APPENDIX K

LEVEL III ROSGEN WORKSHEETS

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Buffalo River**	Location: **Buffalo River-1-1.19**

Observers: **KD, JB**	Reference reach [ ]	Disturbed (impacted reach) [X]	Date: **9/27/2011**

Existing species composition:	Potential species composition:

	Riparian cover categories	Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**15%**	**2%**	**Large trees**	**100%**
					100%
2. Understory	Shrub layer		**2%**	**Shrubs**	**40%**
				Nettle/Burrs	**60%**
					100%
3. Ground level	Herbaceous		**3%**	**Grass**	**100%**
					100%
	Leaf or needle litter		**0%**		
	Bare ground		**93%**		
			Column total = 100%		

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

Remarks:
Condition, vigor and/or usage of existing reach:

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream:	**Buffalo River**	Location:	**Buffalo River-1-1.19**						
Observers:	**KD, JB**					Date:	**9/27/2011**		
List ALL COMBINATIONS that APPLY..............☞		**P1**	**P2**	**P9**					

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order

Stream:	**Buffalo River**
Location:	**Buffalo River-1-1.19**
Observers:	**KD, JB**
Date:	**9/27/2011**
Stream Size Category and Order ☞	**S-7**

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

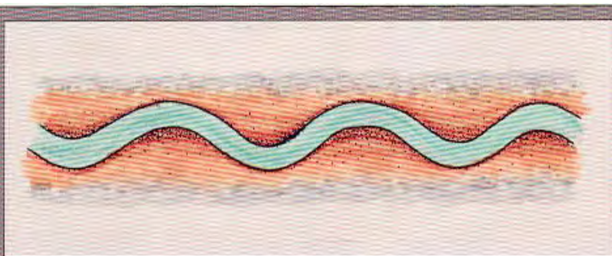
Add categories in parenthesis for specific stream order of reach. For example a third order stream with a bankfull width of 6.1 meters (20 feet) would be indexed as: S-4(3).

Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream: **Buffalo River**			Reach: **Buffalo River-1-1.19**		
Observers: **KD, JB**			Date: **9/27/2011**		
List ALL CATEGORIES that APPLY ☞	**M1**				

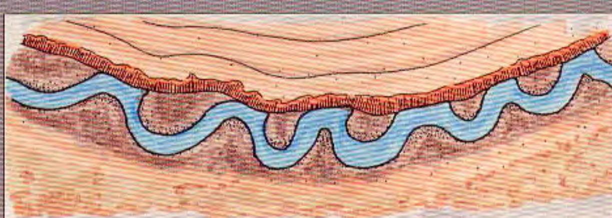
Various Meander Pattern variables modified from Galay et al. (1973)



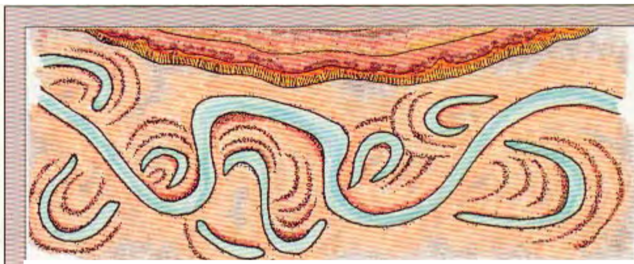
M1 REGULAR MEANDERS

M2 TORTUOUS MEANDERS

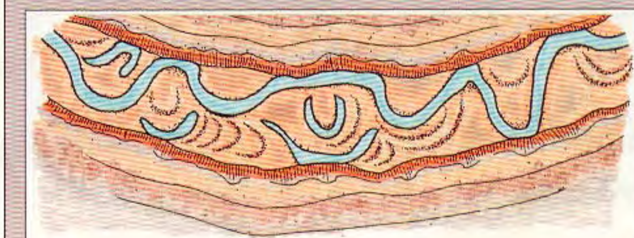
M3 IRREGULAR MEANDERS



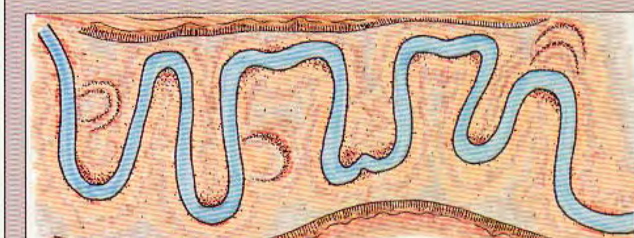
M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS



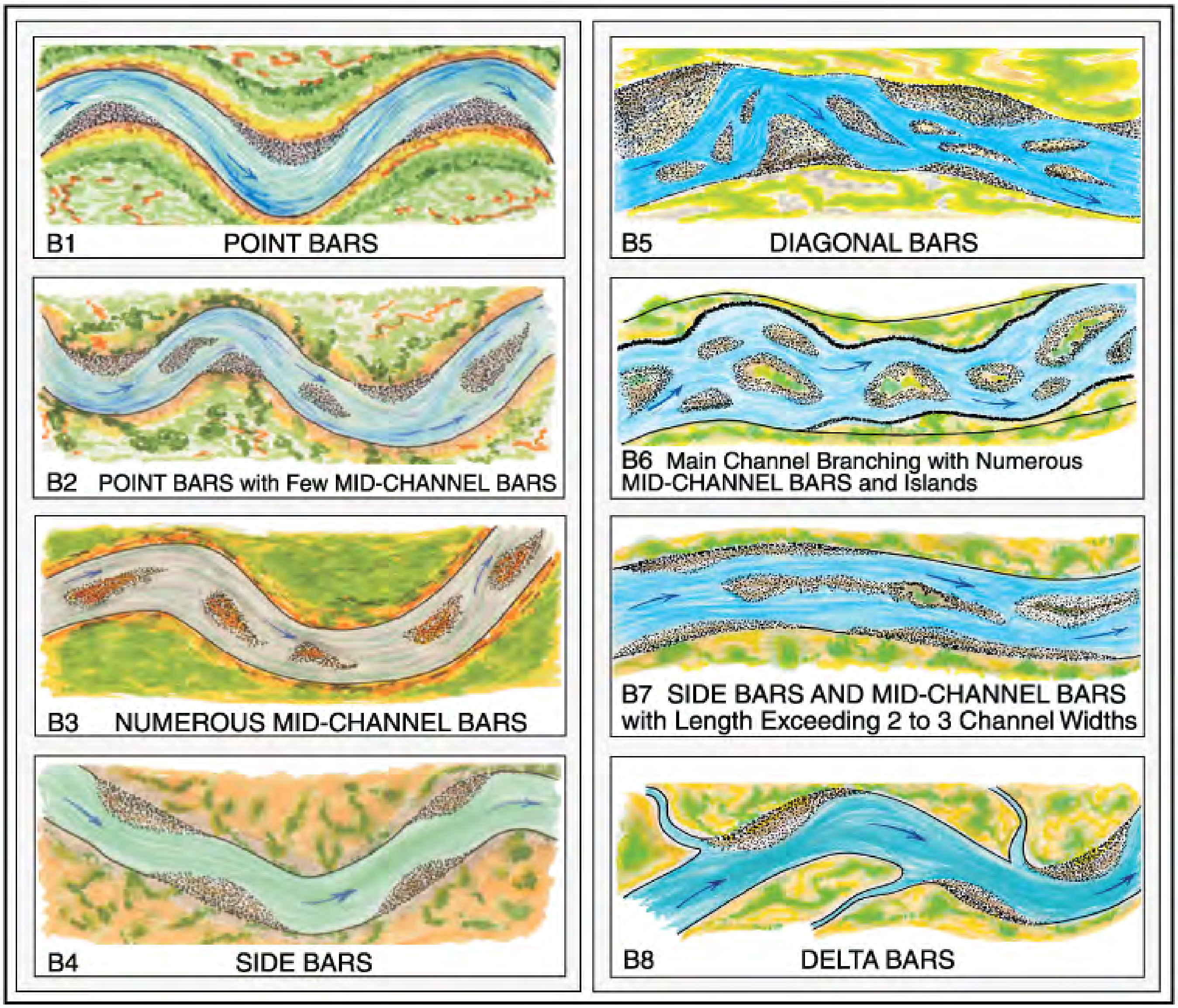
M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns					
Stream:	**Buffalo River**		Reach:	**Buffalo River-1-1.19**	
Observers:	**KD, JB**		Date:	**9/27/2011**	
List ALL CATEGORIES that APPLY ☞	**None**				

