River Assessment and Monitoring
NCTC - Shepherdstown, WV
9/17 – 9/27/2007

Team 1
Day 1
Magruders Branch
Reference Reach

Magruder Branch Reference Reach Team 1

9/18/2007

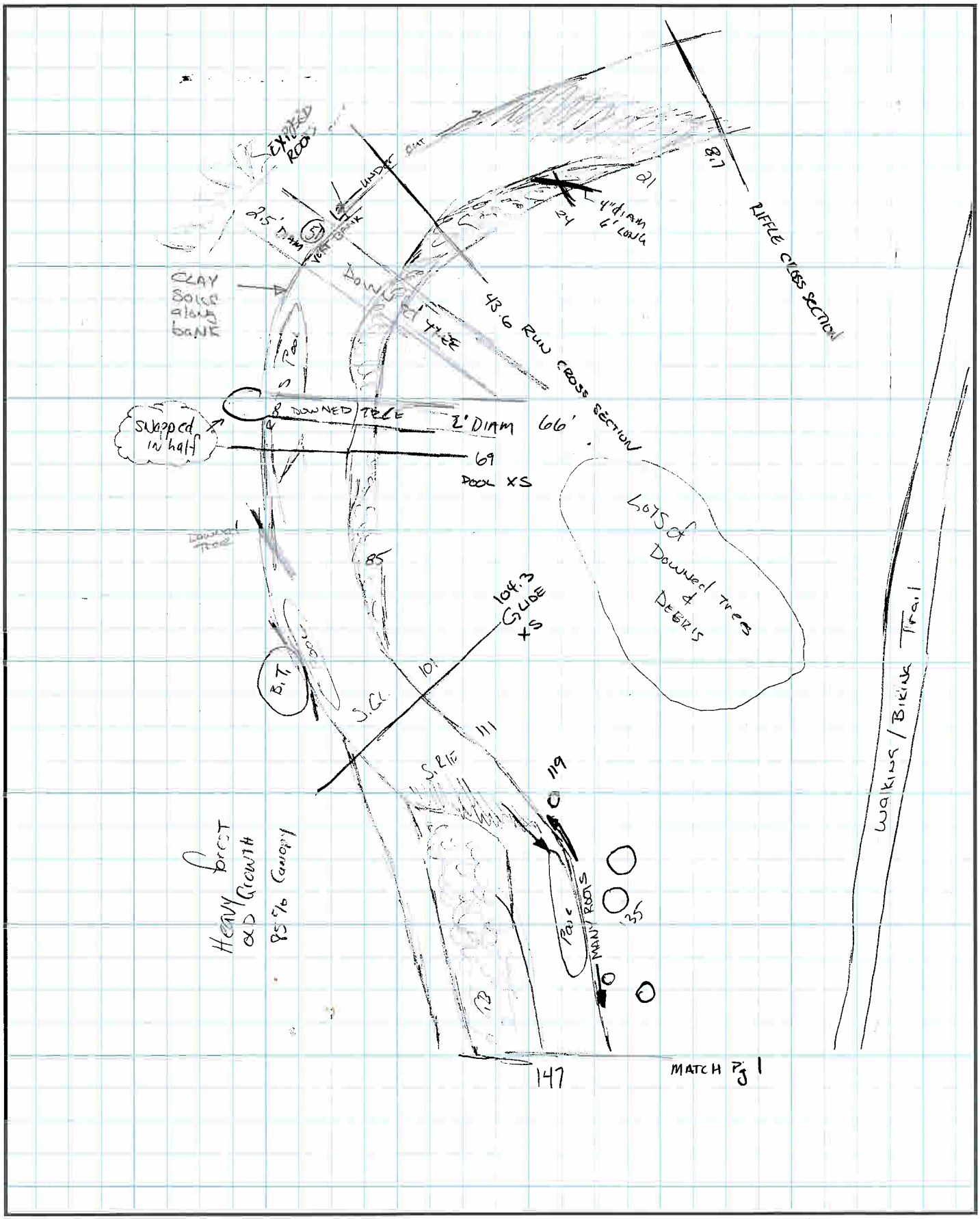
DMJM HARRIS | AECOM

DMJM Harris

JOB TITLE SKETCH PG. 2

JOB NO. McGruder Branch CALCULATION NO. ORIGINATOR TEAM 1 DATE 9/18/07

SHEET OF REVIEWER NCTC DATE



Magruder Branch Reference Reach Team 1

9/18/2007

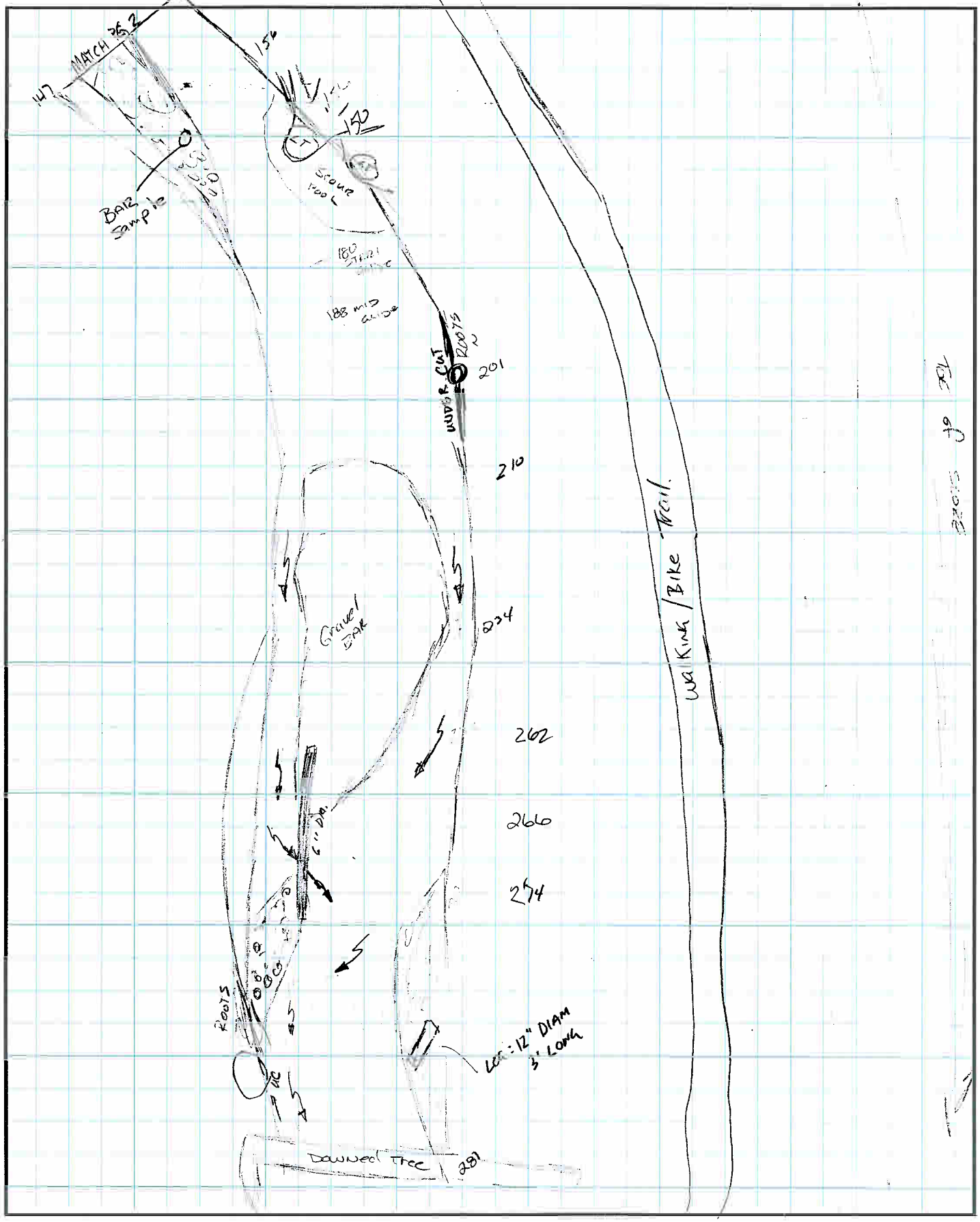
DMJM HARRIS | AECOM

DMJM Harris

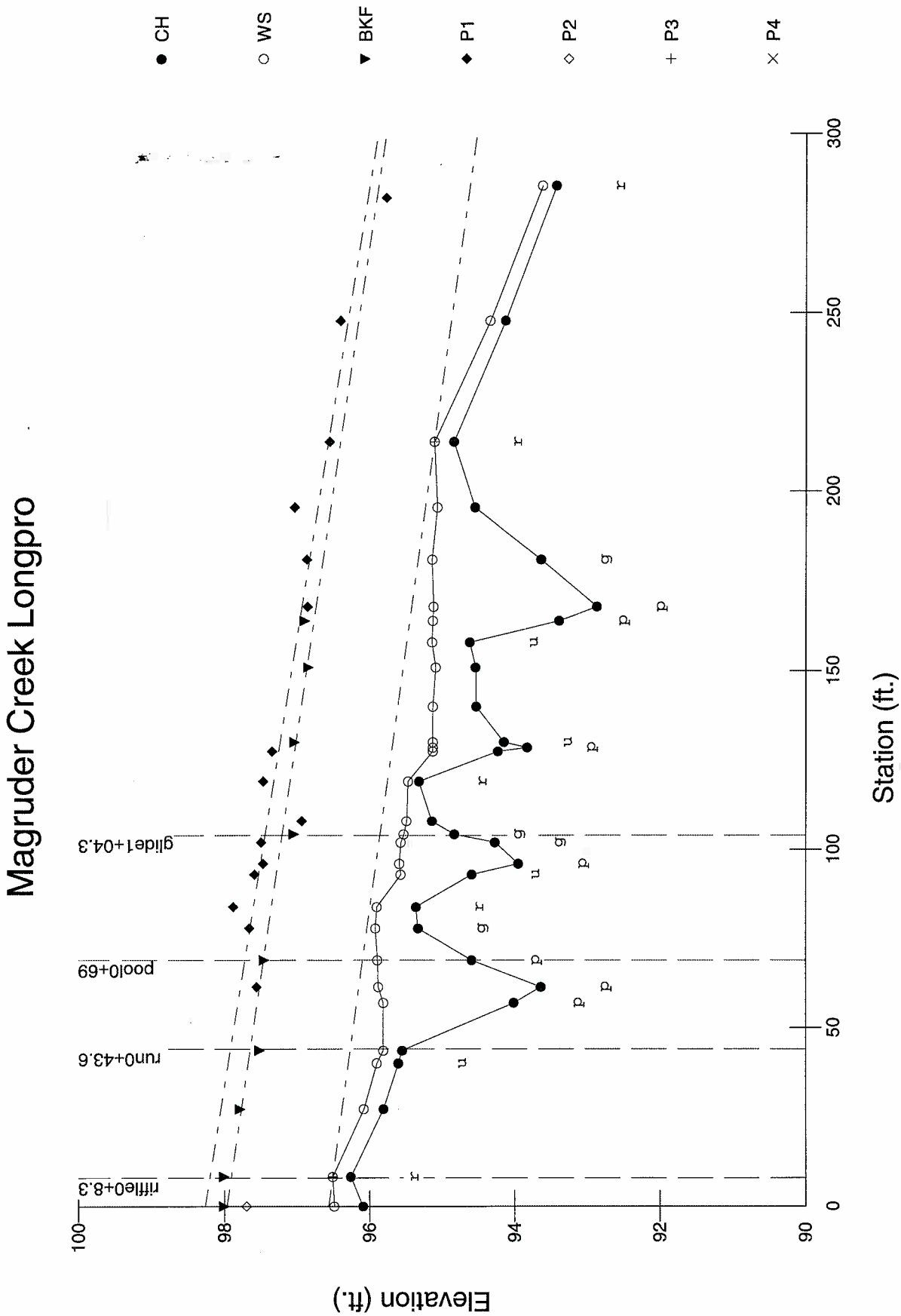
JOB TITLE SKETCH PG 1

JOB NO. Mac Gruber Branch CALCULATION NO. _____ ORIGINATOR TEAM 1 DATE 9/18/07

SHEET _____ OF _____ REVIEWER NCTC DATE _____



Montgomery County, Maryland
Scale: 1" = 1,300'
Date of Photograph: 1995


Magruder Creek Longpro
CH
WS
BKF
P1
P2
P3
P4
riffle0+8.3
run0+43.6
pool0+69
glide1+04.3
Elevation (ft.)
Station (ft.)
100
98
96
94
92
90
0
50
100
150
200
250
300

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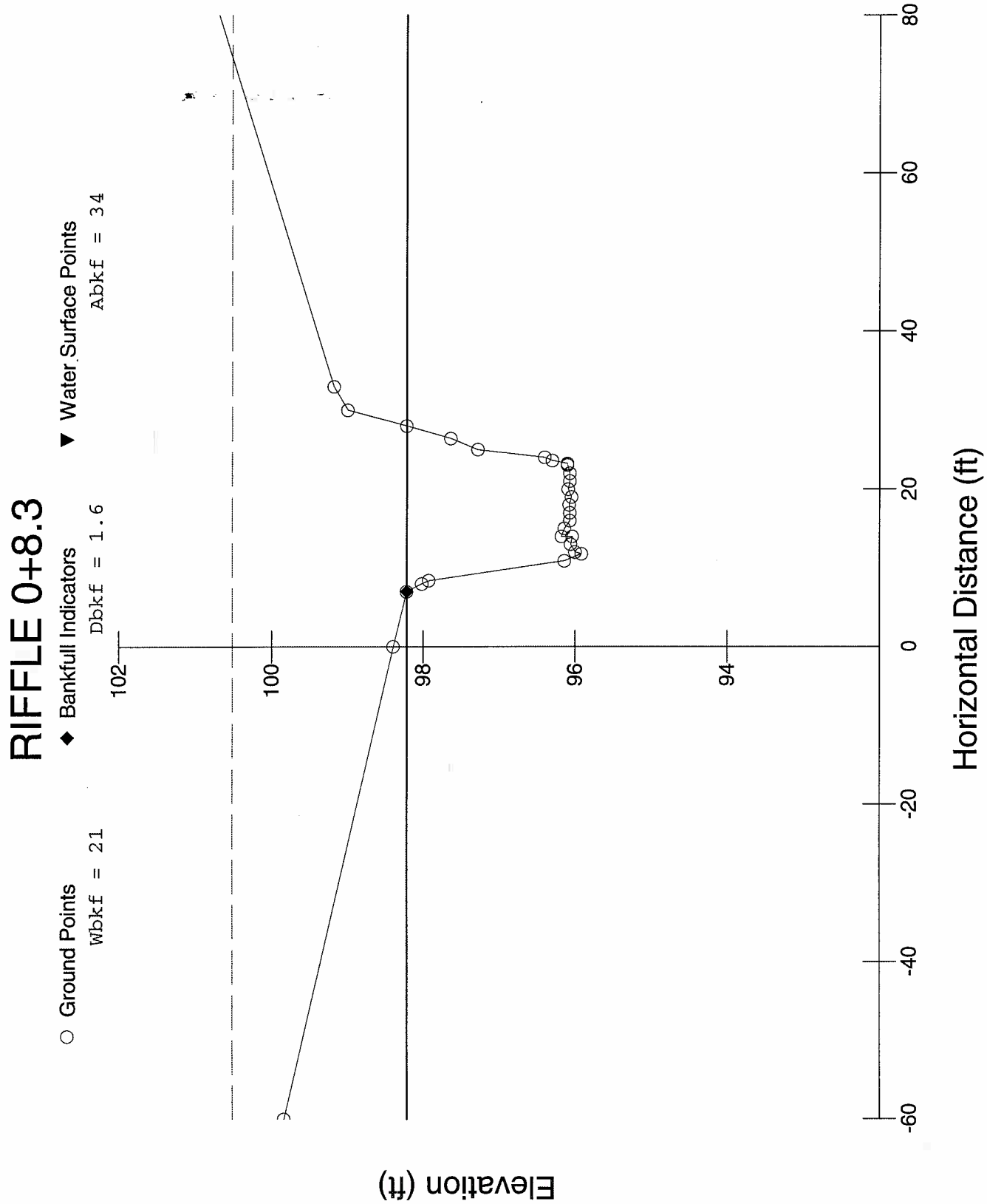
RIFFLE 0+8.3
○ Ground Points
Wbkf = 21
◆ Bankfull Indicators
Dbkf = 1.6
▼ Water Surface Points
Abkf = 34
Elevation (ft)
102
100
98
96
94
-60
-40
-20
0
20
40
60
80
Horizontal Distance (ft)

