that grade changes resulting in increased runoff onto adjacent property is subject to civil damage litigation.

W. Unless specifically stated in this permit, construction pads, haul roads, temporary structures, or other structural appurtenances to be placed in a wetland or on bottomland of the water body are not authorized and shall not be constructed unless authorized by a separate permit or permit revision granted in accordance with the applicable law.

X. For projects with potential impacts to fish spawning or migration, no work shall occur within fish spawning or migration timelines (i.e., windows) unless otherwise approved in writing by the Michigan Department of Natural Resources, Fisheries Division.

Y. Work to be done under authority of this permit is further subject to the following special instructions and specifications:

1. Authority granted by this permit does not waive permit or program requirements under Part 91 of the NREPA or the need to acquire applicable permits from the CEA. To locate the Soil Erosion Program Administrator for your county, visit www.mi.gov/eglestormwater and select "Soil Erosion and Sedimentation Control Program" under "Related Links."
2. The authority to conduct the activity as authorized by this permit is granted solely under the provisions of the governing act as identified above. This permit does not convey, provide, or otherwise imply approval of any other governing act, ordinance, or regulation, nor does it waive the permittee's obligation to acquire any local, county, state, or federal approval or authorization necessary to conduct the activity.
3. No fill, excess soil, or other material shall be placed in any wetland, floodplain, or surface water area not specifically authorized by this permit, its plans, and specifications.
4. This permit does not authorize or sanction work that has been completed in violation of applicable federal, state, or local statutes.
5. The permit placard shall be kept posted at the work site in a prominent location at all times for the duration of the project or until permit expiration.
6. This permit is being issued for the maximum time allowed and no extensions of this permit will be granted. Initiation of the construction work authorized by this permit indicates the permittee's acceptance of this condition. The permit, when signed by EGLE, will be for a five-year period beginning on the date of issuance. If the project is not completed by the expiration date, a new permit must be sought.

Issued By: ______________________________

John Jones
Warren District Office
Water Resources Division
586-787-3630

cc: Alice Bailey, ECT
Northville Township Clerk
Wayne CEA
Wayne County Drain Commissioner

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