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



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Buffalo River**		Location: **Buffalo River-1-1.19**	
Observers: **KD, JB**		Date: **9/27/2011**	
Description/extent		**Materials that 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.	☐

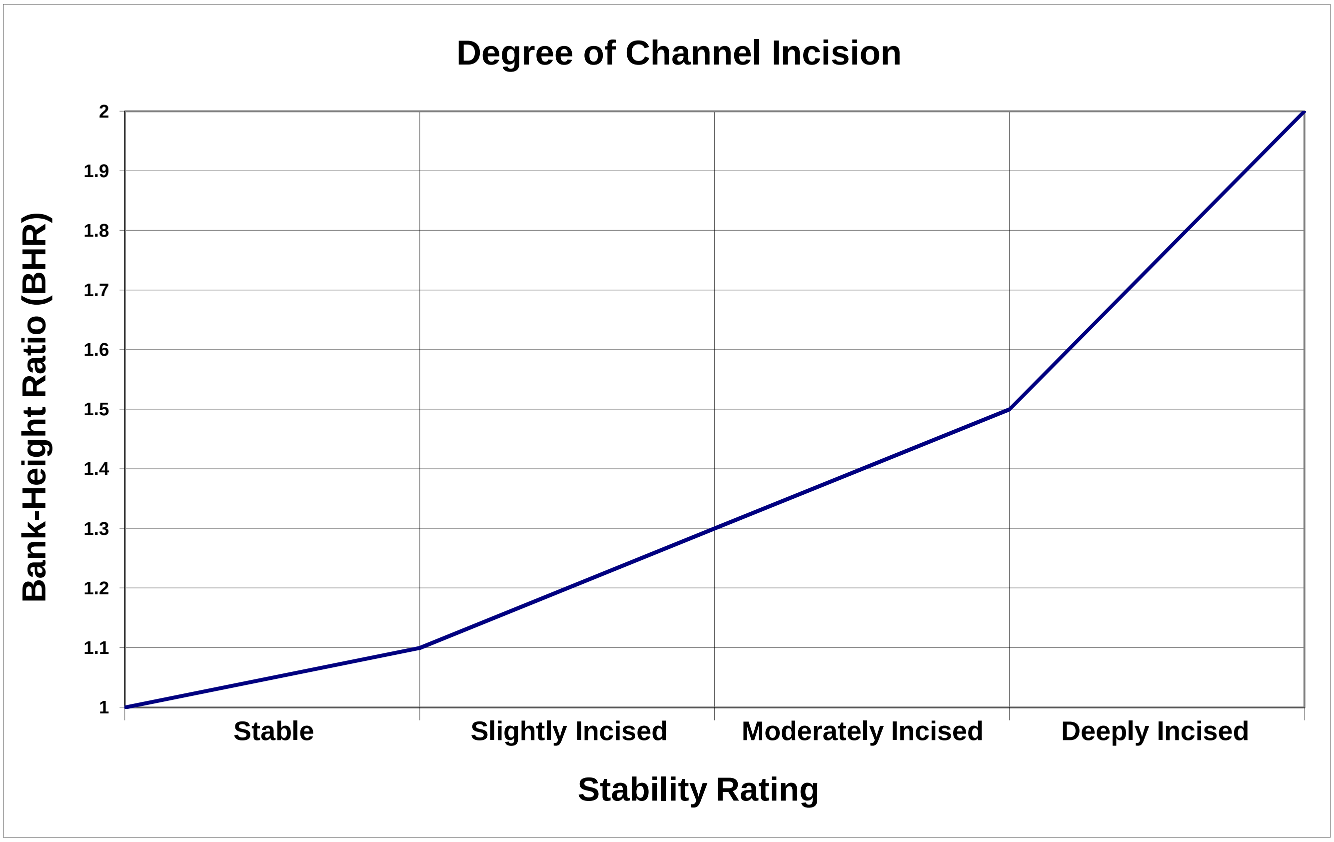
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision