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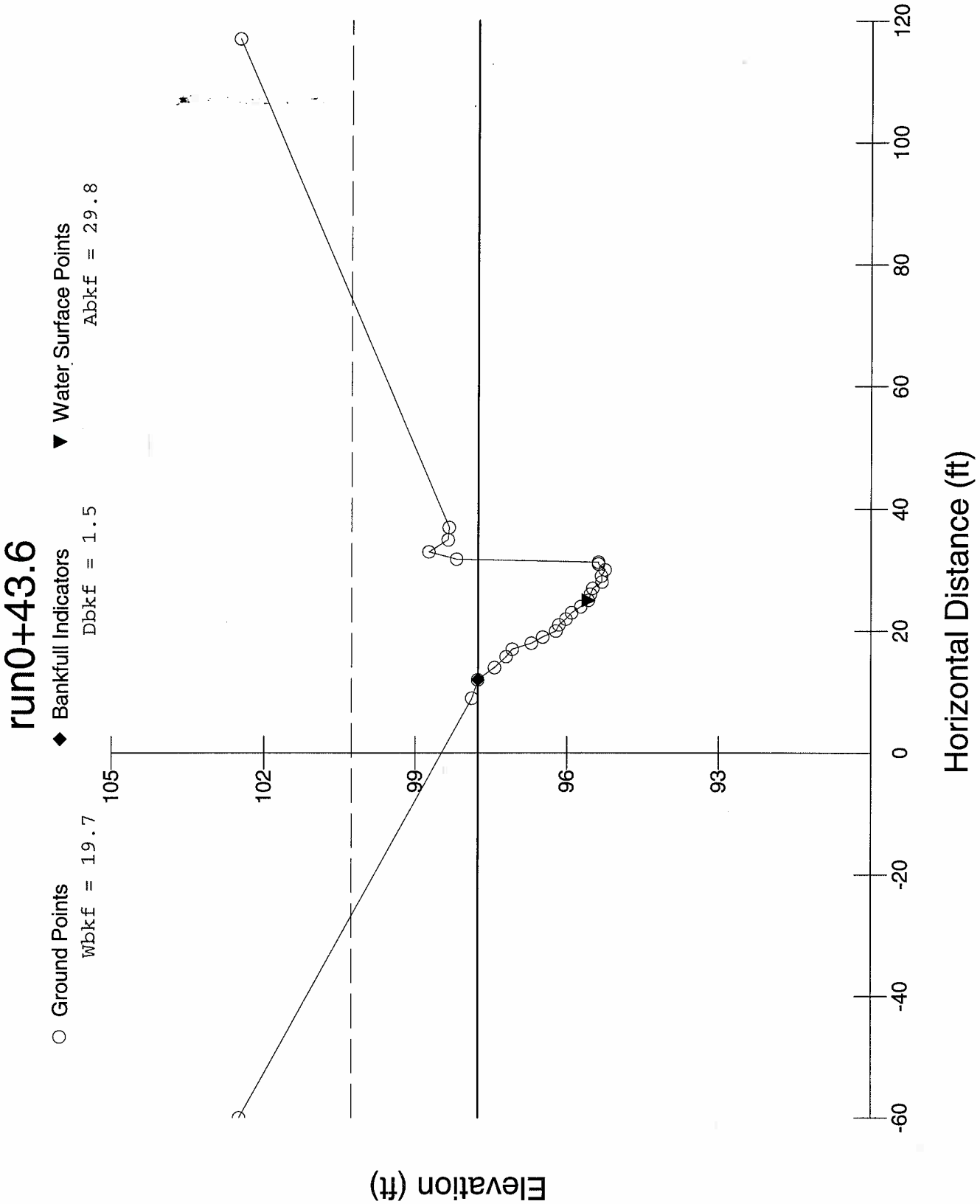
run0+43.6
○ Ground Points
Wbkf = 19.7
◆ Bankfull Indicators
Dbkf = 1.5
▼ Water Surface Points
Abkf = 29.8
Elevation (ft)
105
102
99
96
93
Horizontal Distance (ft)
-60
-40
-20
0
20
40
60
80
100
120

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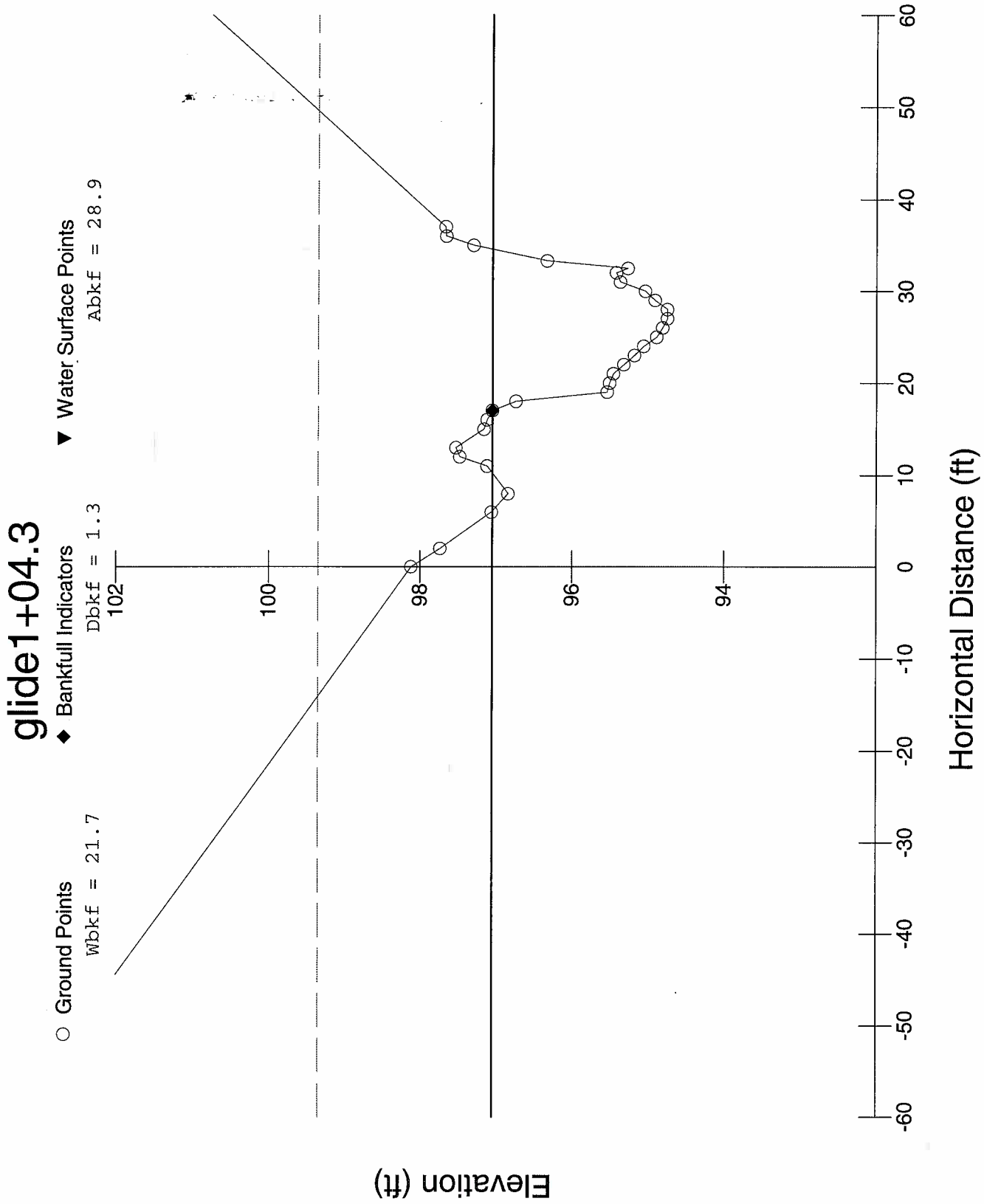
glide1+04.3
○ Ground Points
◆ Bankfull Indicators
▼ Water Surface Points
Wbkf = 21.7
Dbkf = 1.3
Abkf = 28.9
Elevation (ft)
102
100
98
96
94
Horizontal Distance (ft)
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60

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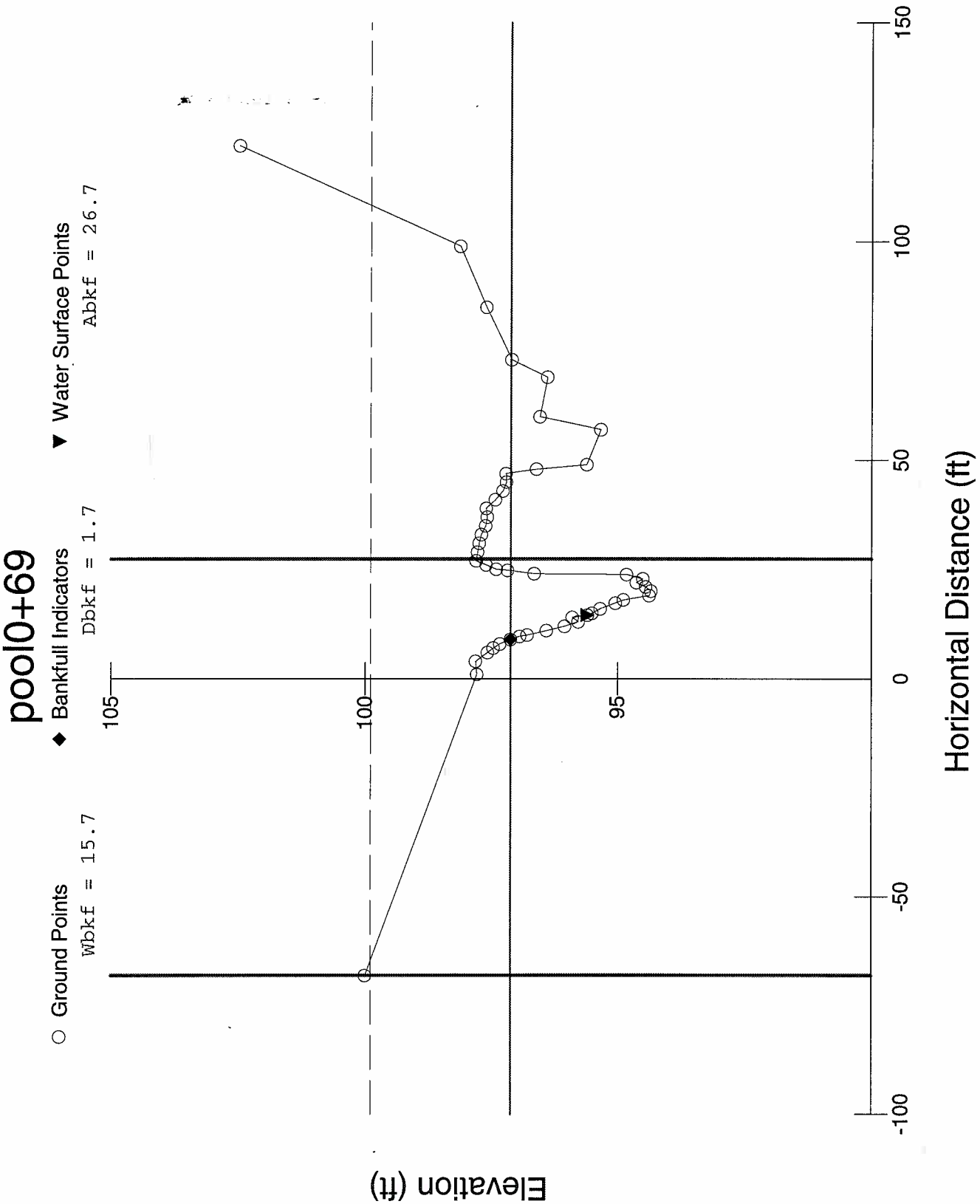
9/18/07


pool0+69
○ Ground Points
Wbkf = 15.7
◆ Bankfull Indicators
Dbkf = 1.7
▼ Water Surface Points
Abkf = 26.7
105
100
95
Elevation (ft)
150
100
50
0
-50
-100
Horizontal Distance (ft)

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9/18/07

Worksheet 5-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen and Silvey, 2005).

Stream: **Macgruder, Reach - Reach 1** Location:

Observers: **Team #1** Date: **9/18/2007** Valley Type: **VIII** Stream Type: **C 4**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	1.62	ft	Riffle Width (W_{bkf})	21	ft	Riffle Area (A_{bkf})	34.03	ft^2
Mean Pool Depth (d_{bkfp})	1.75	ft	Pool Width (W_{bkfp})	15.71	ft	Pool Area (A_{bkfp})	27.42	ft^2
Mean Pool Depth/Mean Riffle Depth	1.08	d_{bkfp}/d_{bkf}	Pool Width/Riffle Width	0.75	W_{bkfp}/W_{bkf}	Pool Area / Riffle Area	0.81	A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{mbkf})	2.28	ft	Max Pool Depth (d_{mbkfp})	3.56	ft	Max Riffle Depth/Mean Riffle Depth	1.41	
Max Pool Depth/Mean Riffle Depth	2.198					Point Bar Slope	17	
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				4.12	ft/s	Estimation Method	MANNINGS	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				140.08	cfs	Drainage Area	1.1	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Length (Lm)	160	160	160	ft	Meander Length Ratio (Lm/W_{bkf})	7.62	7.62	7.62
Radius of Curvature (Rc)	31	14	48	ft	Radius of Curvature/Riffle Width (Rc/W_{bkf})	1.48	0.67	2.29
Belt Width (W_{blt})	42.5	34	51	ft	Meander Width Ratio (W_{blt}/W_{bkf})	2.02	1.62	2.43
Individual Pool Length	11.1	7.71	13.6	ft	Pool Length/Riffle Width	0.53	0.37	0.65
Pool to Pool Spacing	35.4	32.6	39.3	ft	Pool to Pool Spacing/Riffle Width	1.68	1.55	1.87
Riffle Length	51.5	31.1	71.9	ft	Riffle Length/Riffle Width	2.45	1.48	3.43

Channel Profile

Valley Slope (VS)	0.009	ft/ft	Average Water Surface Slope (S)	0.007	ft/ft	Sinuosity (VS/S)	1.29	
Stream Length (SL)	285.4	ft	Valley Length (VL)	153	ft	Sinuosity (SL/VL)	1.87	
Low Bank Height (LBH)	start 2.28 / end 2.31	ft	Max Riffle Depth	start 1.76 / end 1.7	ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	start 1.3 / end 1.36	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	0.020	0.019	0.021	ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif}/S)	2.820	2.677	2.963
Run Slope (S_{run})	0.026	0.026	0.026	ft/ft	Run Slope/Average Water Surface Slope (S_{run}/S)	3.659	3.659	3.659
Pool Slope (S_p)	0.002	0.001	0.004	ft/ft	Pool Slope/Average Water Surface Slope (S_p/S)	0.331	0.207	0.529
Glide Slope (S_g)	0.011	0.003	0.026	ft/ft	Glide Slope/Average Water Surface Slope (S_g/S)	1.563	0.464	3.674

Feature Midpoint[a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Riffle Depth (d_{rif})	2.28	2.08	2.47	ft	Riffle Depth/Mean Riffle Depth (d_{rif}/d_{bkf})	1.41	1.28	1.52
Run Depth (d_{run})	2.1	2.1	2.1	ft	Run Depth/Mean Riffle Depth (d_{run}/d_{bkf})	1.3	1.3	1.3
Pool Depth (d_p)	3.56	3.2	3.91	ft	Pool Depth/Mean Riffle Depth (d_p/d_{bkf})	2.2	1.98	2.41
Glide Depth (d_g)	2.54	2.44	2.62	ft	Glide Depth/Mean Riffle Depth (d_g/d_{bkf})	1.57	1.51	1.62

Channel Materials

	Reach[b]	Riffle[c]	Bar		Reach[b]	Riffle[c]	Bar	Protrusion Height[d]	
% Silt/Clay	6	0	0	D_{16}	6.62	6.27	3.32	0	mm
% Sand	4	7	11.22	D_{35}	17.89	10.75	8.73	0	mm
% Gravel	76	91	82.2	D_{50}	30.43	16	15.6	0	mm
% Cobble	14	2	6.58	D_{84}	61.47	37	50.1	0	mm
% Boulder	0	0	0	D_{95}	83.5	54.5	65.47	0	mm
% Bedrock	0	0	0	D_{100}	128	128	70	0	mm

a Min, max, mean depths are the average mid-point values except pools, which are taken at deepest part of pool.
b Composite sample of riffles and pools within the designated reach.
c Active bed of a riffle.
d Height of roughness feature above bed.

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Bankfull VELOCITY / DISCHARGE Estimates

Site	MCGRUDER		Location	MD	
Date	9·18·07	Stream Type	C4	Valley Type	8
Observers	GROUP 1		HUC		

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-section AREA	34	A_{bkf} (SqFt)	Bankfull Mean DEPTH	1.6	D_{bkf} (Ft)
Bankfull WIDTH	21	W_{bkf} (Ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	22.33	W_{Pbkf} (Ft)
D84 @ Riffle	37	Dia. (mm)	D84 mm / 304.8 =	0.12	D84 (Ft)
Bankfull SLOPE	0.007	S (Ft / Ft)	Hydraulic RADIUS A_{bkf} / W_{Pbkf}	1.52	R (Ft)
Gravitational Acceleration	32.2	g (Ft /Sec^2)	Relative Roughness R (ft) / D84 (ft)	12.6	
Drainage AREA	1.1	DA (SqMi)	Shear Velocity $u^* = \sqrt{gRS}$	0.585	u* (Ft / Sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [\ 2.83 + 5.66\text{Log}\{ R / D84 \}\ ]u^*$		Ft / Sec		CFS
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness. $u = 1.4895 * R^{2/3} * S^{1/2} / n$ n = 0.037		Ft / Sec	175	CFS
2. Roughness Coefficient: $u = 1.4895 * R^{2/3} * S^{1/2} / n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39 S^{.38} R^{-.16}$ n = 0.[illegible] Note: This equation is for applications involving steep, step-pool, high boundary roughness, cobble-boulder-dominated stream systems; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	3.3	Ft / Sec	112	CFS
2. Roughness Coefficient: $u = 1.4895 * R^{2/3} * S^{1/2} / n$ c) Manning's 'n' from Stream Type n = 0.[illegible]		Ft / Sec		CFS
3. Other Methods, ie. Hydraulic Geometry (Hey, Darcy-Weisbach, Chezy C, etc.)	N/A	Ft / Sec	N/A	CFS
3. Other Methods, ie. Hydraulic Geometry (Hey, Darcy-Weisbach, Chezy C, etc.) DARCY	5	Ft / Sec	180	CFS
4. Continuity Equations: a) Regional Curves $u = Q / A$ Return Period for Bankfull Discharge Q = 2.65	2.65	Ft / Sec	90	CFS
4. Continuity Equations: b) USGS Gage Data $u = Q / A$	N/A	Ft / Sec	N/A	CFS

Options for using the D84 term in the **relative roughness relation** (R/D84), when using estimation method 1.

Option 1. For **sand-bed** channels: measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in feet) for the D84 term in estimation method 1.

Option 2. For **boulder-dominated** channels: measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an average boulder protrusion height (h_{bo} in feet) for the D84 term in estimation method 1.

Option 3. For **bedrock-dominated** channels: measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D84 term in estimation method 1.

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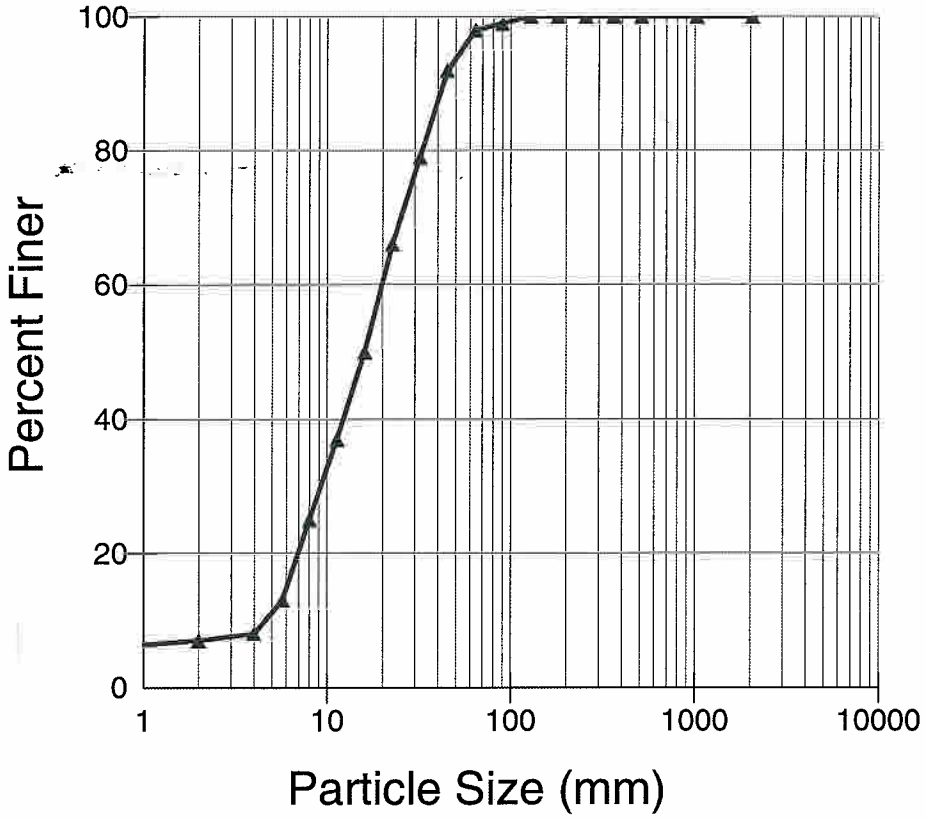
River Name: Macgruder
Reach Name: Reach 1
Sample Name: Riffle
Survey Date: 09/19/2007

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	0	0.00	0.00
0.062 - 0.125	0	0.00	0.00
0.125 - 0.25	0	0.00	0.00
0.25 - 0.50	0	0.00	0.00
0.50 - 1.0	0	0.00	0.00
1.0 - 2.0	7	7.00	7.00
2.0 - 4.0	1	1.00	8.00
4.0 - 5.7	5	5.00	13.00
5.7 - 8.0	12	12.00	25.00
8.0 - 11.3	12	12.00	37.00
11.3 - 16.0	13	13.00	50.00
16.0 - 22.6	16	16.00	66.00
22.6 - 32.0	13	13.00	79.00
32 - 45	13	13.00	92.00
45 - 64	6	6.00	98.00
64 - 90	1	1.00	99.00
90 - 128	1	1.00	100.00
128 - 180	0	0.00	100.00
180 - 256	0	0.00	100.00
256 - 362	0	0.00	100.00
362 - 512	0	0.00	100.00
512 - 1024	0	0.00	100.00
1024 - 2048	0	0.00	100.00
Bedrock	0	0.00	100.00

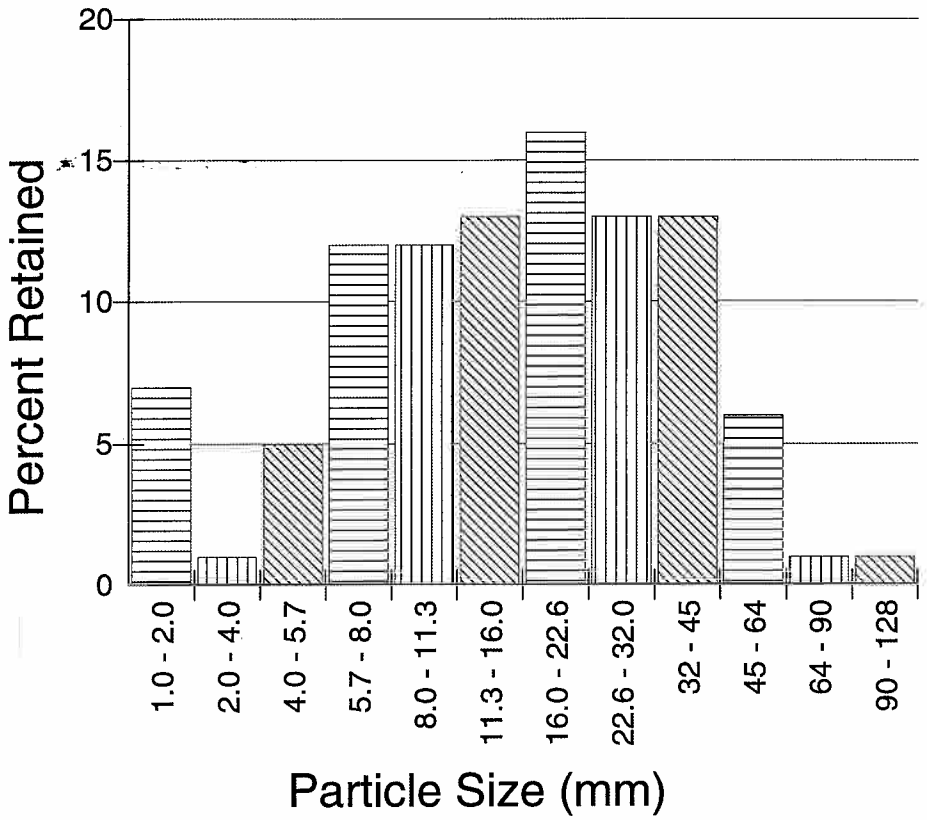
D16 (mm)	6.27
D35 (mm)	10.75
D50 (mm)	16
D84 (mm)	37
D95 (mm)	54.5
D100 (mm)	128
Silt/Clay (%)	0
Sand (%)	7
Gravel (%)	91
Cobble (%)	2
Boulder (%)	0
Bedrock (%)	0

Total Particles = 100.

Riffle


Percent Finer
100
80
60
40
20
0
1
10
100
1000
10000
Particle Size (mm)

Riffle


20
15
10
5
0
Percent Retained
1.0 - 2.0
2.0 - 4.0
4.0 - 5.7
5.7 - 8.0
8.0 - 11.3
11.3 - 16.0
16.0 - 22.6
22.6 - 32.0
32 - 45
45 - 64
64 - 90
90 - 128
Particle Size (mm)

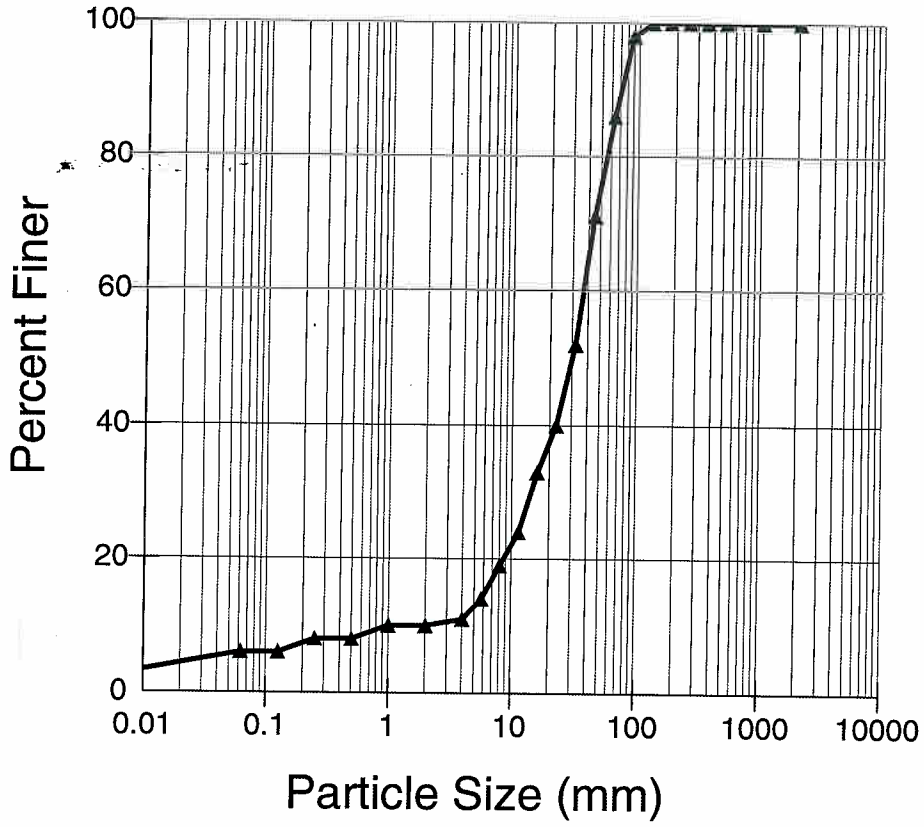
River Name: Macgruder
Reach Name: Reach 1
Sample Name: Reach Average
Survey Date: 09/19/2007

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	6	6.00	6.00
0.062 - 0.125	0	0.00	6.00
0.125 - 0.25	2	2.00	8.00
0.25 - 0.50	0	0.00	8.00
0.50 - 1.0	2	2.00	10.00
1.0 - 2.0	0	0.00	10.00
2.0 - 4.0	1	1.00	11.00
4.0 - 5.7	3	3.00	14.00
5.7 - 8.0	5	5.00	19.00
8.0 - 11.3	5	5.00	24.00
11.3 - 16.0	9	9.00	33.00
16.0 - 22.6	7	7.00	40.00
22.6 - 32.0	12	12.00	52.00
32 - 45	19	19.00	71.00
45 - 64	15	15.00	86.00
64 - 90	12	12.00	98.00
90 - 128	2	2.00	100.00
128 - 180	0	0.00	100.00
180 - 256	0	0.00	100.00
256 - 362	0	0.00	100.00
362 - 512	0	0.00	100.00
512 - 1024	0	0.00	100.00
1024 - 2048	0	0.00	100.00
Bedrock	0	0.00	100.00

D16 (mm)	6.62
D35 (mm)	17.89
D50 (mm)	30.43
D84 (mm)	61.47
D95 (mm)	83.5
D100 (mm)	128
Silt/Clay (%)	6
Sand (%)	4
Gravel (%)	76
Cobble (%)	14
Boulder (%)	0
Bedrock (%)	0

Total Particles = 100.

Reach Average



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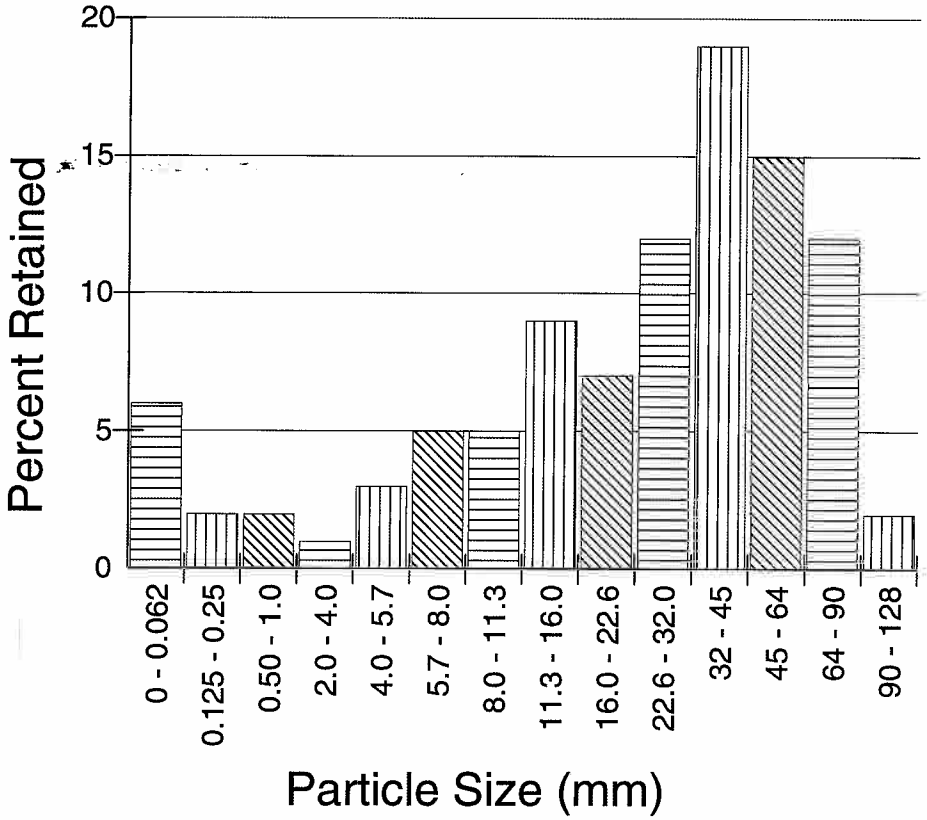
Reach Average

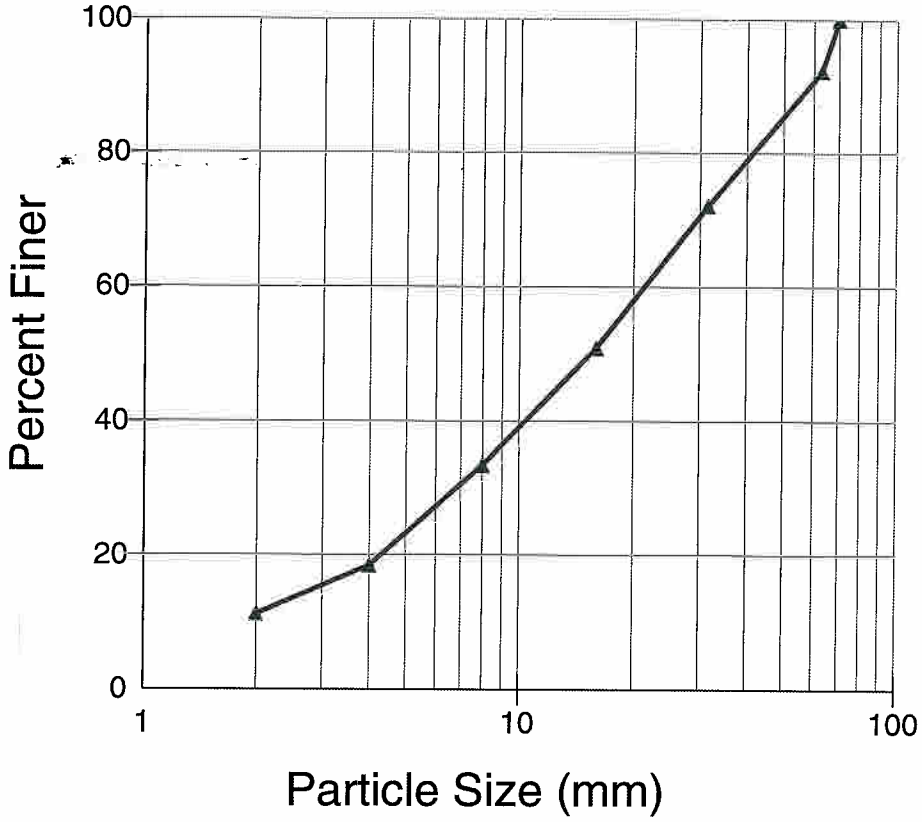


River Name: Macgruder
Reach Name: Reach 1
Sample Name: Bar Sample
Survey Date: 09/19/2007

SIEVE (mm)	NET WT
63	1.6
31.5	8.1
16	8.5
8	7
4	6
2	2.9
PAN	4.5
D16 (mm)	3.32
D35 (mm)	8.73
D50 (mm)	15.6
D84 (mm)	50.1
D95 (mm)	65.47
D100 (mm)	70
Silt/Clay (%)	0
Sand (%)	11.22
Gravel (%)	82.2
Cobble (%)	6.58
Boulder (%)	0
Bedrock (%)	0

Total Weight = 40.1000.