Low Bank Height:	**17.4**
Max Bankfull Depth:	**9.0**

Bank-Height Ratio:	**1.9**

Degree of Channel Incision Stability Rating ☞	**Deeply Incised**

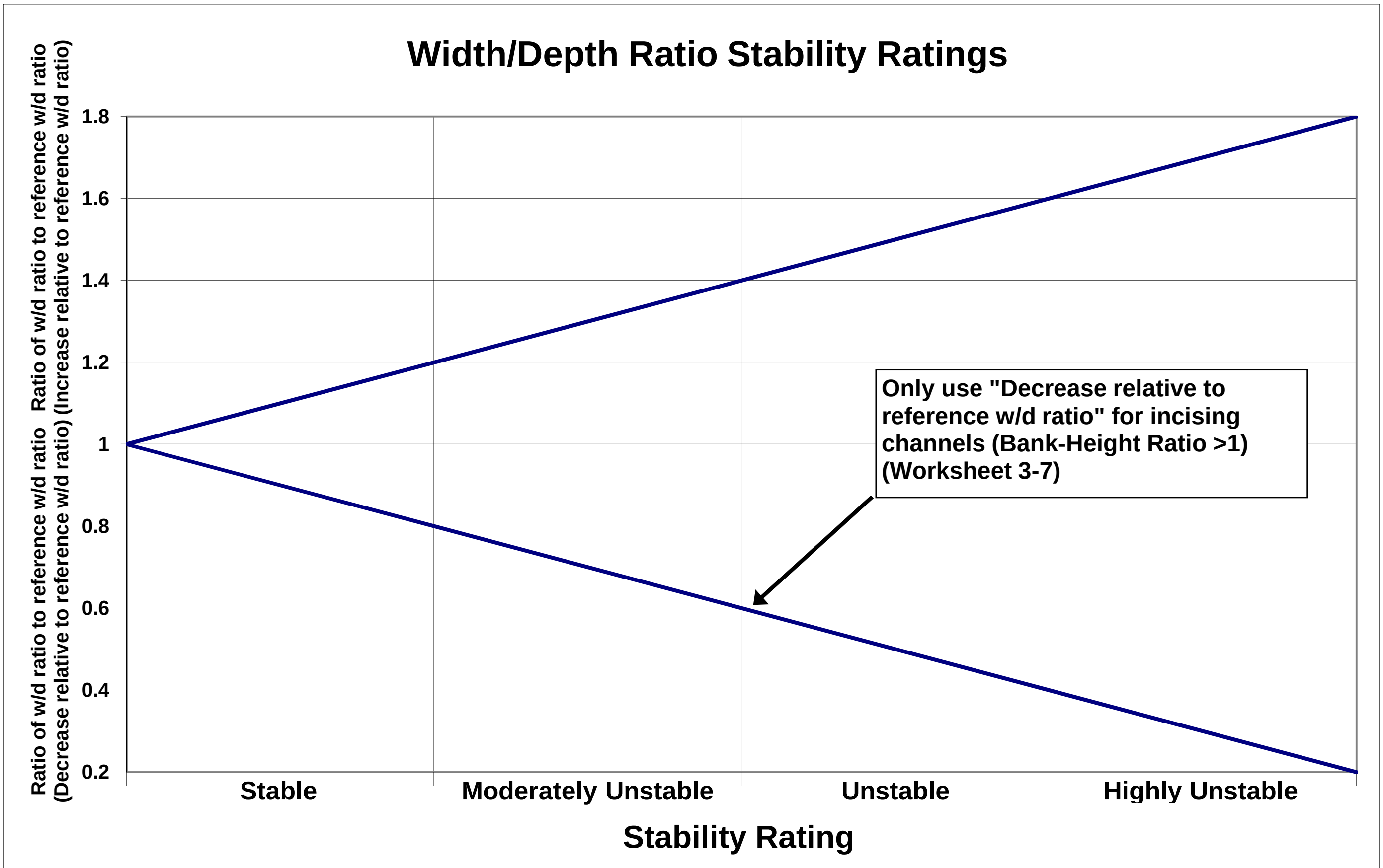


Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State

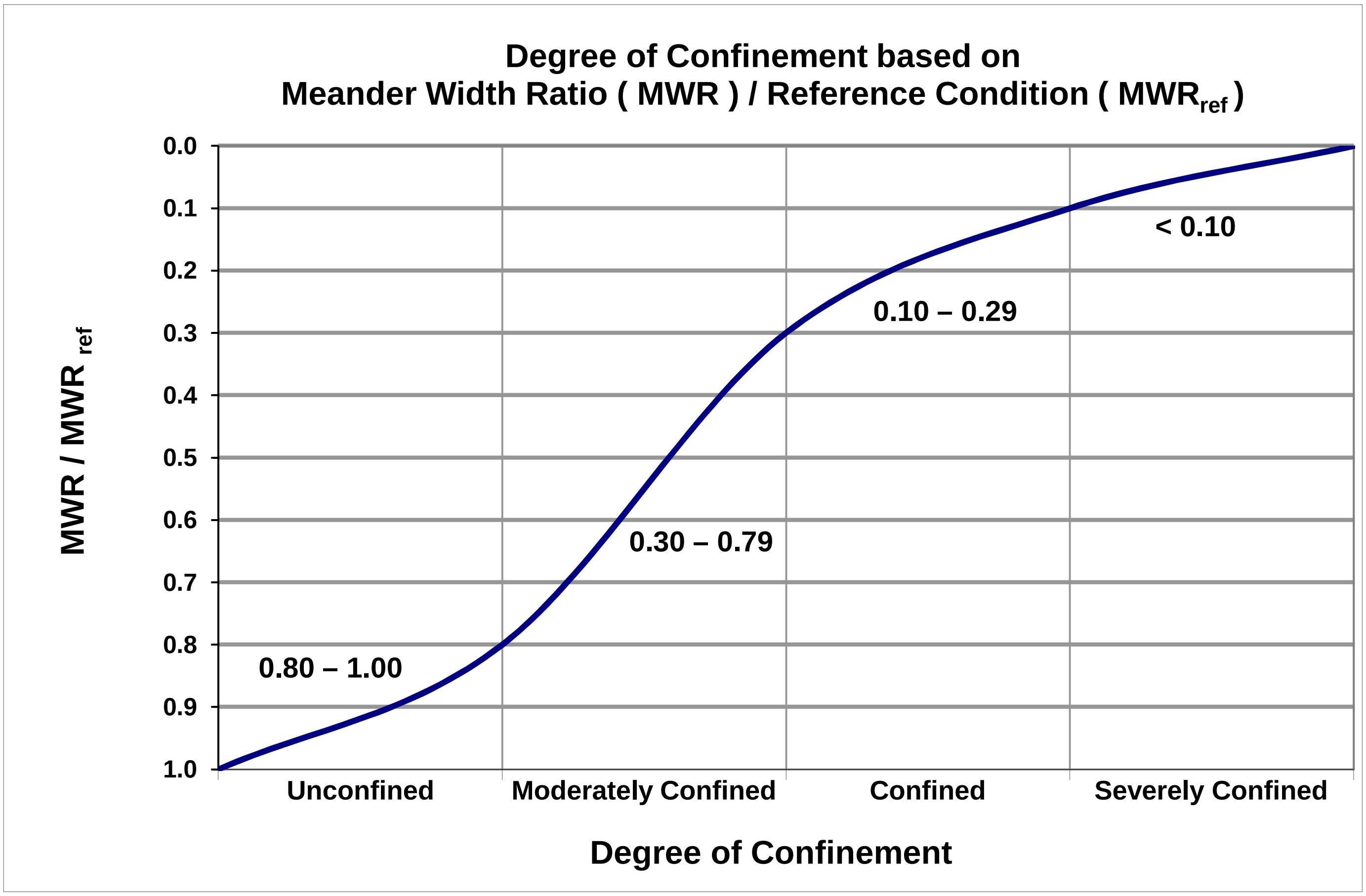
Existing Width/Depth Ratio:	11.5	Ratio of existing W/d to reference W/d:	1.0
Reference Width/Depth Ratio:	11.5		

Width/Depth Ratio State Stability Rating ☞	**Stable**



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	9.3	Ratio of MWR to MWR_{ref}:	1.0
Reference Meander Width Ratio (MWR_{ref}):	9.3		
Degree of Confinement Stability Rating ☞		**Unconfined**	



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Buffalo River **Location:** Buffalo River-1-1.19 **Valley Type:** X **Observers:** KD, JB **Date:** 9/27/2011

Location	Key	Category	Excellent Description	Excellent Rating	Good Description	Good Rating	Fair Description	Fair Rating	Poor Description	Poor Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	**4**	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	**12**
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	**6**	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	**12**
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	**2**	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	**4**	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	**16**
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	6	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	**12**	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	15	Good total =	20	Fair total =	6	Poor total =	44

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	85
Existing stream type =	E6
*Potential stream type =	E6
Modified channel stability rating =	Fair

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream: **Buffalo River**		Location: **Buffalo River-1-1.19**	
Station:		Observers: **KD, JB**	
Date: **9/27/2011**	Stream Type: **E6**	Valley Type: **X**	

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	19.6 (A)	Bankfull Height (ft) =	7.3 (B)	(A) / (B) =	2.7 (C)	9

Root Depth / Study Bank Height (E)

Root Depth (ft) =	2 (D)	Study Bank Height (ft) =	19.6 (A)	(D) / (A) =	0.1 (E)	8

Weighted Root Density (G)

Root Density as % =	3% (F)	(F) x (E) =	0% (G)	10

Bank Angle (H)

Bank Angle as *Degrees* =	26 (H)	2

Surface Protection (I)

Surface Protection as % =	0% (I)	10

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)