Bar Sample



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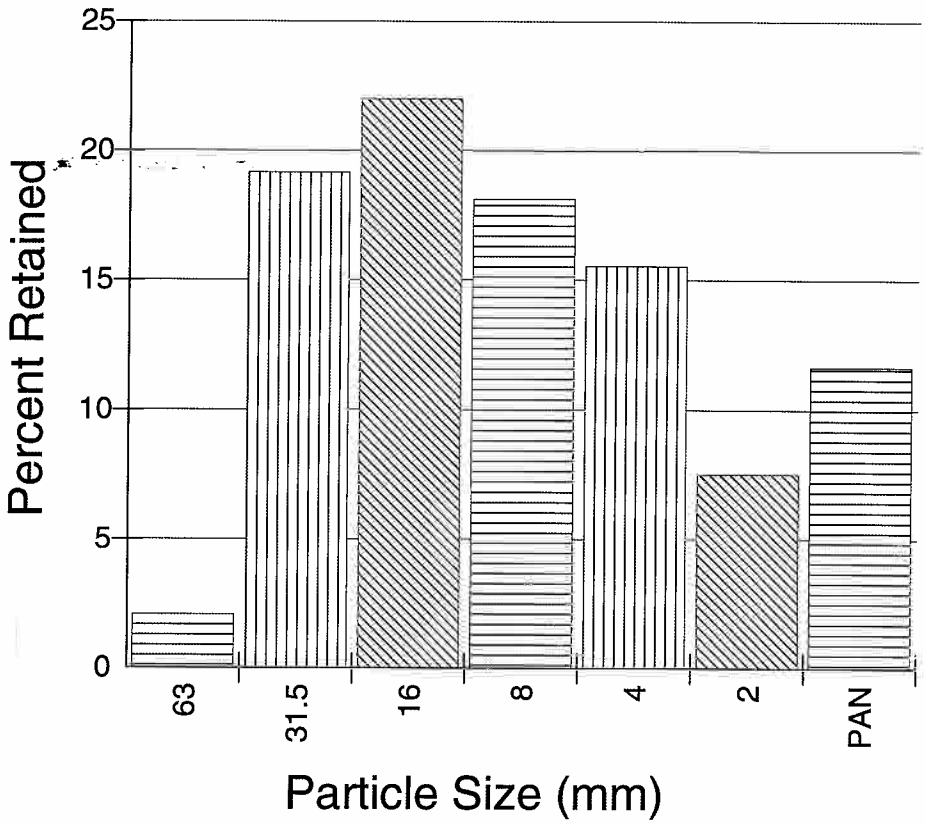
Bar Sample



Worksheet 5-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen and Silvey, 2005).

Stream:	**Macgruder, Reach - Reach 1**				
Basin:		Drainage Area:	**704** acres	**1.1**	mi^2
Location:					
Twp.&Rge:	**;**		Sec.&Qtr.: **;**		
Cross-Section Monuments (Lat./Long.):	**0 Lat / 0 Long**			Date:	**9/18/2007**
Observers:	**Team #1**			Valley Type:	VIII

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	17.59	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	1.31	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	22.99	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	13.43	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	1.72	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	78.6	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	4.47	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	30.43	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	0.007	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	1.29	

Stream Type C 4 (See **Figure 2-14**)

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TEAM 1
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River Name: Macgruder
Reach Name: Reach 1 <-- This is a Reference Reach
Drainage Area: 1.1 sq mi
State: Maryland
County: Montgomery
Latitude: 0
Longitude: 0
Survey Date: 09/18/2007

Classification Data

Valley Type:	Type VIII	
Valley Slope:	0.009	ft/ft
Number of Channels:	Single	
Width:	17.59	ft
Mean Depth:	1.31	ft
Flood-Prone Width:	78.6	ft
Channel Materials D50:	30.43	mm
Water Surface Slope:	0	ft/ft
Sinuosity:	1.29	
Discharge:	140.08	cfs
Velocity:	4.12	fps
Cross Sectional Area:	22.99	sq ft
Entrenchment Ratio:	4.47	
Width to Depth Ratio:	13.43	
Rosgen Stream Classification:	C 4	

RIVERMORPH PFANKUCH SUMMARY

River Name: Macgruder
Reach Name: Reach 1
Survey Date: 09/19/2007

Upper Bank

Landform Slope:	2
Mass Wasting:	3
Debris Jam Potential:	6
Vegetative Protection:	5

Lower Bank

Channel Capacity:	1
Bank Rock Content:	3
Obstructions to Flow:	3
Cutting:	8
Deposition:	6

Channel Bottom

Rock Angularity:	1
Brightness:	2
Consolidation of Particles:	5
Bottom Size Distribution:	6
Scouring and Deposition:	12
Aquatic Vegetation:	3

Channel Stability Evaluation

Sediment Supply:	
Stream Bed Stability:	
W/D Condition:	Normal
Stream Type:	C4

Rating - 66
Condition - Good

Worksheet 5-10. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	Macgruder, Reach - Reach 1			Location:			
Graph Used:		Total Bank Length (ft): 283				Date: 9/18/2007	
Observers:		Valley Type: VIII				Stream Type: C 4	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Station (ft)	BEHI rating (Worksheet 5-8) (adjective)	NBS rating (Worksheet 5-9) (adjective)	Bank erosion rate (Figure 5-38 or 5-39) (ft/yr)	Length of bank (ft)	Study bank height (ft)	Erosion subtotal [(4)x(5)x(6)] (ft^3/yr)	Erosion Rate (tons/yr/ft) {[(7)/27] x 1.3 / (5)}
1. Root Density @	Moderate	Low	0.1209375	64	1.5	11.61	0.01
2. Root density @	Moderate	Low	0.12	66	1.5	11.88	0.01
3. Roots density	Very Low	Low	0.0225	6	2	0.27	0.00
4. sta 107 to 84 L	Moderate	Moderate	0.3005217	23	2.5	17.28	0.04
5. STA 166 TO 118 L	Low	Moderate	0	48	2.3	0	0.00
6. sta 211 to 166 R	Moderate	Moderate	0.3	45	1.5	20.25	0.02
7. sta 254 to 244 L	Moderate	Low	0.1215	10	2	2.43	0.01
8. sta 268 to254 L	Moderate	Moderate	0.2967033	14	1.3	5.4	0.02
9. sta 60 to 64 R	Low	High	0.135	4	3	1.62	0.02
10. sta 80 to 0 R	High	High	0.9996429	84	3	251.91	0.14
11.							
12.							
13.							
14.							
15.							
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					Total erosion (ft^3/yr)	322.65	
Convert erosion in ft^3/yr to yds^3/yr {divide Total erosion (ft^3/yr) by 27}					Total erosion (yds^3/yr)	11.95	
Convert erosion in yds^3/yr to tons/yr {multiply Total erosion (yds^3/yr) by 1.3}					Total erosion (tons/yr)	15.54	
Calculate erosion per unit length of channel {divide Total erosion (tons/yr) by total length of stream (ft) surveyed}					Total erosion (tons/yr/ft)	0.0549	

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Magruder Branch Reference Reach Team 1 9/18/2007

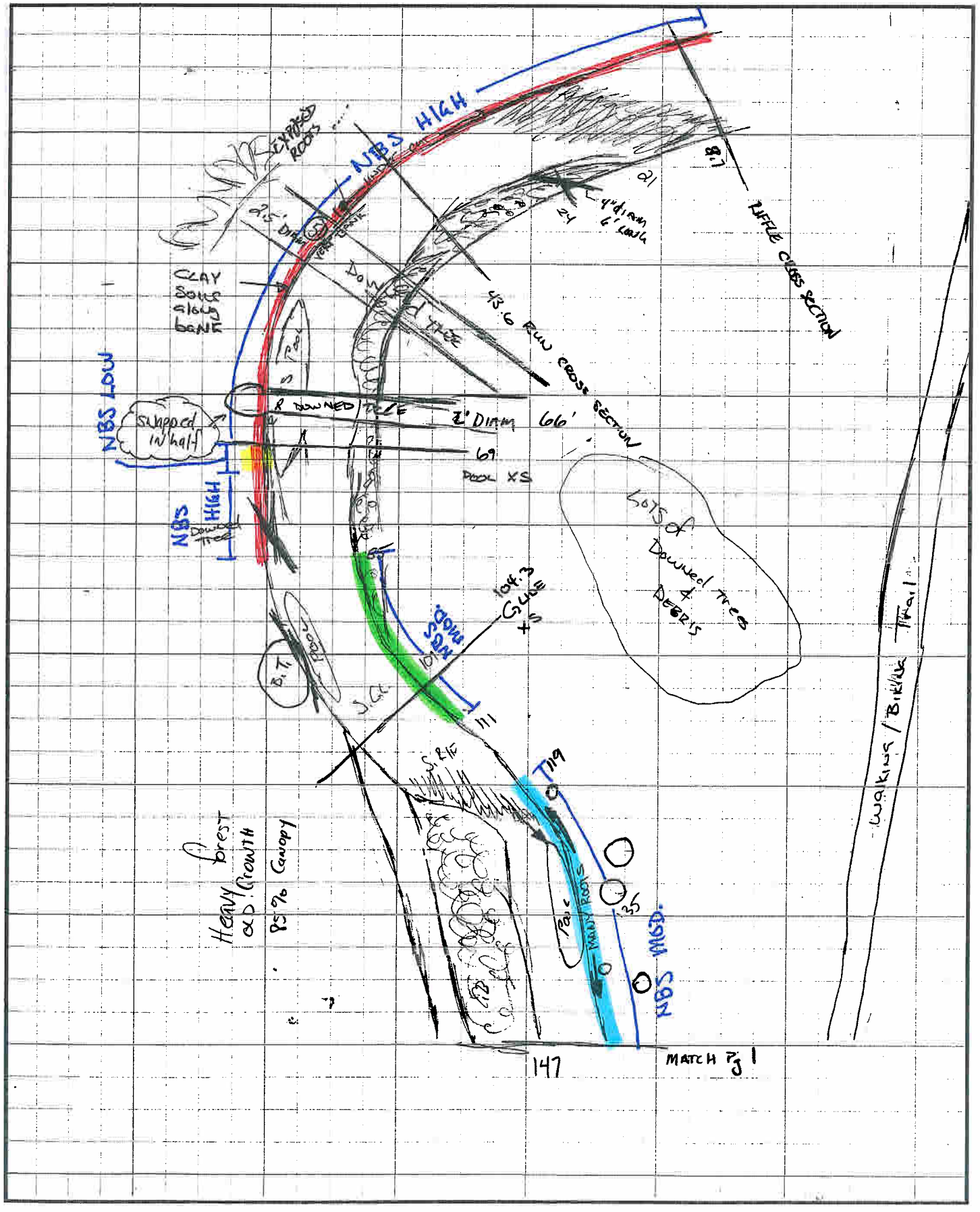
DMJM Harris

DMJM HARRIS | AECOM

JOB TITLE SKETCH PG 2

JOB NO. McGruder Branch CALCULATION NO. ORIGINATOR TEAM 1 DATE 9/17/07

SHEET OF REVIEWER DATE



Magruder Branch Reference Reach Team 1 9/18/2007

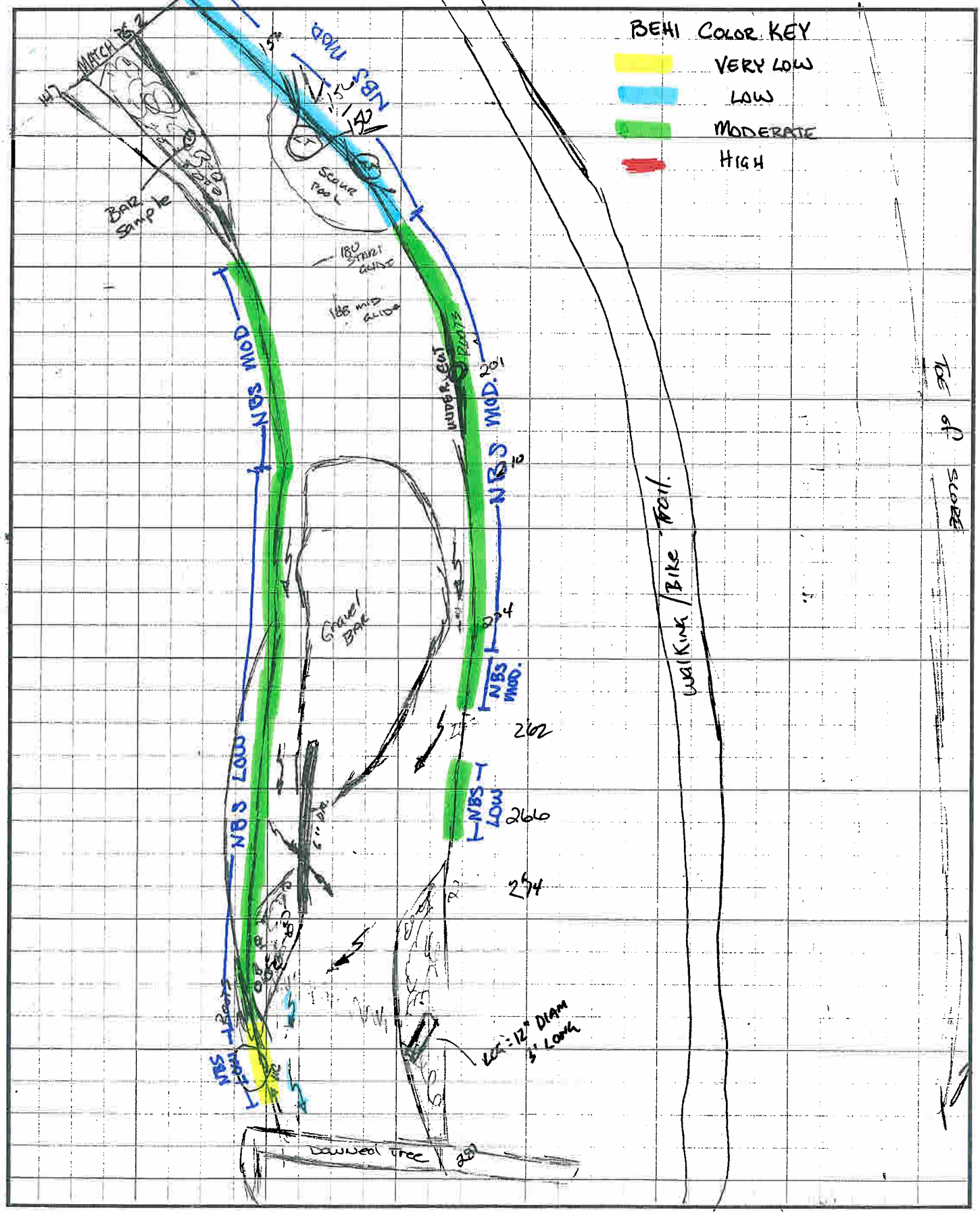
DMJM Harris

DMJM HARRIS | AECOM

JOB TITLE SKETCH PG 1

JOB NO. McGruder Branch CALCULATION NO. ORIGINATOR TEAM 1 DATE 9/17/07

SHEET OF REVIEWER DATE



a. Riparian Vegetation

Worksheet A-4. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: MAGRUDER R. Location: MD

Observers: TEAM 1 Reference reach: X Disturbed (impacted reach): Date: 9.18.07

Existing species composition: Tulip Poplar dominated Mixed Hardwood Forest

Potential species composition: Oak/Hickory dominated Mixed Hardwoods

	Riparian cover categories	Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	85 %	30 %	MAPLE	25
				ELM	13
				WHITE OAK	12
				RED OAK	12
				BLACK GUM	8
				TULIP POPLAR	50
					100%
2. Understory	Shrub layer		25 %	DOGWOOD	5
				IRONWOOD	5
				SPICE BUSH	10
				BLACKBERRY	5
				MULTI FLORAL ROSE	15
				ALDER	10
					100%
3. Ground level	Herbaceous		20 %	JEWEL WEED	5
				FERNS	10
				SMARTWEED	50
				POA	5
				CLEARWEED	10
				TAP. STILTGRASS	20
					100%
	Leaf or needle litter		10 %		
	Bare ground		15 %		

*Based on crown closure.
**Based on basal area to surface area.

Column total = 100%

Remarks:

Condition, vigor and/or usage of existing reach:

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b. Flow Regime

Worksheet A-5. Flow Regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: McGRUDER	Location: MD							
Observers: GROUP 1						Date: 9.18.07		
List ALL COMBINATIONS that APPLY.....	S	P	2	8				

General Category

E	Ephemeral stream channels: flows only in response to precipitation. Often used in conjunction with intermittent.
S	Subterranean stream channel: flows parallel to and near the surface for various seasons - a sub-surface flow that follows the stream bed.
I	Intermittent stream channel: one that flows only seasonally or sporadically. Surface sources involve springs, snowmelt, artificial controls, etc. Often this term is associated with flows that reappear along various locations of a reach then run subterranean.
P	Perennial stream channels: surface water persists yearlong.

Specific Category

1	Seasonal variation in streamflow dominated primarily by snowmelt runoff.
2	Seasonal variation in streamflow dominated primarily by stormflow runoff.
3	Uniform stage and associated streamflow due to spring-fed condition, backwater, etc.
4	Streamflow regulated by glacial melt.
5	Ice flows/ice torrents from ice dam breaches.
6	Alternating flow/backwater due to tidal influence.
7	Regulated streamflow due to diversions, dam release, dewatering, etc.
8	Altered due to development, such as urban streams, cut-over watersheds or vegetation conversions (forested to grassland) that change flow response to precipitation events.
9	Rain-on-snow generated runoff.

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c. Stream Size and Order

Worksheet A-6. Stream size/order categories for stratification by stream type.

Stream Size and Order			
Stream: MAGRUDER			
Location: MD			
Observers: TEAM 1			
Date: 9.18.07			
Stream Size Category and Order ☞			S4(2)
Category	**STREAM SIZE: Bankfull width**		**Check (✓) appropriate category**
	meters	**feet**	
S-1	0.305	<1	☐
S-2	0.3 – 1.5	1 – 5	☐
S-3	1.5 – 4.6	5 – 15	☐
S-4	4.6 – 9	15 – 30	☑
S-5	9 – 15	30 – 50	☐
S-6	15 – 22.8	50 – 75	☐
S-7	22.8 – 30.5	75 – 100	☐
S-8	30.5 – 46	100 – 150	☐
S-9	46 – 76	150 – 250	☐
S-10	76 – 107	250 – 350	☐
S-11	107 – 150	350 – 500	☐
S-12	150 – 305	500 – 1000	☐
S-13	>305	>1000	☐
Stream Order			
Add categories in parenthesis for specific stream order of reach. For example a third order stream with a bankfull width of 6.1 meters (20 feet) would be indexed as: S-4(3).			

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f. Channel Blockages

Worksheet A-9. Various categories of in-channel debris, dams and/or channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: Magruders Branch		Location: Montgomery Co. MD	
Observers: Team 1		Date: 9/18/07	
Description/extent		**Materials, which upon placement into the active channel or flood-prone area, may cause adjustments in channel dimensions or conditions due to influences on the existing flow regime.**	**Check (✓) all that apply**
D1	None	Minor amounts of small, floatable material.	☐
D2	Infrequent	Debris consists of small, easily moved, floatable material, e.g., leaves, needles, small limbs and twigs.	☑
D3	Moderate	Increasing frequency of small- to medium-sized material, such as large limbs, branches and small logs, that when accumulated, affect 10% or less of the active channel cross-section area.	☑
D4	Numerous	Significant build-up of medium- to large-sized materials, e.g., large limbs, branches, small logs or portions of trees that may occupy 10–30% of the active channel cross-section area.	☐
D5	Extensive	Debris "dams" of predominantly larger materials, e.g., branches, logs and trees, occupying 30–50% of the active channel cross-section area, often extending across the width of the active channel.	☐
D6	Dominating	Large, somewhat continuous debris "dams," extensive in nature and occupying over 50% of the active channel cross-section area. Such accumulations may divert water into the flood-prone areas and form fish migration barriers, even when flows are at less than bankfull.	☐
D7	Beaver dams: Few	An infrequent number of dams spaced such that normal streamflow and expected channel conditions exist in the reaches between dams.	☐
D8	Beaver dams: Frequent	Frequency of dams is such that backwater conditions exist for channel reaches between structures where streamflow velocities are reduced and channel dimensions or conditions are influenced.	☐
D9	Beaver dams: Abandoned	Numerous abandoned dams, many of which have filled with sediment and/or breached, initiating a series of channel adjustments, such as bank erosion, lateral migration, avulsion, aggradation and degradation.	☐
D10	Human influences	Structures, facilities or materials related to land uses or development located within the flood-prone area, such as diversions or low-head dams, controlled by-pass channels, velocity control structures and various transportation encroachments that have an influence on the existing flow regime, such that significant channel adjustments occur.	☐

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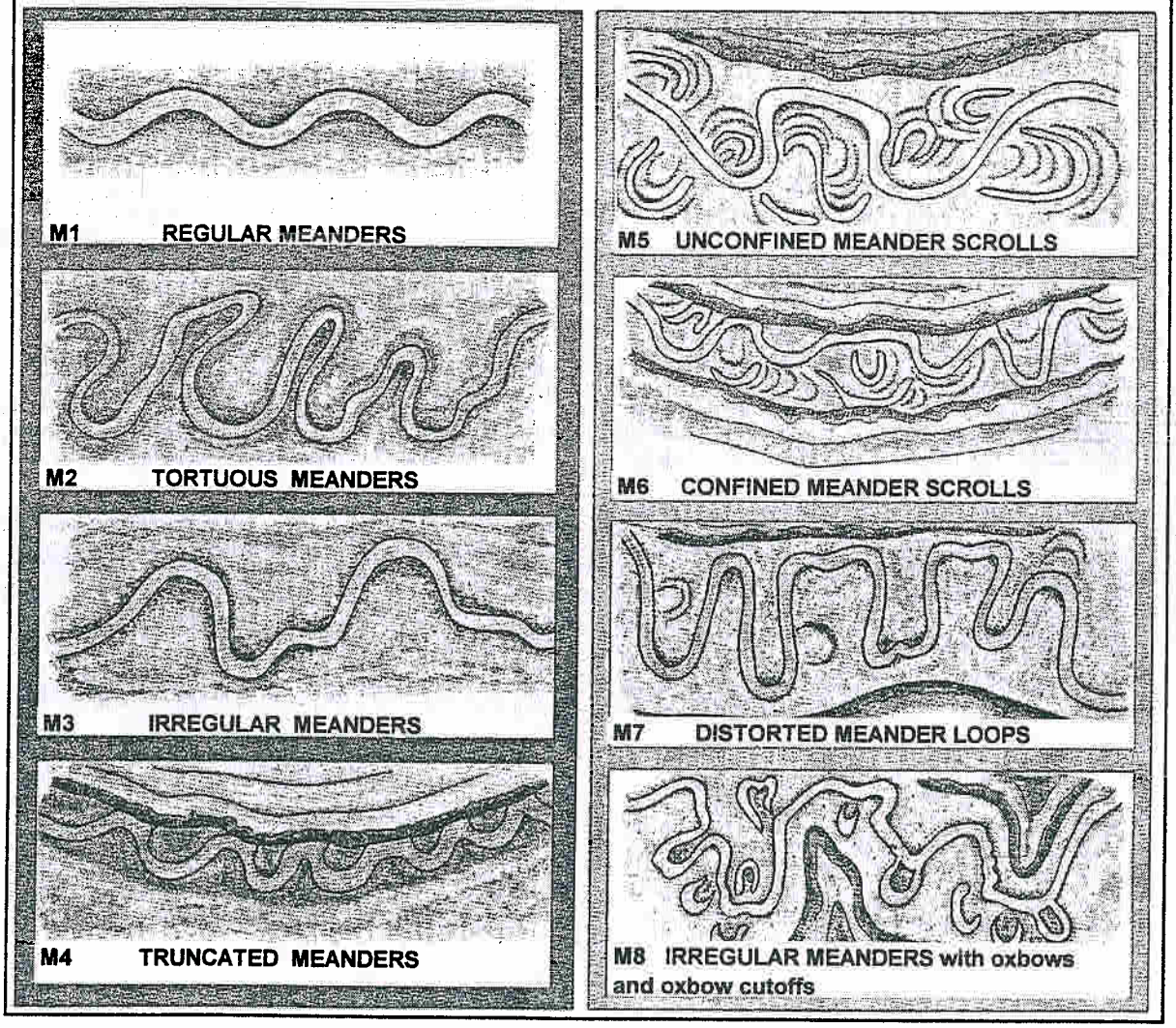
d. Meander Patterns

Worksheet A-7. Meander pattern relations used for interpretations for river stability.

Meander Patterns					
Stream: Magruder Branch		Reach: 1			
Observers: Team 1		Date: 9/18/07			
List ALL CATEGORIES that APPLY	M3				

Various Meander Pattern variables modified from Galay et al. (1973)



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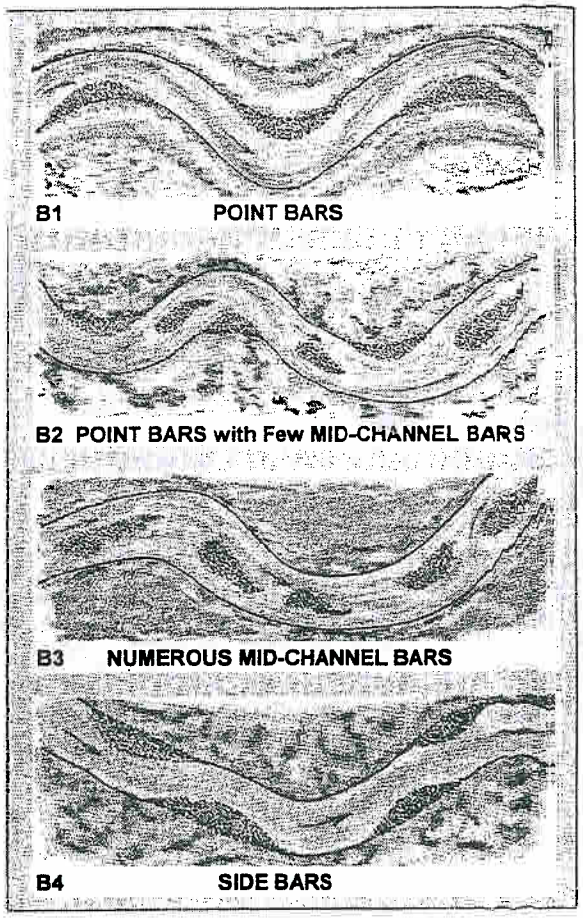
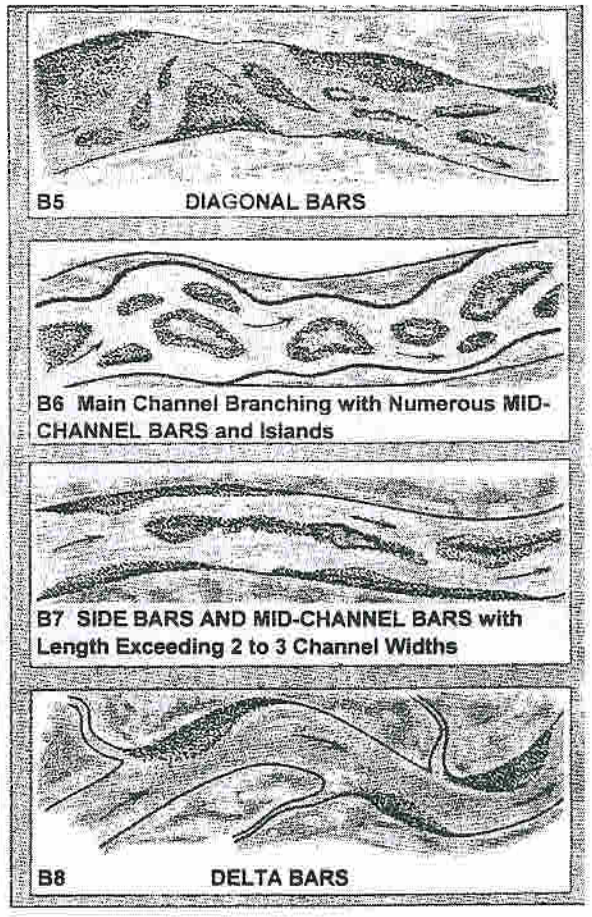
e. Depositional Patterns

Worksheet A-8. Depositional patterns used for stability assessment interpretations.

Depositional Patterns						
Stream: Macgruders			Reach: 1			
Observers: Team 1			Date: 9/18/07			
List ALL CATEGORIES that APPLY	B7					

Various Depositional Features modified from Galay et al. (1973)





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Worksheet 5-8. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating (Rosgen, 1996, 2001a). Use **Figure 5-19** with BEHI variables to determine BEHI score.

Stream:	**Macgruder, Reach - Reach 1**	Location:	
Station:	**Roots density @85%**	Observers:	
Date:	**09/18/07**	Stream Type: **C 4**	Valley Type: **VIII**

							BEHI Score (Fig. 5-19)
Study Bank Height / Bankfull Height (C)							
Study Bank Height (ft) =	2 (A)	Bankfull Height (ft) =	2 (B)	(A) / (B) =	1 (C)		1
Root Depth / Study Bank Height (E)							
Root Depth (ft) =	2 (D)	Study Bank Height (ft) =	2 (A)	(D) / (A) =	1 (E)		1
Weighted Root Density (G)							
Root Density as % =	85 (F)			(F) × (E) =	85 (G)		1.67
Bank Angle (H)							
Bank Angle as *Degrees* =	62 (H)						4.1
Surface Protection (I)							
Surface Protection as % =	85 (I)						1.67

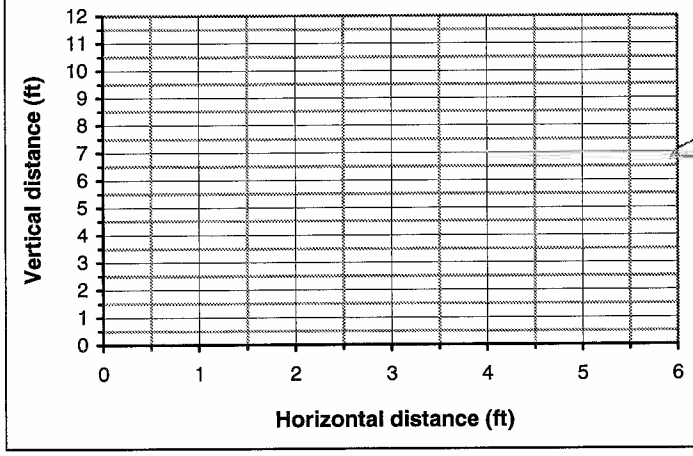
Bank Material Adjustment:

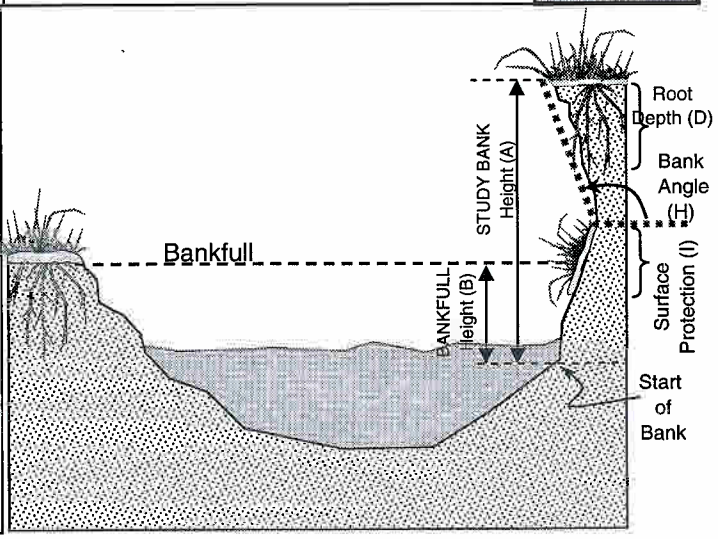
Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

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	Adjective Rating and Total Score	Very Low
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50		9.4

Bank Sketch





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Worksheet 5-8. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating (Rosgen, 1996, 2001a). Use **Figure 5-19** with BEHI variables to determine BEHI score.

Stream:	**Macgruder, Reach - Reach 1**	Location:	
Station:	**Root density @ 30%**	Observers:	
Date:	**09/18/07**	Stream Type: **C 4**	Valley Type: **VIII**

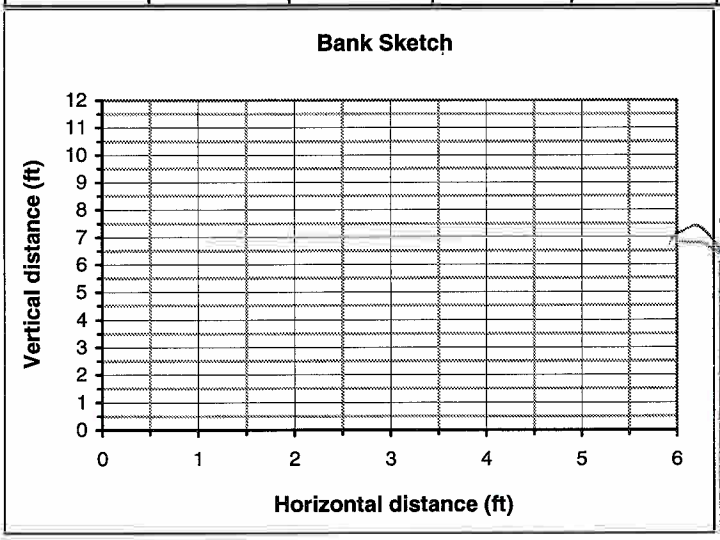
							BEHI Score (Fig. 5-19)
Study Bank Height / Bankfull Height (C)							
Study Bank Height (ft) =	1.5 (A)	Bankfull Height (ft) =	1.5 (B)	(A) / (B) =	1 (C)		1
Root Depth / Study Bank Height (E)							
Root Depth (ft) =	0.8 (D)	Study Bank Height (ft) =	1.5 (A)	(D) / (A) =	0.53333 (E)		3.75
Weighted Root Density (G)							
Root Density as % =	30 (F)			(F) x (E) =	16 (G)		7.76
Bank Angle (H)							
Bank Angle as *Degrees* =	64 (H)						4.3
Surface Protection (I)							
Surface Protection as % =	13 (I)						8.25

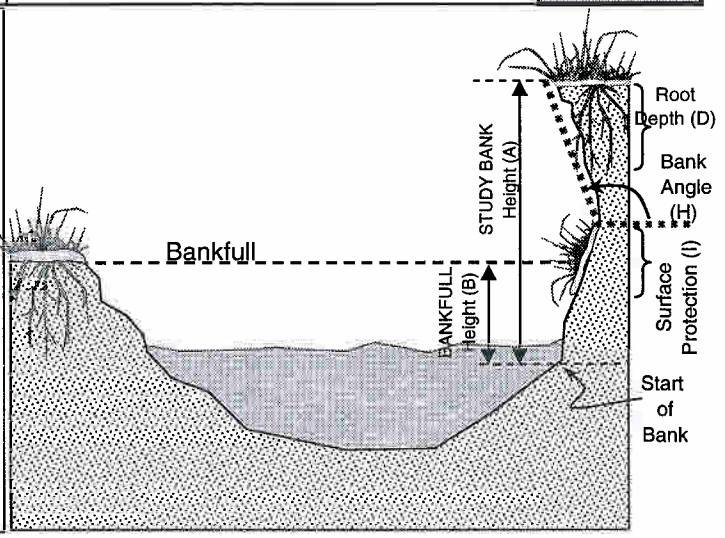
Bank Material Adjustment:

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	Adjective Rating and Total Score	Moderate
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50		25.1





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Worksheet 5-8. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating (Rosgen, 1996, 2001a). Use **Figure 5-19** with BEHI variables to determine BEHI score.