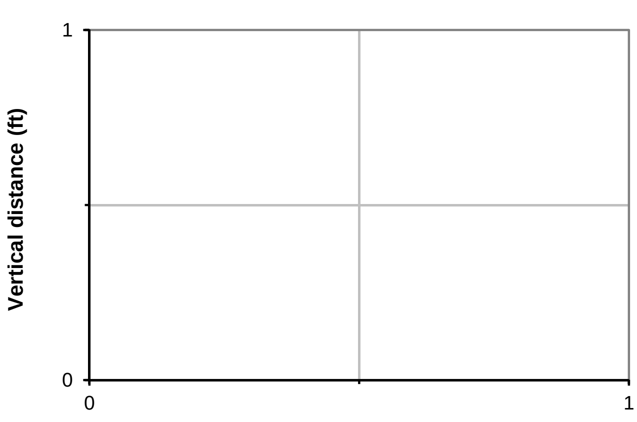
Bank Material Adjustment: 0

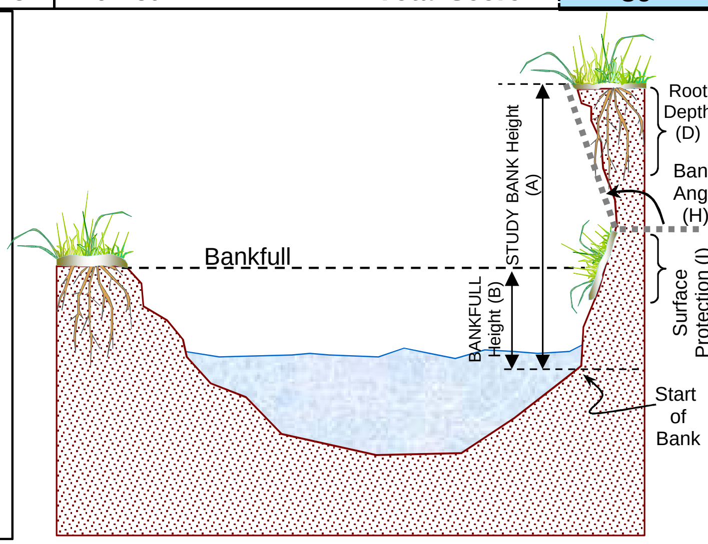
Stratification Adjustment
Add 5–10 points, depending on position of unstable layers in relation to bankfull stage: 0

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**: **High** / **39**

Bank Sketch





Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Buffalo River**	Location: **Buffalo River-1-1.19**	
Station: **0**	Stream Type: **E6**	Valley Type: **X**
Observers: **KD, JB**		Date: **9/27/11**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})...	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S)..	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})..	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf}).........................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient..	Level IV	Validation

Level I

(1)
- Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
- Extensive deposition (continuous, cross-channel).. ....NBS = Extreme
- Chute cutoffs, down-valley meander migration, converging flow...NBS = Extreme

Level II

(2)

Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)

(3)

Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)

(4)

Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)

Dominant Near-Bank Stress
Very Low

Level III

(5)

Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)

(6)

Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)

Level IV

(7)

Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
0.03	**Very Low**

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating	**Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Buffalo River**			Location:	**Buffalo River-1-1.19**		
Graph Used:	**Fig 3-9**	Total Bank Length (ft):	**4552.5**			Date:	**9/27/2011**
Observers:	**KD, JB**	Valley Type:	**X**			Stream Type:	**E6**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**4552.5**	**19.6**	**14723**	**0.16**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**14723**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**545**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**709**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.16**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Buffalo River**		Stream Type: **E6**		
Location:	**Buffalo River-1-1.19**		Valley Type: **X**		
Observers:	**KD, JB**		Date: **9/27/2011**		
Enter Required Information for Existing Condition					
	D_{50}	Riffle bed material D_{50} (mm)			
-	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
-	D_{max}	Largest particle from bar sample (ft)	-	(mm)	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			
Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress					
-	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1: $\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$		
-	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2: $\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$		
-	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:		2
Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample					
-	d	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)	
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample					
-	S	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)	
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Sediment Competence Using Dimensional Shear Stress					
0	Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope				
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**				
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**				
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope		$d = \dfrac{\tau}{\gamma S}$		
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth		$S = \dfrac{\tau}{\gamma d}$		

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis	Observers: **KD, JB**
Stream: **Buffalo River** / Location: **Buffalo River-1-1.19**	Date: **9/27/2011**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		0		0		0		0		0		0		0		0		0
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		100%

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	0
Materials less than:	mm

Be sure to add separate material weights to grand total

GRAND TOTAL: 0

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream:	**Buffalo River**	Stream Type:	**E6**
Location:	**Buffalo River-1-1.19**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**9/27/2011**

Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream:	**Buffalo River**			Stream Type:	**E6**
Location:	**Buffalo River-1-1.19**			Valley Type:	**X**
Observers:	**KD, JB**			Date:	**9/27/2011**

Lateral stability criteria (choose one stability category for each criterion 1–5)	**Lateral Stability Categories** Stable	Moderately unstable	Unstable	Highly unstable	**Selected points** (from each row)
1 **W/d ratio state (Worksheet 3-8)**	< 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	> 1.6 **(8)**	**2**
2 **Depositional pattern (Worksheet 3-5)**	B1, B2 **(1)**	B4, B8 **(2)**	B3 **(3)**	B5, B6, B7 **(4)**	**1**
3 **Meander pattern (Worksheet 3-4)**	M1, M3, M4 **(1)**		M2, M5, M6, M7, M8 **(3)**		**1**
4 **Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL **(2)**	M/L, M/M, M/H, L/Ex, H/L **(4)**	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL **(6)**	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex **(8)**	**4**
5 **Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.8 – 1.0 **(1)**	0.3 – 0.79 **(2)**	0.1 – 0.29 **(3)**	< 0.1 **(4)**	**1**
				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** ☐

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Buffalo River**	Stream Type:	**E6**
Location:	**Buffalo River-1-1.19**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**9/27/2011**

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 3-14)**	Sufficient depth and/or slope to transport largest size available (2)	Trend toward insufficient depth and/or slope-slightly incompetent (4)	Cannot move D_{35} of bed material and/or D_{100} of bar material (6)	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size (8)	**2**
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load (2)	Trend toward insufficient sediment capacity (4)	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand (6)	Reduction over 25% of annual sediment yield for bedload and/or suspended sand (8)	**2**
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 (2)	1.2 – 1.4 (4)	1.4 – 1.6 (6)	>1.6 (8)	**2**
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation (2)	(E→C) (4)	(C→High W/d C), (B→High W/d B), (C→F) (6)	(C→D), (F→D) (8)	**2**
5 **Depositional patterns (Worksheet 3-5)**	B1 (1)	B2, B4 (2)	B3, B5 (3)	B6, B7, B8 (4)	**1**
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 (1)	D4, D7 (2)	D5, D8 (3)	D6, D9, D10 (4)	**3**
				Total points	**12**

	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** ☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream: **Buffalo River**			Stream Type:	**E6**	
Location: **Buffalo River-1-1.19**			Valley Type:	**X**	
Observers: **KD, JB**			Date:	**9/27/2011**	
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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	2
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	2
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	8
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	4
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	1
				Total points	**17**
	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** ☐	

Worksheet 3-20. Channel enlargement prediction summary.

Stream: Buffalo River				Stream Type: E6	
Location: Buffalo River-1-1.19				Valley Type: X	
Observers: KD, JB				Date: 9/27/2011	
Channel enlargement prediction criteria (choose one stability category for each criterion 1–4)	**Channel Enlargement Prediction Categories**				**Selected points** (from each row)
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) **(2)**	(C→High W/d C), (E→C) **(4)**	(G→F), (F→D) **(6)**	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) **(8)**	**2**
2 **Lateral stability (Worksheet 3-17)**	Stable **(2)**	Moderately unstable **(4)**	Unstable **(6)**	Highly unstable **(8)**	**2**
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition **(2)**	Moderate deposition **(4)**	Excess deposition **(6)**	Aggradation **(8)**	**2**
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised **(2)**	Slightly incised **(4)**	Moderately incised **(6)**	Degradation **(8)**	**4**
				Total points	**10**
	Category point range				
Channel enlargement prediction (use total points and check stability rating)	**No increase** **8 – 10** ☑	**Slight increase** **11 – 16** ☐	**Moderate increase** **17 – 24** ☐	**Extensive** **> 24** ☐	

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream: **Buffalo River**		Stream Type:	**E6**
Location: **Buffalo River-1-1.19**		Valley Type:	**X**
Observers: **KD, JB**		Date:	**9/27/2011**