Stream:	**Macgruder, Reach - Reach 1**	Location:	
Station:	**Root Density @ 20%**	Observers:	
Date:	**09/18/07**	Stream Type: **C 4**	Valley Type: **VIII**

						BEHI Score (Fig. 5-19)
Study Bank Height / Bankfull Height (C)						
Study Bank Height (ft) =	1.5 (A)	Bankfull Height (ft) =	2 (B)	(A) / (B) =	0.75 (C)	1.25
Root Depth / Study Bank Height (E)						
Root Depth (ft) =	0.8 (D)	Study Bank Height (ft) =	1.5 (A)	(D) / (A) =	0.53333 (E)	3.75
Weighted Root Density (G)						
Root Density as % =	20 (F)			(F) × (E) =	10.6667 (G)	8.37
Bank Angle (H)						
Bank Angle as *Degrees* =	110 (H)					8.68
Surface Protection (I)						
Surface Protection as % =	33 (I)					5.66

Bank Material Adjustment:

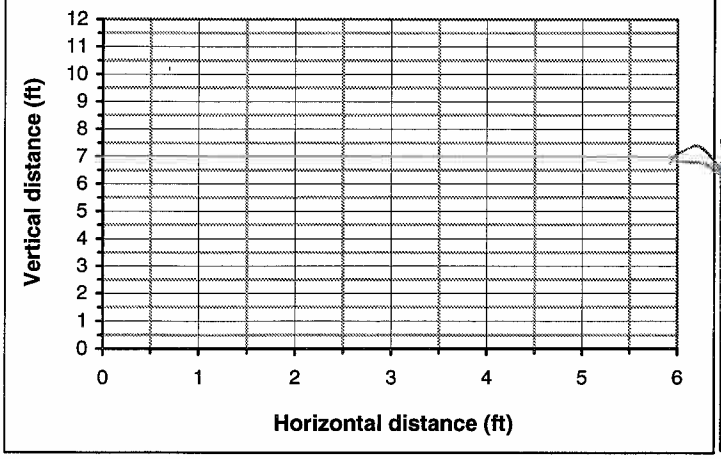
Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

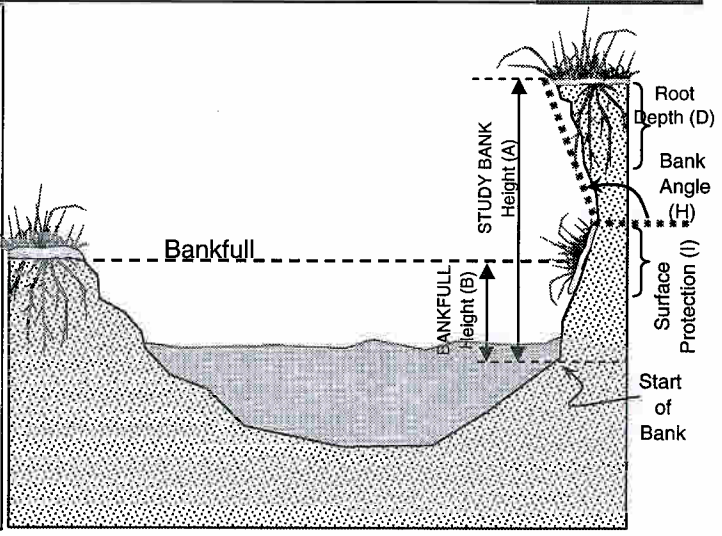
Bank Material Adjustment: 0

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	Adjective Rating and Total Score
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50	Moderate 27.7

Bank Sketch





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Worksheet 5-8. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating (Rosgen, 1996, 2001a). Use **Figure 5-19** with BEHI variables to determine BEHI score.

Stream:	**Macgruder, Reach - Reach 1**	Location:	
Station:	**sta 80 to 0 R**	Observers:	
Date:	**09/18/07**	Stream Type: **C 4**	Valley Type: **VIII**

							BEHI Score (Fig. 5-19)
Study Bank Height / Bankfull Height (C)							
Study Bank Height (ft) =	3 (A)	Bankfull Height (ft) =	1.6 (B)	(A) / (B) =	1.875 (C)		7.33
Root Depth / Study Bank Height (E)							
Root Depth (ft) =	1.4 (D)	Study Bank Height (ft) =	3 (A)	(D) / (A) =	0.46667 (E)		4.2
Weighted Root Density (G)							
Root Density as % =	25 (F)			(F) × (E) =	11.6667 (G)		8.26
Bank Angle (H)							
Bank Angle as *Degrees* =	90 (H)						7.9
Surface Protection (I)							
Surface Protection as % =	20 (I)						7.22

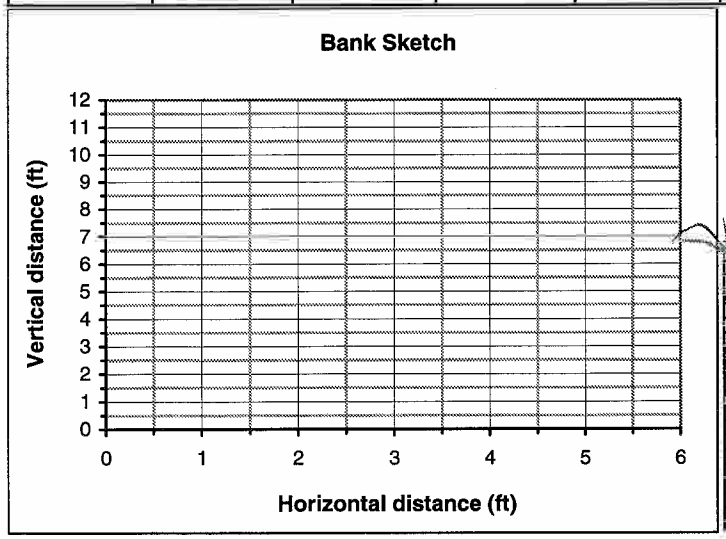
Bank Material Adjustment:

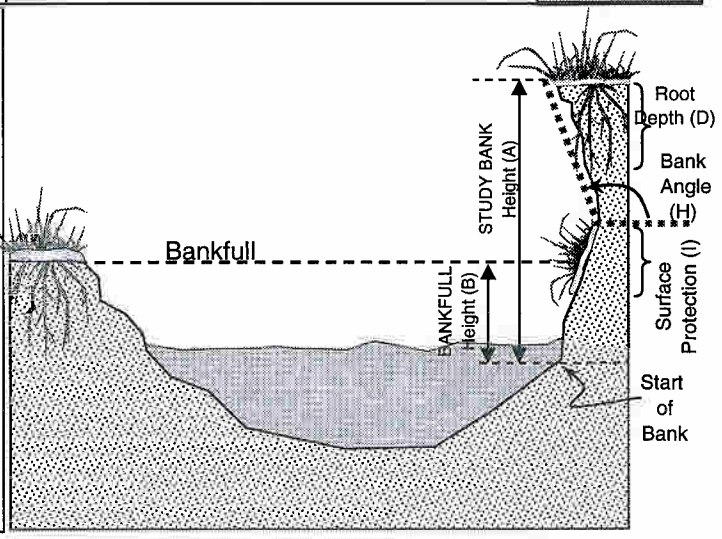
Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

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	Adjective Rating and Total Score
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50	High 34.9

Bank Sketch





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Worksheet 5-8. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating (Rosgen, 1996, 2001a). Use **Figure 5-19** with BEHI variables to determine BEHI score.

Stream:	**Macgruder, Reach - Reach 1**	Location:	
Station:	**sta 211 to 166 R**	Observers:	
Date:	**09/18/07**	Stream Type: **C 4**	Valley Type: **VIII**

							BEHI Score (Fig. 5-19)
Study Bank Height / Bankfull Height (C)							
Study Bank Height (ft) =	1.5 (A)	Bankfull Height (ft) =	2.3 (B)	(A) / (B) =	0.65217 (C)		2.15
Root Depth / Study Bank Height (E)							
Root Depth (ft) =	0.9 (D)	Study Bank Height (ft) =	1.5 (A)	(D) / (A) =	0.6 (E)		3.41
Weighted Root Density (G)							
Root Density as % =	30 (F)	(F) × (E) =	18 (G)				7.49
Bank Angle (H)							
Bank Angle as *Degrees* =	110 (H)						8.68
Surface Protection (I)							
Surface Protection as % =	40 (I)						5.11

Bank Material Adjustment:

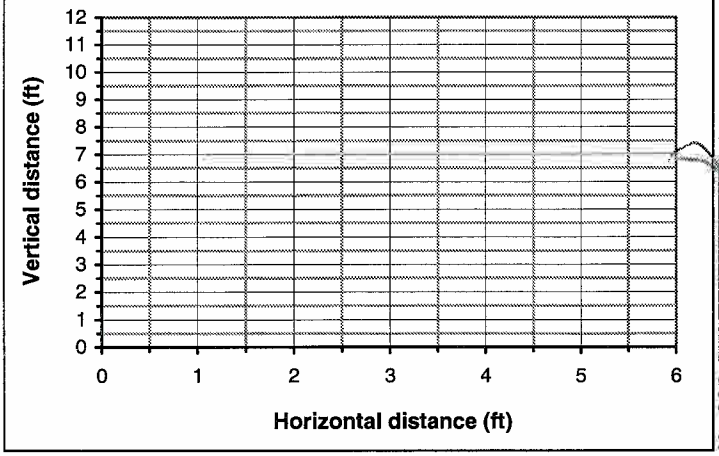
Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

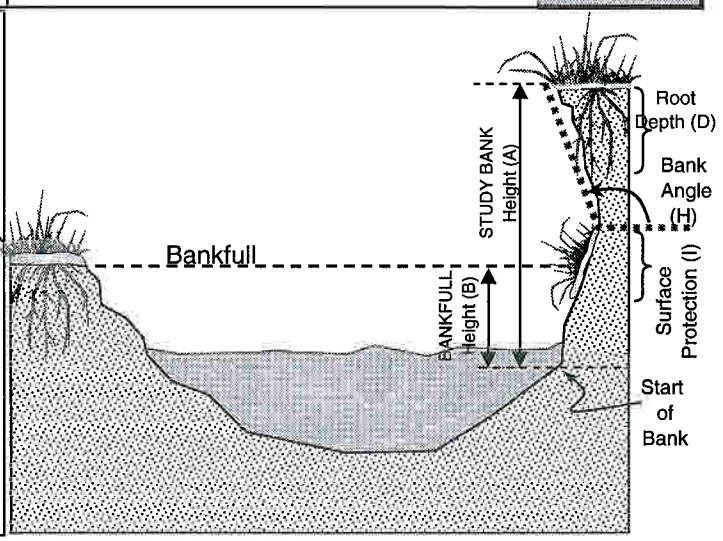
Bank Material Adjustment: 0

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	Adjective Rating and Total Score
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50	Moderate 26.8

Bank Sketch





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River Name: Macgruder
Reach Name: Reach 1
BEHI Name: sta 107 to 84 L
Survey Date: 09/19/2007

Bankfull Height: 0 ft
Bank Height: 2.5 ft
Root Depth: 0 ft
Root Density: 0 %
Bank Angle: 0 Degrees
Surface Protection: 0 %

Bank Material Adjustment: 0

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

NBS Method #5: Ratio of Near-Bank Maximum Bankfull Depth to Mean Bankfull Depth

NB Max Depth: 2.3 ft Mean Depth: 1.5 ft
Ratio: 1.53

BEHI Numerical Rating: 0
BEHI Adjective Rating:
NBS Numerical Rating: 1.53
NBS Adjective Rating: Moderate
Total Bank Length: 23 ft
Estimated Sediment Loss: 0.64 Cu Yds per Year
Estimated Sediment Loss: 0.83 Tons per Year

Macgruder Branch Reference Reach Team 1

River Name: Macgruder
Reach Name: Reach 1
BEHI Name: STA 166 TO 118 L
Survey Date: 09/19/2007

Bankfull Height: 0 ft
Bank Height: 2.3 ft
Root Depth: 0 ft
Root Density: 0 %
Bank Angle: 0 Degrees
Surface Protection: 0 %

Bank Material Adjustment: 0

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

NBS Method #5: Ratio of Near-Bank Maximum Bankfull Depth to Mean Bankfull Depth

NB Max Depth: 2.3 ft Mean Depth: 1.5 ft
Ratio: 1.53

BEHI Numerical Rating: 0
BEHI Adjective Rating:
NBS Numerical Rating: 1.53
NBS Adjective Rating: Moderate
Total Bank Length: 48 ft
Estimated Sediment Loss: 0 Cu Yds per Year
Estimated Sediment Loss: 0 Tons per Year

TEAM 1 RIVERMORPH BANK EROSION HAZARD INDEX (BEHI) 9/18/2007
9/18/07
Magruder Branch Reference Reach Team 1

River Name: Macgruder
Reach Name: Reach 1
BEHI Name: Roots density @85%
Survey Date: 09/19/2007

Bankfull Height: 2 ft
Bank Height: 2 ft
Root Depth: 2 ft
Root Density: 85 %
Bank Angle: 62 Degrees
Surface Protection: 85 %

Bank Material Adjustment: 0

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

NBS Method #5: Ratio of Near-Bank Maximum Bankfull Depth to Mean Bankfull Depth

NB Max Depth: 1.8 ft Mean Depth: 1.5 ft
Ratio: 1.20

BEHI Numerical Rating: 9.4
BEHI Adjective Rating: Very Low
NBS Numerical Rating: 1.20
NBS Adjective Rating: Low
Total Bank Length: 6 ft
Estimated Sediment Loss: 0.01 Cu Yds per Year
Estimated Sediment Loss: 0.01 Tons per Year

RIVERMORPH BANK EROSION HAZARD INDEX (BEHI)

River Name: Macgruder
Reach Name: Reach 1
BEHI Name: Root density @ 30%
Survey Date: 09/19/2007

Bankfull Height: 1.5 ft
Bank Height: 1.5 ft
Root Depth: 0.8 ft
Root Density: 30 %
Bank Angle: 64 Degrees
Surface Protection: 13 %

Bank Material Adjustment: 0

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

NBS Method #5: Ratio of Near-Bank Maximum Bankfull Depth to Mean Bankfull Depth

NB Max Depth: 1.83 ft Mean Depth: 1.5 ft
Ratio: 1.22

BEHI Numerical Rating: 25.1
BEHI Adjective Rating: Moderate
NBS Numerical Rating: 1.22
NBS Adjective Rating: Low
Total Bank Length: 66 ft
Estimated Sediment Loss: 0.44 Cu Yds per Year
Estimated Sediment Loss: 0.57 Tons per Year

River Name: Macgruder
Reach Name: Reach 1
BEHI Name: Root Density @ 20%
Survey Date: 09/19/2007

Bankfull Height: 2 ft
Bank Height: 1.5 ft
Root Depth: 0.8 ft
Root Density: 20 %
Bank Angle: 110 Degrees
Surface Protection: 33 %

Bank Material Adjustment: 0

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

NBS Method #5: Ratio of Near-Bank Maximum Bankfull Depth to Mean Bankfull Depth

NB Max Depth: 2 ft Mean Depth: 1.5 ft
Ratio: 1.33

BEHI Numerical Rating: 27.7
BEHI Adjective Rating: Moderate
NBS Numerical Rating: 1.33
NBS Adjective Rating: Low
Total Bank Length: 64 ft
Estimated Sediment Loss: 0.43 Cu Yds per Year
Estimated Sediment Loss: 0.56 Tons per Year

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RIVERMORPH BANK EROSION HAZARD INDEX (BEHI)

River Name: Macgruder
Reach Name: Reach 1
BEHI Name: sta 268 to254 L
Survey Date: 09/19/2007

Bankfull Height: 0 ft
Bank Height: 1.3 ft
Root Depth: 0 ft
Root Density: 0 %
Bank Angle: 0 Degrees
Surface Protection: 0 %

Bank Material Adjustment: 0

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

NBS Method #5: Ratio of Near-Bank Maximum Bankfull Depth to Mean Bankfull Depth

NB Max Depth: 2.3 ft Mean Depth: 1.5 ft
Ratio: 1.53

BEHI Numerical Rating: 0
BEHI Adjective Rating:
NBS Numerical Rating: 1.53
NBS Adjective Rating: Moderate
Total Bank Length: 14 ft
Estimated Sediment Loss: 0.2 Cu Yds per Year
Estimated Sediment Loss: 0.26 Tons per Year