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	**Stability Rating**	**Points**	**Selected Points**
1 Lateral stability (Worksheet 3-17)	**Stable**	**1**	**1**
	Mod. unstable	**2**	
	Unstable	**3**	
	Highly unstable	**4**	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	**No deposition**	**1**	**1**
	Mod. deposition	**2**	
	Excess deposition	**3**	
	Aggradation	**4**	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	**Not incised**	**1**	**2**
	Slightly incised	**2**	
	Mod. Incised	**3**	
	Degradation	**4**	
4 Channel enlargement prediction (Worksheet 3-20)	**No increase**	**1**	**1**
	Slight increase	**2**	
	Mod. increase	**3**	
	Extensive	**4**	
5 Pfankuch channel stability (Worksheet 3-10)	**Good: stable**	**1**	**2**
	Fair: mod unstable	**2**	
	Poor: unstable	**4**	
		Total Points	**7**

	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 ☐

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Buffalo River**			Location: **Buffalo River-1-1.19**			
Observers:	**KD, JB**	Date: **9/27/2011**		Stream Type: **E6**		Valley Type: **X**	
Channel Dimension	Mean bankfull depth (ft): **6.3**	Mean bankfull width (ft): **73.1**	Cross-section area (ft^2): **462.7**	Width of flood-prone area (ft): **196.0**	Entrenchment ratio: **2.7**		
Channel Pattern	Mean: Range:	MWR: **9.3**	Lm/W_{bkf}: **9.3**	Rc/W_{bkf}: **1.3**	Sinuosity: **2.2**		
River Profile and Bed Features	Check: ☐ Riffle/pool ☐ Step/pool ☐ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed						
	Max bankfull depth (ft): Riffle **9.0**, Pool	Depth ratio (max/mean): Riffle **1.4**, Pool	Pool to pool spacing: Ratio	Slope: Valley:	Average bankfull: **3.7E-05**		
Level III Stream Stability Indices	Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:			
	Flow regime: **P-1, 2, 9**	Stream size and order: **S-7**	Meander pattern(s): **M-1**	Depositional pattern(s): **None**	Debris/channel blockage(s): **D1-5**		
	Degree of incision (Bank-Height Ratio): **1.9**	Degree of incision stability rating: **Deeply Incised**	Modified Pfankuch stability rating (numeric and adjective rating): **Fair**				
	Width/depth ratio (W/d): **11.5**	Reference W/d ratio (W/d_{ref}): **11.5**	Width/depth ratio state $(W/d) / (W/d_{ref})$: **1.0**	W/d ratio state stability rating: **Stable**			
	Meander Width Ratio (MWR): **9.3**	Reference MWR_{ref}: **9.3**	Degree of confinement (MWR / MWR_{ref}): **1.0**	MWR / MWR_{ref} stability rating: **Unconfined**			
Bank Erosion Summary	Length of reach studied (ft): **4553**	Annual streambank erosion rate: **709** (tons/yr) **0.16** (tons/yr/ft)	Curve used: **Fig 3-9**	Remarks:			
Sediment Capacity (POWERSED)	☑ Sufficient capacity ☐ Insufficient capacity ☐ Excess capacity			Remarks:			
Entrainment/ Competence	Largest particle from bar sample (mm):	$\tau =$	$\tau^* =$	Existing $depth_{bkf}$:	Required $depth_{bkf}$:	Existing $slope_{bkf}$:	Required $slope_{bkf}$:
Successional Stage Shift	→ → → → →			Existing stream state (type): **E6**	Potential stream state (type): **E6**		
Lateral Stability	☑ Stable ☐ Mod. unstable ☐ Unstable ☐ Highly unstable			Remarks/causes:			
Vertical Stability (Aggradation)	☑ No deposition ☐ Mod. deposition ☐ Ex. deposition ☐ Aggradation			Remarks/causes:			
Vertical Stability (Degradation)	☐ Not incised ☑ Slightly incised ☐ Mod. incised ☐ Degradation			Remarks/causes:			
Channel Enlargement	☑ No increase ☐ Slight increase ☐ Mod. increase ☐ Extensive			Remarks/causes:			
Sediment Supply (Channel Source)	☐ Low ☑ Moderate ☐ High ☐ Very high			Remarks/causes:			

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Lower Rush River**			Location: **Lower Rush River-1-1.10**	
Observers: **KP, AL**	Reference reach	Disturbed (impacted reach) **X**	Date: **9/29/2011**	
Existing species composition:			Potential species composition:	

Riparian cover categories		Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**0%**	**0%**		100%
2. Understory	Shrub layer		**20%**		100%
3. Ground level	Herbaceous		**48%**		100%
	Leaf or needle litter		**2%**	**Remarks:** Condition, vigor and/or usage of existing reach:	
	Bare ground		**30%**		
			Column total = 100%		

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

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Lower Rush River**				Location: **Lower Rush River-1-1.10**				
Observers: **KP, AL**							Date: **9/29/2011**	
List ALL COMBINATIONS that APPLY..............☞	**E1**	**E2**	**E9**					

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order

Stream:	**Lower Rush River**
Location:	**Lower Rush River-1-1.10**
Observers:	**KP, AL**
Date:	**9/29/2011**
Stream Size Category and Order ☞	**S-5**

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).

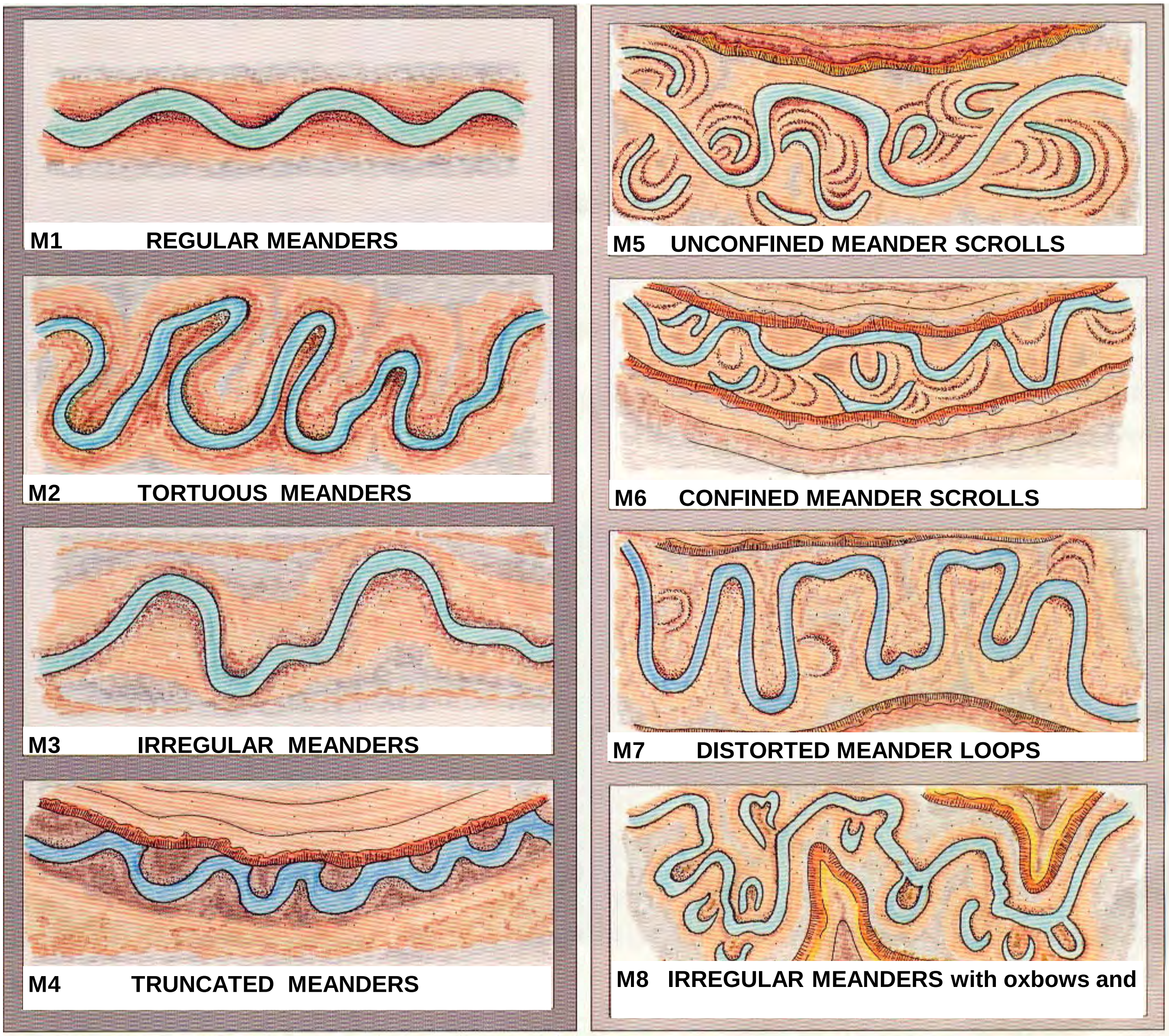
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Lower Rush River**	Reach:	**Lower Rush River-1-1.10**
Observers:	**KP, AL**	Date:	**9/29/2011**