River Name: Macgruder
Reach Name: Reach 1
BEHI Name: sta 254 to 244 L
Survey Date: 09/19/2007

Bankfull Height: 0 ft
Bank Height: 2 ft
Root Depth: 0 ft
Root Density: 0 %
Bank Angle: 0 Degrees
Surface Protection: 0 %

Bank Material Adjustment: 0

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

NBS Method #5: Ratio of Near-Bank Maximum Bankfull Depth to Mean Bankfull Depth

NB Max Depth: 1.8 ft Mean Depth: 1.5 ft
Ratio: 1.20

BEHI Numerical Rating: 0
BEHI Adjective Rating:
NBS Numerical Rating: 1.20
NBS Adjective Rating: Low
Total Bank Length: 10 ft
Estimated Sediment Loss: 0.09 Cu Yds per Year
Estimated Sediment Loss: 0.12 Tons per Year

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RIVERMORPH BANK EROSION HAZARD INDEX (BEHI)

River Name: Macgruder
Reach Name: Reach 1
BEHI Name: sta 211 to 166 R
Survey Date: 09/19/2007

Bankfull Height: 2.3 ft
Bank Height: 1.5 ft
Root Depth: 0.9 ft
Root Density: 30 %
Bank Angle: 110 Degrees
Surface Protection: 40 %

Bank Material Adjustment: 0

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

NBS Method #5: Ratio of Near-Bank Maximum Bankfull Depth to Mean Bankfull Depth

NB Max Depth: 2.3 ft Mean Depth: 1.5 ft
Ratio: 1.53

BEHI Numerical Rating: 26.8
BEHI Adjective Rating: Moderate
NBS Numerical Rating: 1.53
NBS Adjective Rating: Moderate
Total Bank Length: 45 ft
Estimated Sediment Loss: 0.75 Cu Yds per Year
Estimated Sediment Loss: 0.98 Tons per Year

TEAM 1 RIVERMORPH BANK EROSION HARZARD INDEX (BEHI)
9/18/07 Magruder Branch Reference Reach Team 1 9/18/2007

River Name: Macgruder
Reach Name: Reach 1
BEHI Name: sta 80 to 0 R
Survey Date: 09/19/2007

Bankfull Height: 1.6 ft
Bank Height: 3 ft
Root Depth: 1.4 ft
Root Density: 25 %
Bank Angle: 90 Degrees
Surface Protection: 20 %

Bank Material Adjustment: 0

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Yellowstone

NBS Method #5: Ratio of Near-Bank Maximum Bankfull Depth to Mean Bankfull Depth

NB Max Depth: 3 ft Mean Depth: 1.6 ft
Ratio: 1.88

BEHI Numerical Rating: 34.9
BEHI Adjective Rating: High
NBS Numerical Rating: 1.88
NBS Adjective Rating: High
Total Bank Length: 84 ft
Estimated Sediment Loss: 9.33 Cu Yds per Year
Estimated Sediment Loss: 12.13 Tons per Year

TEAM 1 RIVERMORPH BANK EROSION HAZARD INDEX (BEHI) 9/18/2007
9/18/07

Macgruder Branch Reference Reach Team 1

River Name: Macgruder
Reach Name: Reach 1
BEHI Name: sta 60 to 64 R
Survey Date: 09/19/2007

Bankfull Height: 0 ft
Bank Height: 3 ft
Root Depth: 0 ft
Root Density: 0 %
Bank Angle: 0 Degrees
Surface Protection: 0 %

Bank Material Adjustment: 0

Bank Stratification Adjustment: None 0

Erosion Loss Curve: Colorado

NBS Method #5: Ratio of Near-Bank Maximum Bankfull Depth to Mean Bankfull Depth

NB Max Depth: 3 ft Mean Depth: 1.6 ft
Ratio: 1.88

BEHI Numerical Rating: 0
BEHI Adjective Rating:
NBS Numerical Rating: 1.88
NBS Adjective Rating: High
Total Bank Length: 4 ft
Estimated Sediment Loss: 0.06 Cu Yds per Year
Estimated Sediment Loss: 0.08 Tons per Year

River Name: Macgruder
Reach Name: Reach 1

Table 1. Bank Identification Summary

Bank	Name
1	Roots density @85%
2	Root density @ 30%
3	Root Density @ 20%
4	sta 268 to254 L
5	sta 254 to 244 L
6	sta 211 to 166 R
7	STA 166 TO 118 L
8	sta 107 to 84 L
9	sta 80 to 0 R
10	sta 60 to 64 R

Table 2. Predicted Annual Bank Erosion Rates

Bank	BEHI Numeric Rating	BEHI Adjective Rating	NBS Adjective Rating	Length ft	Loss cu yds/yr	Loss tons/yr
1	9.4	Very Low	Low	6	0.01	0.01
2	25.1	Moderate	Low	66	0.44	0.57
3	27.7	Moderate	Low	64	0.43	0.56
4	0	Moderate	Moderate	14	0.2	0.26
5	0	Moderate	Low	10	0.09	0.12
6	26.8	Moderate	Moderate	45	0.75	0.98
7	0	Low	Moderate	48	0	0
8	0	Moderate	Moderate	23	0.64	0.83
9	34.9	High	High	84	9.33	12.13
10	0	Low	High	4	0.06	0.08
Totals				364	11.95	15.54

Total Reach Ln: 283 Total Loss (tons/yr) per ft of Reach: 0.0549

Worksheet 5-10. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	Macgruder, Reach - Reach 1		Location:				
Graph Used:		Total Bank Length (ft): 283				Date: 9/18/2007	
Observers:			Valley Type: VIII			Stream Type: C 4	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Station (ft)	BEHI rating (Worksheet 5-8) (adjective)	NBS rating (Worksheet 5-9) (adjective)	Bank erosion rate (Figure 5-38 or 5-39) (ft/yr)	Length of bank (ft)	Study bank height (ft)	Erosion subtotal [(4)×(5)×(6)] (ft^3/yr)	Erosion Rate (tons/yr/ft) {[(7)/27] × 1.3 / (5)}
1. Root Density @	Moderate	Low	0.1209375	64	1.5	11.61	0.01
2. Root density @	Moderate	Low	0.12	66	1.5	11.88	0.01
3. Roots density	Very Low	Low	0.0225	6	2	0.27	0.00
4. sta 107 to 84 L	Moderate	Moderate	0.3005217	23	2.5	17.28	0.04
5. STA 166 TO 118 L	Low	Moderate	0	48	2.3	0	0.00
6. sta 211 to 166 R	Moderate	Moderate	0.3	45	1.5	20.25	0.02
7. sta 254 to 244 L	Moderate	Low	0.1215	10	2	2.43	0.01
8. sta 268 to254 L	Moderate	Moderate	0.2967033	14	1.3	5.4	0.02
9. sta 60 to 64 R	Low	High	0.135	4	3	1.62	0.02
10. sta 80 to 0 R	High	High	0.9996429	84	3	251.91	0.14
11.							
12.							
13.							
14.							
15.							
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					Total erosion (ft^3/yr)	322.65	
Convert erosion in ft^3/yr to yds^3/yr {divide Total erosion (ft^3/yr) by 27}					Total erosion (yds^3/yr)	11.95	
Convert erosion in yds^3/yr to tons/yr {multiply Total erosion (yds^3/yr) by 1.3}					Total erosion (tons/yr)	15.54	
Calculate erosion per unit length of channel {divide Total erosion (tons/yr) by total length of stream (ft) surveyed}					Total erosion (tons/yr/ft)	0.0549	

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River Name: Macgruder
Reach Name: Reach 1

Stream Type	Valley Type	D50(mm)	Val Slope	BKF Q(cfs)	DA(sq mi)
C 4	VIII	30.43	0.009	140.08	1.1

Dimension Summary

Database based on the following Cross Sections:

Variable	Min	Avg	Max
Floodprone Width (ft)	134.7	134.7	134.7
Riffle Area (Sq ft)	34.03	34.03	34.03
Max Riffle Depth (ft)	1.72	1.72	1.72
Mean Riffle Depth (ft)	1.62	1.62	1.62
Riffle Width (ft)	21	21	21
Pool Area (Sq ft)	27.42	27.42	27.42
Max Pool Depth (ft)	2.77	2.77	2.77
Mean Pool Depth (ft)	1.75	1.75	1.75
Pool Width (ft)	15.71	15.71	15.71
Run Area (Sq ft)	29.79	29.79	29.79
Max Run Depth (ft)	1.95	1.95	1.95
Mean Run Depth (ft)	1.51	1.51	1.51
Run Width (ft)	19.72	19.72	19.72
Glide Area (Sq ft)	28.93	28.93	28.93
Max Glide Depth (ft)	2.3	2.3	2.3
Mean Glide Depth (ft)	1.33	1.33	1.33
Glide Width (ft)	21.72	21.72	21.72

Pattern Summary

Variable	Min	Avg	Max
Sinuosity		1.29	
Meander Wavelength (ft)	160	160	160
Radius of Curvature (ft)	14	31	48
Belt Width (ft)	34	42.5	51

Profile Summary

Data Based on the following:

Variable	Min	Avg	Max
S riffle (ft/ft)	0.01874	0.01974	0.02074
S pool (ft/ft)	0.00145	0.00232	0.0037
S run (ft/ft)	0.02561	0.02561	0.02561
S glide (ft/ft)	0.00325	0.01094	0.02572
P - P (ft)	32.62	35.36	39.3
Pool length (ft)	7.71	11.13	13.61
Riffle length (ft)	31.08	51.51	71.93
Dmax riffle (ft)	0	1.72	0
Dmax pool (ft)	2.77	2.77	2.77
Dmax run (ft)	1.95	1.95	1.95
Dmax glide (ft)	2.3	2.3	2.3
Low bank ht (ft)	2.28	2.3	2.31

Bankfull slope (ft/ft) 0

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Hydraulic Summary

Variable	Min	Avg	Max
Discharge (cfs)		140.08	
Velocity (fps)		4.12	
Hyd Radius (ft)	1.52	1.52	1.52

TEAM 9/18/07

Worksheet A-25. Summary of stability condition categories.

Stream: W. GRUDER Location: MD

Observers: TEAM Date: 9/18/07 Stream Type: C4 Valley Type: 8

Channel Dimension	Mean bankfull depth (ft): 1.6	Mean bankfull width (ft): 21	Cross-section area (ft^2): 34	Width of flood-prone area (ft): 100	Entrenchment ratio: >4
Channel Pattern	Mean (range) MWR: 2.02	Lm/W_{bkf}: 7.6	Rc/W_{bkf}: 1.48	Sinuosity: 1.29	
River Profile and Bed Features	Circle: Riffle/pool Step/pool Plane bed Convergence/divergence Dunes/antidunes/smooth bed				
	Max bankfull depth (ft): Riffle 1.7 Pool 2.77	Depth ratio (max/mean): Riffle 1 Pool 1	Pool to pool spacing: Ratio 1.5	Slope: Valley: 0.009 Average bankfull: .007	
Level III Stream Stability Indices	Riparian vegetation: Current composition/density: 95%	Potential composition/density: 100%	Remarks: Condition, vigor and/or usage of exiting reach: Second generation climax forest		
	Flow regime: P	Stream size and order: S3	Meander pattern(s): M3	Depositional pattern(s): B2	Debris/channel blockage(s): 02/03
	Degree of incision (Bank-Height Ratio): 1.15	Degree of incision stability rating:	Modified Pfankuch stability rating (numeric and adjective rating): Good		
	Width/depth ratio (W/D): 13.4	Reference W/D ratio (W/D_{ref}): 13.4	Width/depth ratio state (W/D) / (W/D_{ref}): 1	W/D ratio state stability rating: STABLE	
	Meander Width Ratio (MWR): 2.02	Reference MWR_{ref}: 2.02	Degree of confinement (MWR / MWR_{ref}): 1	MWR / MWR_{ref} stability rating: 1	
Bank Erosion Summary	Length of reach studied (ft): 28[illegible]	Annual streambank erosion rate: 15.54 (tons/yr) .0549 (tons/yr/ft)	Curve used: Piedmont / 1 Region	Remarks:	
Sediment Capacity (POWERSED)	Sufficent capacity	Insufficient capacity	Remarks: NA		
Entrainment/ Competence	Largest particle from bar sample (mm): 70	$\tau = 0.742$	$\tau^* = 0.019$	Existing $depth_{bkf}$: 1.7	Required $depth_{bkf}$: 1.7
	Existing $slope_{bkf}$: .007	Required $slope_{bkf}$: .004			
Successional Stage Shift	E → F → → → →	Existing stream state (type): C4	Potential stream state (type): C4		
Lateral Stability	Circle: Stable	Moderately unstable	Unstable	Highly unstable	Remarks/causes:
Vertical Stability (Aggradation)	Circle: No deposition	Moderate deposition	Excess deposition	Aggradation	Remarks/causes:
Vertical Stability (Degradation)	Circle: Not incised	Slightly incised	Moderately incised	Degradation	Remarks/causes:
Channel Enlargement	Circle: No increase	Slight increase	Moderate increase	Extensive	Remarks/causes:
Sediment Supply (Channel Source)	Circle: Low	Moderate	High	Very high	Remarks/causes:

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Worksheet A-24. Overall sediment supply rating determined from individual stability rating categories.

Stream: MAGRUDER		Stream Type:	C4
Location: MD		Valley Type:	8
Observers: TEAM 1		Date:	9.18.07
Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	**Stability rating**	**Points**	**Selected points**
1 **Lateral stability (Worksheet A-20)**	Stable	1	1
	Mod. unstable	2	
	Unstable	3	
	Highly unstable	4	
2 **Vertical stability excess deposition/ aggradation (Worksheet A-21)**	No deposition	1	1
	Mod. deposition	2	
	Excess deposition	3	
	Aggradation	4	
3 **Vertical stability channel incision/ degradation (Worksheet A-22)**	Not incised	1	2
	Slightly incised	2	
	Mod. Incised	3	
	Degradation	4	
4 **Channel enlargement prediction (Worksheet A-23)**	No increase	1	2
	Slight increase	2	
	Mod. increase	3	
	Extensive	4	
5 **Pfankuch channel stability (Worksheet A-11)**	Good: stable	1	1
	Fair: mod unstable	2	
	Poor: unstable	4	
		Total Points	6

	Category point range			
Overall sediment supply rating (use total points and check stability rating)	**Low** 5 ☐	**Moderate** 6 – 10 ☑	**High** 11 – 15 ☐	**Very High** 16 – 20 ☐

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Worksheet A-23. Channel enlargement prediction summary.

Stream:	McGRUDER		Stream Type:	C4	
Location:			Valley Type:	8	
Observers:	TEAM 1		Date:	9.18.07	

	Channel enlargement prediction criteria (choose one stability category for each criterion 1–4)	Channel enlargement prediction categories: No increase	Slight increase	Moderate increase	Extensive	Selected points (from each row)
1	**Successional stage shift (Worksheet A-19)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C)	(E→C)	(G→F), (F→D)	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F)	28
		(2)	(4)	(6)	(8)	
2	**Lateral stability (Worksheet A-20)**	Stable	Moderately unstable	Unstable	Highly unstable	2
		(2)	(4)	(6)	(8)	
3	**Vertical stability excess deposition/ aggradation (Worksheet A-21)**	No deposition	Moderate deposition	Excess deposition	Aggradation	2
		(2)	(4)	(6)	(8)	
4	**Vertical stability incision/ degradation (Worksheet A-22)**	Not incised	Slightly incised	Moderately incised	Degradation	4
		(2)	(4)	(6)	(8)	
					Total points	16

	Category point range: No increase 8 – 10	Slight increase 11 – 16	Moderate increase 17 – 24	Extensive > 24
Channel enlargement prediction (use total points and check stability rating)	☐	☑	☐	☐

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Worksheet A-22. Vertical stability prediction for channel incision/degradation.

Stream: MCGRUDER				Stream Type: C4	
Location:				Valley Type: 8	
Observers: TEAM 1				Date: 9/18/07	
Vertical stability criteria (choose one stability category for each criterion 1–5)	**Vertical stability categories for channel incision / degradation**				**Selected points (from each row)**
	Not incised	**Slightly incised**	**Moderately incised**	**Degradation**	
1 Sediment competence (Worksheet A-18)	Does not indicate excess competence	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed	D_{100} of bed moved	Particles much larger than D_{100} of bed moved	4 8
	(2)	(4)	(6)	(8)	
2 Sediment capacity (POWERSED)	Does not indicate excess capacity	Slight excess energy: up to 10% increase above reference	Excess energy sufficient to increase load up to 50% of annual load	Excess energy transporting more than 50% of annual load	2
	(2)	(4)	(6)	(8)	
3 Degree of channel incision (BHR) (Workshet A-10)	1.00 – 1.10	1.11 – 1.30	1.31 – 1.50	> 1.50	4
	(2)	(4)	(6)	(8)	
4 Stream succession states (Worksheets A-19 and A-10)	Does not indicate incision or degradation	If BHR > 1.1 and stream type has w/d between 5–10	If BHR > 1.1 and stream type has w/d less than 5	(B→G), (C→G), (E→G), (D→G)	4
	(2)	(4)	(6)	(8)	
5 Confinement (MWR / MWR_{ref}) (Worksheet A-13)	0.80 – 1.00	0.30 – 0.79	0.10 – 0.29	< 0.10	1
	(1)	(2)	(3)	(4)	
				Total points	17 15
	Vertical stability category point range for channel incision / degradation				
Vertical stability for channel incision/ degradation (use total points and check stability rating)	**Not incised** 9 – 11 ☐	**Slightly incised** 12 – 18 ☑	**Moderately incised** 19 – 27 ☐	**Degradation** > 27 ☐	

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Worksheet A-20. Lateral stability prediction summary.

Stream: MCGRUDER			Stream Type: C4		
Location: MD			Valley Type: VIII		
Observers: TEAM 1			Date: 9.18.07		
Lateral stability criteria (choose one stability category for each criterion 1–5)	**Lateral stability categories**				**Selected points (from each row)**
	Stable	**Moderately unstable**	**Unstable**	**Highly unstable**	
1 **W/d ratio state (Worksheet A-12)**	< 1.2	1.2 – 1.4	1.4 – 1.6	> 1.6	2
	(2)	(4)	(6)	(8)	
2 **Depositional pattern (Worksheet A-8)**	B1, B2	B4, B8	B3	B5, B6, B7	1
	(1)	(2)	(3)	(4)	
3 **Meander pattern (Worksheet A-7)**	M1, M3, M4		M2, M5, M6, M7, M8		1
	(1)		(3)		
4 **Dominant BEHI / NBS (Worksheet A-16)**	L/VL, L/L, L/M, L/H, L/VH, M/VL	M/L, M/M, M/H, L/Ex, H/L	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex	2
	(2)	(4)	(6)	(8)	
5 **Degree of confinement (MWR / MWR_{ref}) (Worksheet A-13)**	0.8 – 1.0	0.3 – 0.79	0.1 – 0.29	< 0.1	1
	(1)	(2)	(3)	(4)	
				Total points	9
	Lateral stability category point range				
Overall lateral stability category (use total points and check stability rating)	**Stable** 7 – 9 ☑	**Moderately unstable** 10 – 12 ☐	**Unstable** 13 – 21 ☐	**Highly unstable** > 21 ☐	

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River Assessment and Monitoring: Reference Reach 1st Field Day

Worksheet A-21. Vertical stability prediction for excess deposition/aggradation.

Stream: MAGRUDER			Stream Type: C4		
Location: MD			Valley Type: 8		
Observers: TEAM 1			Date: 9/18/07		
Vertical stability criteria (choose one stability category for each criterion 1–6)	**Vertical stability categories for excess deposition / aggradation**				**Selected points (from each row)**
	No deposition	**Moderate deposition**	**Excess deposition**	**Aggradation**	
1 Sediment competence (Worksheet A-18)	Sufficient depth and/or slope to transport largest size available	Trend toward insufficient depth and/or slope-slightly incompetent	Cannot move D_{35} of bed material and/or D_{100} of bar material	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size	9
	(2)	(4)	(6)	(8)	
2 Sediment capacity (POWERSED)	Sufficient capacity to transport annual load	Trend toward insufficient sediment capacity	Reduction up to 25% of annual sediment yield of bedload and/or suspended	Reduction over 25% of annual sediment yield for bedload and/or suspended	2
	(2)	(4)	(6)	(8)	
3 W/d ratio state (Worksheet A-12)	1.0 – 1.2	1.2 – 1.4	1.4 – 1.6	>1.6	2
	(2)	(4)	(6)	(8)	
4 Stream succession states (Worksheet A-19)	Current stream type at potential or does not indicate deposition/ aggradation	(E→C)	(C→High w/d C), (B→High w/d B), (C→F)	(C→D), (F→D)	6
	(2)	(4)	(6)	(8)	
5 Depositional patterns (Worksheet A-8)	B1	B2, B4	B3, B5	B6, B7, B8	1
	(1)	(2)	(3)	(4)	
6 Debris / blockages (Worksheet A-9)	D1, D2, D3	D4, D7	D5, D8	D6, D9, D10	1
	(1)	(2)	(3)	(4)	
				Total points	10
	Vertical stability category point range for excess deposition / aggradation				
Vertical stability for excess deposition / aggradation (use total points and check stability rating)	**No deposition** 10 – 14 ☑	**Moderate deposition** 15 – 20 ☐	**Excess deposition** 21 – 30 ☐	**Aggradation** > 30 ☐	

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Worksheet A-19. Stability ratings for corresponding successional stage shifts of stream types. Check (✓) the appropriate stability rating.

Stream: MACRUDER	Stream Type: C4
Location: MP	Valley Type: 8
Observers: TEAM 1	Date: 9/18/07
Stream type changes due to successional stage shifts (Figure A-29)	**Stability rating (check appropriate rating)**
Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C)	☐ Stable
(E→C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☒ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

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Worksheet A-18. Sediment competence calculation form to assess bed stability.

Stream: Magruder Branch			Stream Type: C4		
Location:			Valley Type: B		
Observers: TEAM 1			Date: 9/18/07		
Enter required information					
32	D_{50}	Riffle bed material D_{50} (mm)			
14.7	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
0.23	D_{max}	Largest particle from bar sample (ft)	70	(mm)	304.8 mm/ft
.007	S	Existing bankfull water surface slope (ft/ft)			
1.76	d	Existing bankfull mean depth (ft)			
1.2	γ_s	Submerged specific weight of sediment			
Select the appropriate equation and calculate critical dimensionless shear stress					
× 2.17	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1: $\tau^* = 0.0834 (D_{50}/\hat{D}_{50})^{-0.872}$ 0.077		
* 0.01 Avg 2.19	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2: $\tau^* = 0.0384 (D_{max}/D_{50})^{-0.887}$ 0.0112		
.019	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:		2
Calculate bankfull mean depth required for entrainment of largest particle in bar sample					
1.06	d	Required bankfull mean depth (ft)	$d = \frac{\tau^* \gamma_s D_{max}}{S}$		
Check: ☐ Stable ☐ Aggrading ☒ Degrading					
Calculate bankfull water surface slope required for entrainment of largest particle in bar sample					
.0043	S	Required bankfull water surface slope (ft/ft)	$S = \frac{\tau^* \gamma_s D_{max}}{d}$		
Check: ☒ Stable ☐ Aggrading ☒ Degrading			Slope < Actual slope		
Sediment competence using dimensional shear stress					
.742	Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d)				
120	Moveable particle size (mm) at bankfull shear stress **(Figure A-28)**				
0.35	Predicted shear stress required to initiate movement of D_{max} (mm) **(Figure A-28)**				
1.6987	Predicted mean depth required to initiate movement of D_{max} (mm) $d = \frac{\tau}{\gamma S}$ lbs/sf / lbs/cf = 41.2 ft				
.0069	Predicted slope required to initiate movement of D_{max} (mm) $S = \frac{\tau}{\gamma d}$ lbs/sf / lbs/cf · ft				

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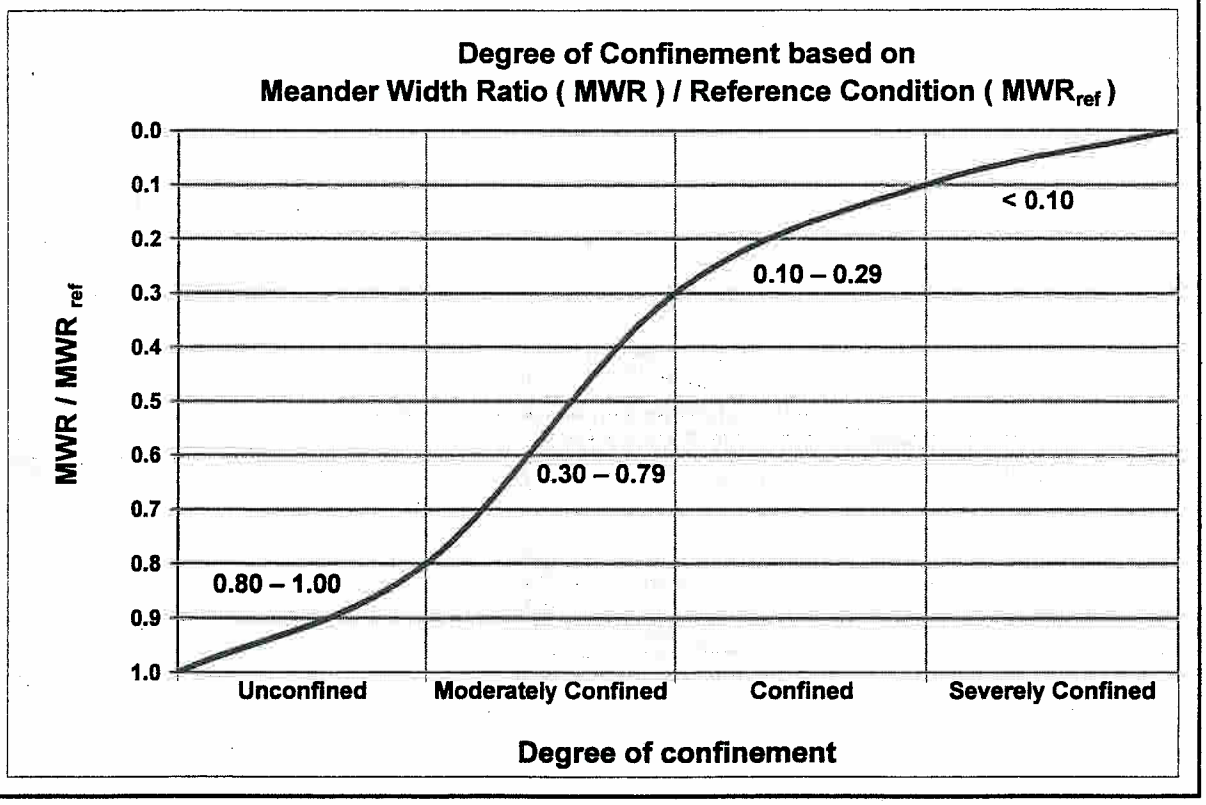
j. Degree of Channel Confinement (Meander Width Ratio (MWR)) (*Continued*)

TEAM 1
9/18/07

Worksheet A-13. Degree of confinement stability ratings based on meander width ratio divided by reference meander width ratio.

Degree of Confinement			
Existing Meander Width Ratio (MWR):	2.3	Ratio of MWR to MWRref:	1
Reference Meander Width Ratio (MWR_{ref}):	2.3		
Degree of Confinement Stability Rating ☞	UNCONFINED		



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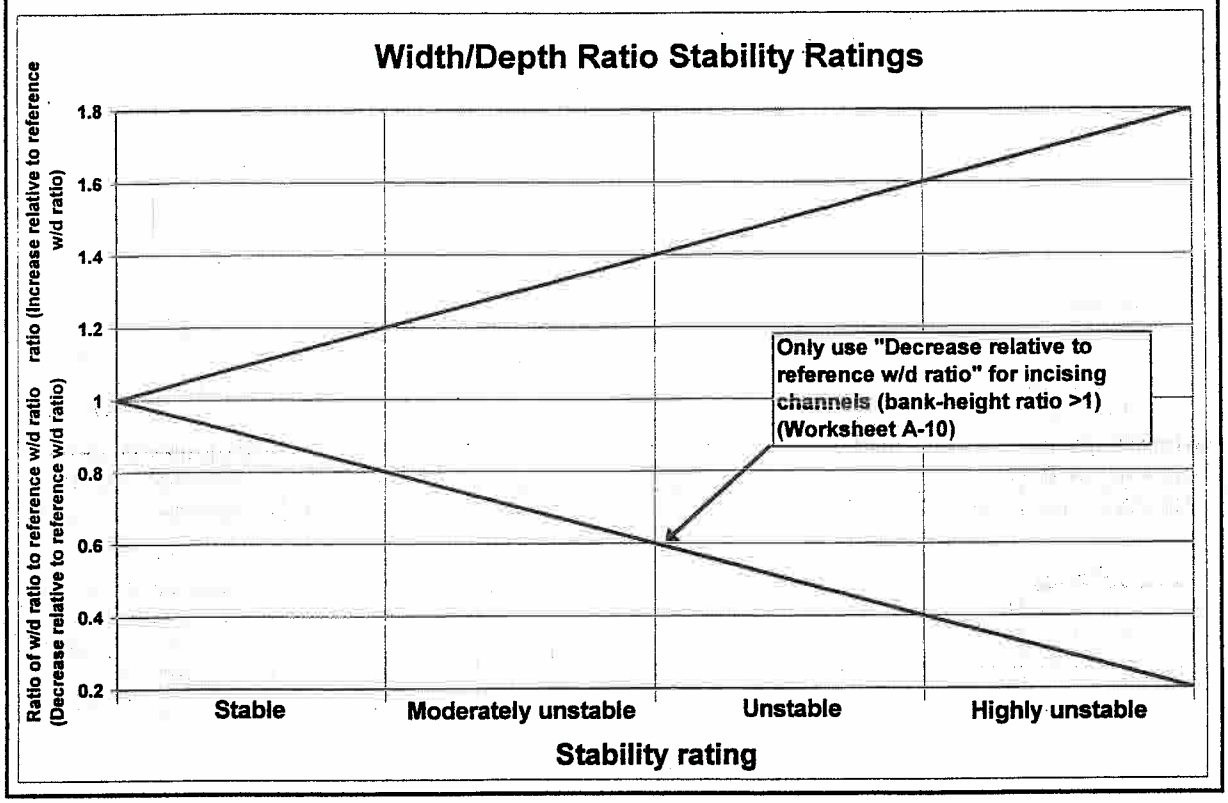
i. Width/Depth Ratio State (*Continued*)

TEAM 1
9/18/07

Worksheet A-12. Width/depth ratio state stability rating.

Width/Depth Ratio State			
Existing Width/Depth Ratio:	13.4	Ratio of existing w/d to reference w/d:	1
Reference Width/Depth Ratio:	13.4		
Width/Depth Ratio State Stability Rating		STABLE	



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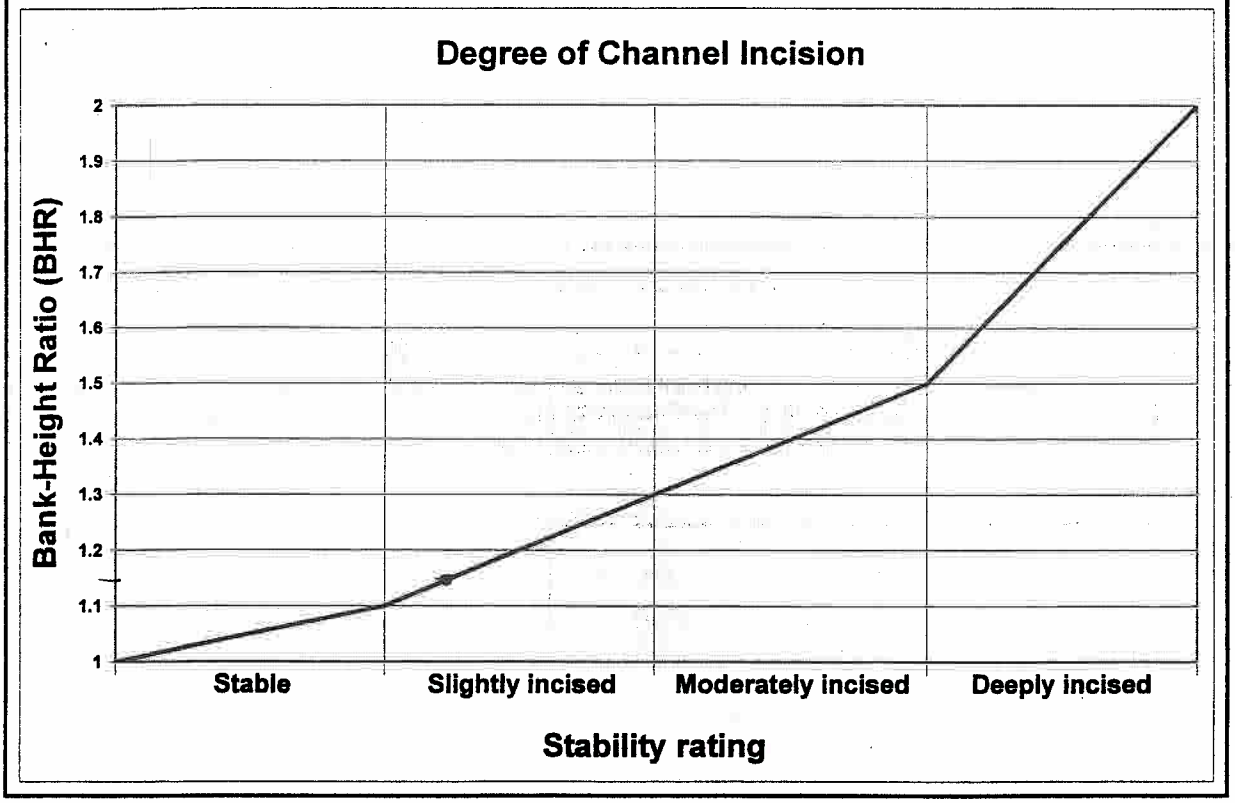
g. Degree of Channel Incision (Bank-Height Ratio) (*continued*)

TEAM 1
9/18/07

Worksheet A-10. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings to determine degree of channel incision.

Degree of Channel Incision			
Low Bank Height:	1.95	Bank-Height Ratio:	1.15
Max Bankfull Depth:	1.7		
Degree of Channel Incision Stability Rating		SLIGHTLY INCISED	



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