List ALL CATEGORIES that APPLY ☞	M1				

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



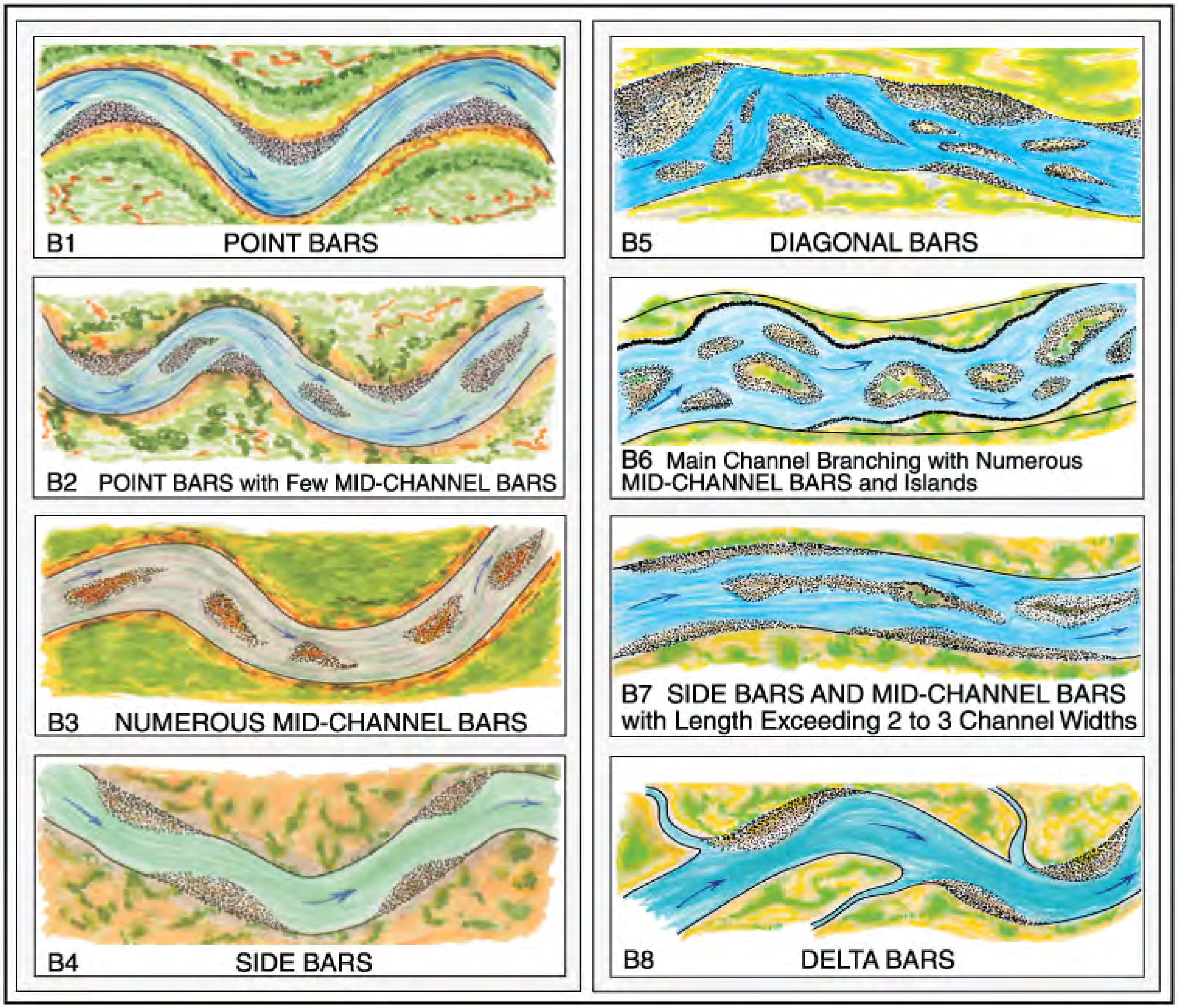
Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns

Stream:	**Lower Rush River**	Reach:	**Lower Rush River-1-1.10**
Observers:	**KP, AL**	Date:	**9/29/2011**

List ALL CATEGORIES that APPLY ☞	N/A				

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

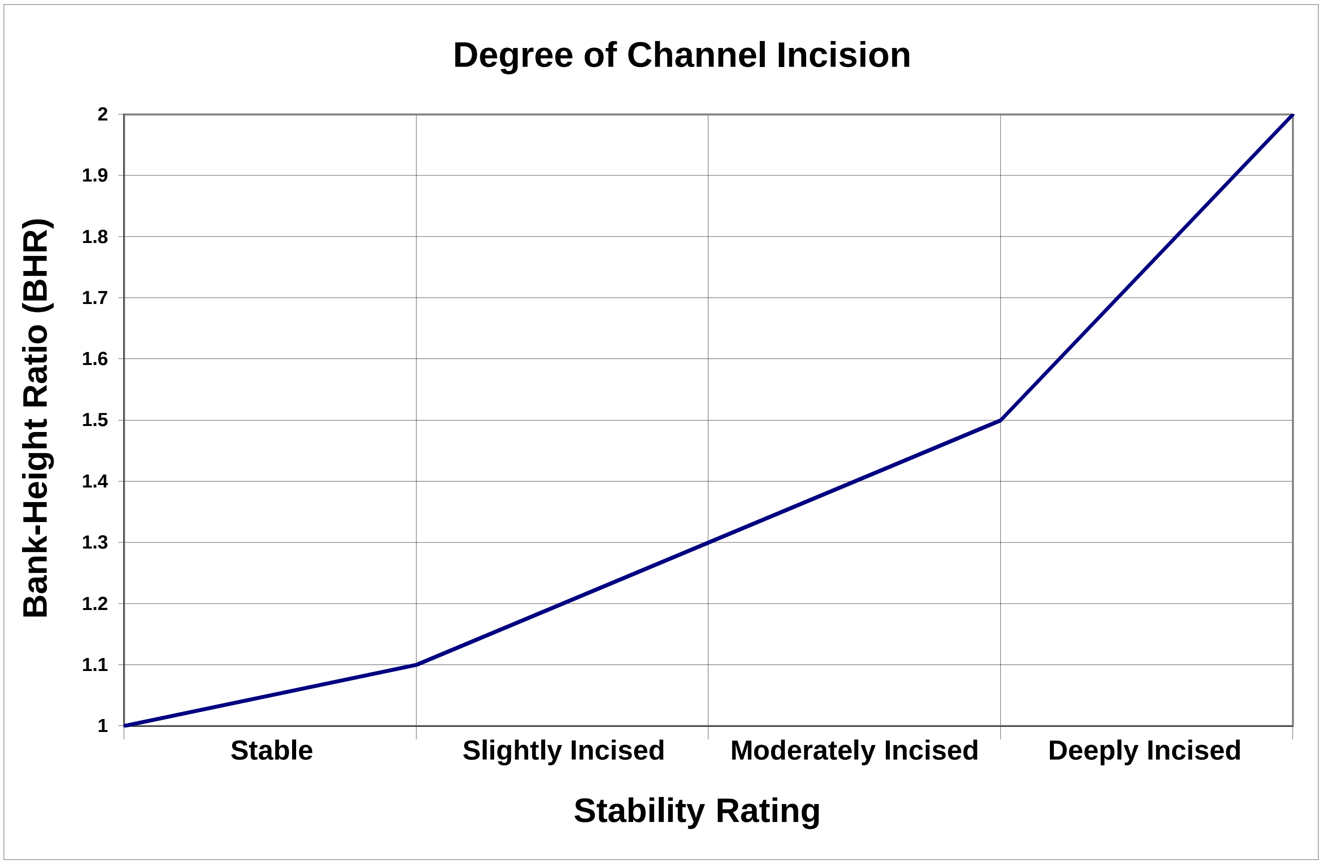


Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Lower Rush River**		Location: **Lower Rush River-1-1.10**	
Observers: **KP, AL**		Date: **9/29/2011**	
Description/extent		**Materials that 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.	☐

Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision			
Low Bank Height:	4.8	Bank-Height Ratio:	1.7
Max Bankfull Depth:	2.868		
Degree of Channel Incision Stability Rating ☞		Deeply Incised	

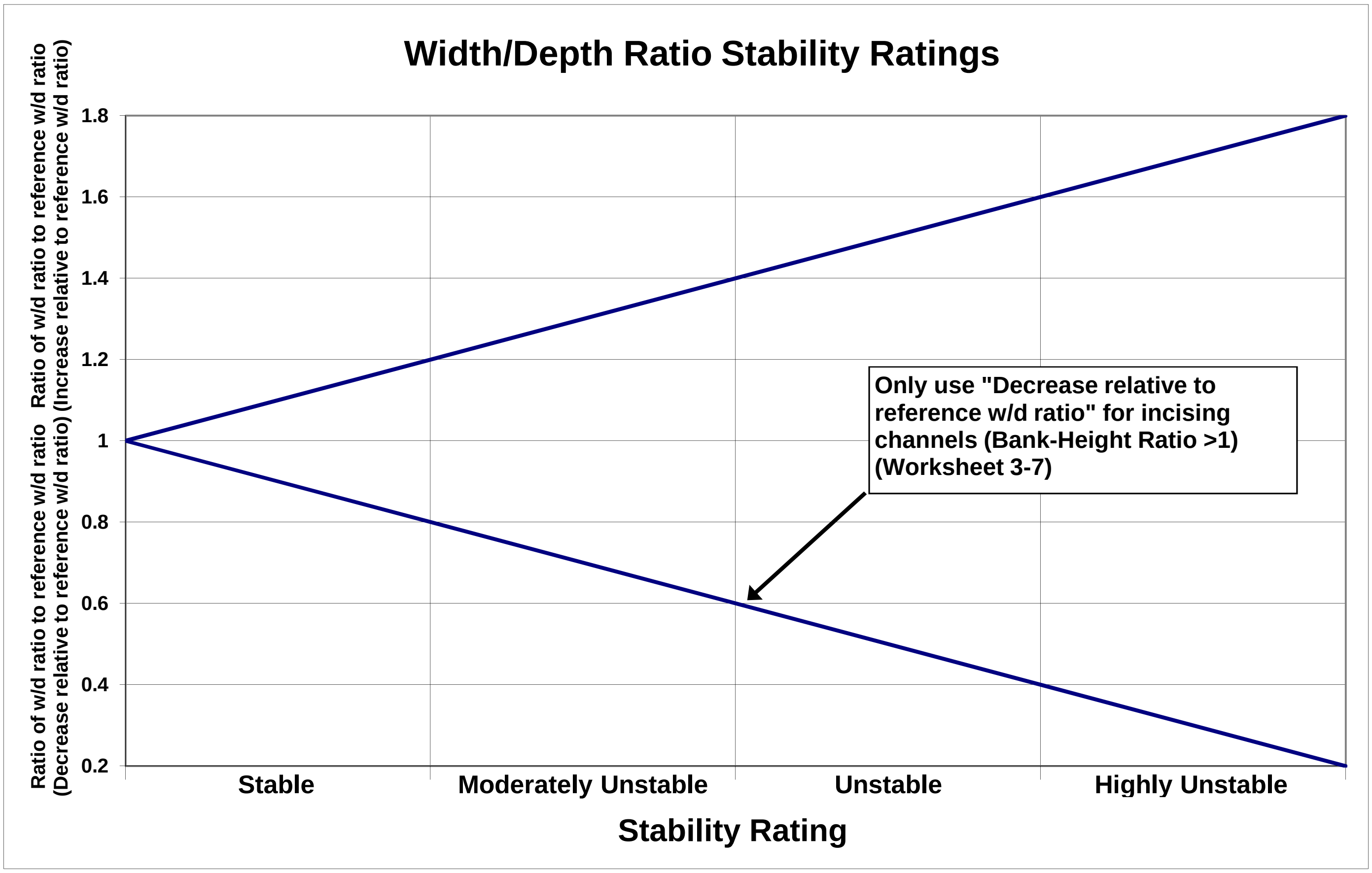


Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State

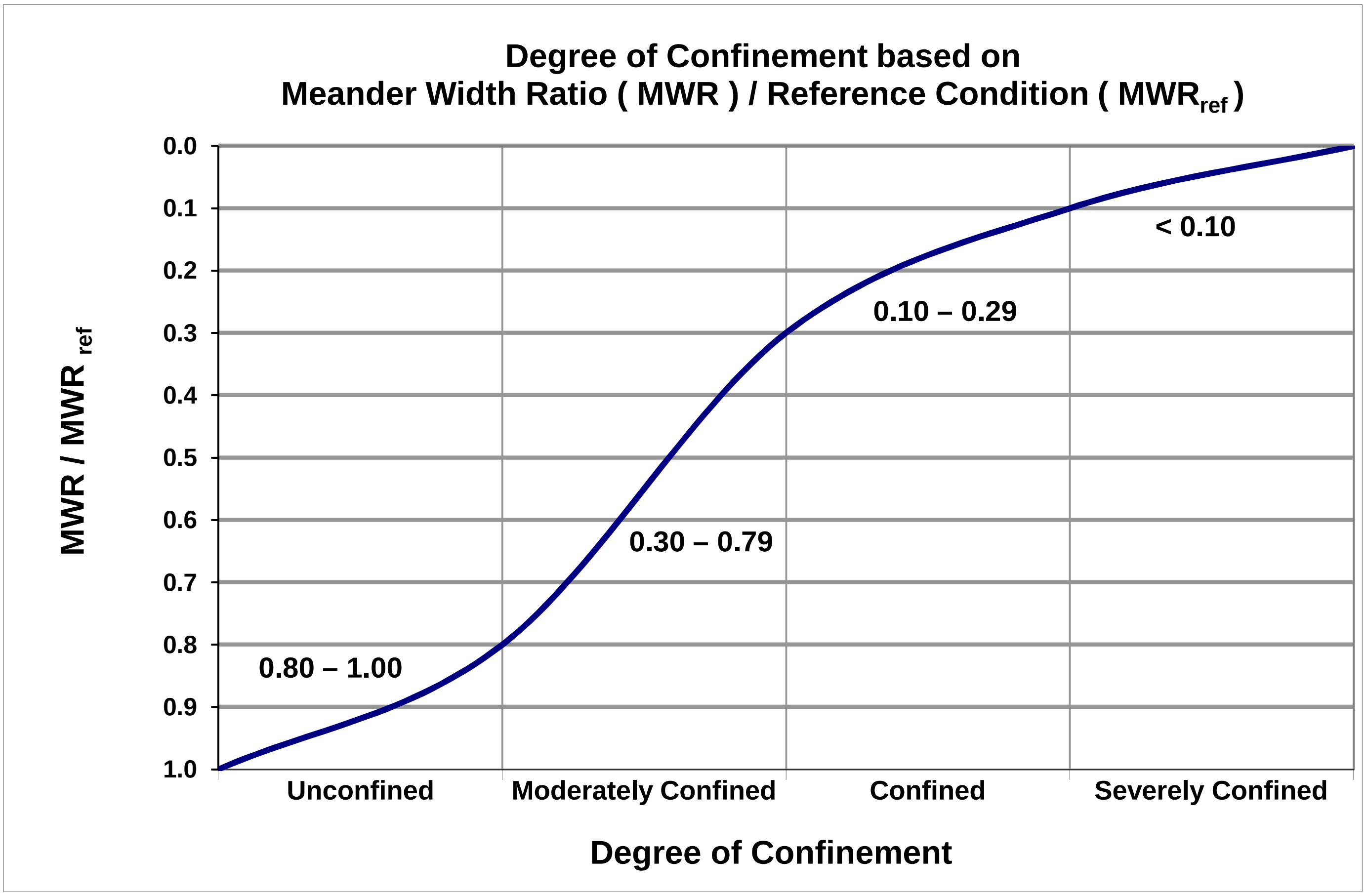
Existing Width/Depth Ratio:	**25.5**	Ratio of existing W/d to reference W/d:	**1**
Reference Width/Depth Ratio:	**25.5**		

Width/Depth Ratio State Stability Rating ☞	**Stable**



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	0.0	Ratio of MWR to MWR_{ref}:	1
Reference Meander Width Ratio (MWR_{ref}):	0.0		
Degree of Confinement Stability Rating ☞		Unconfined	



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Lower Rush River **Location:** Lower Rush River-1-1. **Valley Type:** X **Observers:** KP, AL **Date:** 9/29/2011

Location	Key	Category	Excellent – Description	Excellent – Rating	Good – Description	Good – Rating	Fair – Description	Fair – Rating	Poor – Description	Poor – Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	**2**	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	**6**	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	**2**	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	**6**	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	**2**	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	**2**	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	**4**	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	**31**	**Good total =**	**12**	**Fair total =**	**0**	**Poor total =**	**4**

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	**47**
Existing stream type =	**B6c**
***Potential stream type =**	**B6c**
Modified channel stability rating =	**Good**

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream: **Lower Rush River** Location: **Lower Rush River-1-1.10**

Station: Observers: **KP, AL**

Date: **9/29/2011** Stream Type: **B6c** Valley Type: **X**

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	**5.6** **(A)**	**Bankfull Height** (ft) =	**1.7** **(B)**	(A) / (B) =	**3.3** **(C)**	**10**

Root Depth / Study Bank Height (E)

Root Depth (ft) =	**1** **(D)**	**Study Bank Height** (ft) =	**5.6** **(A)**	(D) / (A) =	**0.2** **(E)**	**7**

Weighted Root Density (G)

Root Density as **%** =	**20%** **(F)**	(F) x (E) =	**4%** **(G)**	**10**

Bank Angle (H)

Bank Angle as *Degrees* =	**10** **(H)**	**1**

Surface Protection (I)

Surface Protection as **%** =	**10%** **(I)**	**9**

Bank Material Adjustment:

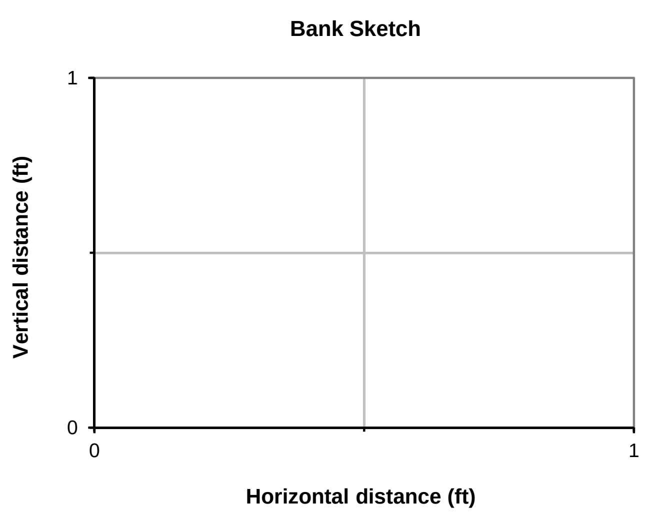
Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

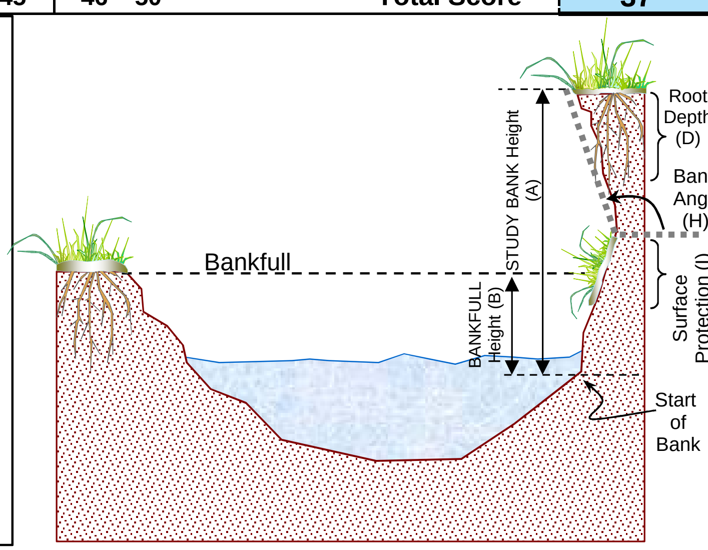
Bank Material Adjustment: **0**

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**: **High** **37**





Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Lower Rush River**	Location: **Lower Rush River-1-1.10**	
Station: **0**	Stream Type: **B6c**	Valley Type: **X**
Observers: **KP, AL**		Date: **9/29/11**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})...	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S).....................................	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})..	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})...........................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient...	Level IV	Validation

Level I

(1)
- Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
- Extensive deposition (continuous, cross-channel)...................................... ....NBS = Extreme
- Chute cutoffs, down-valley meander migration, converging flow...NBS = Extreme

Level II

(2)	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)

(3)	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)

(4)	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)

Dominant Near-Bank Stress
Very Low

Level III

(5)	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)

(6)	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)

Level IV

(7)	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
		Very Low

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating	**Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Lower Rush River**			Location:	**Lower Rush River-1-1.10**		
Graph Used:	**Fig 3-9**		Total Bank Length (ft):	**4743.8**		Date:	**9/29/2011**
Observers:	**KP, AL**		Valley Type:	**X**		Stream Type:	**B6c**
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**4743.8**	**5.6**	**4383**	**0.04**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**4383**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**162**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**211**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.04**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Lower Rush River**	Stream Type:	**B6c**
Location:	**Lower Rush River-1-1.10**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**9/29/2011**

Enter Required Information for Existing Condition

	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
0	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	**#DIV/0!**

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	d	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	S	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Sediment Competence Using Dimensional Shear Stress

0	Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) $\quad d = \dfrac{\tau}{\gamma S}$ τ = predicted shear stress, γ = 62.4, S = existing slope
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) $\quad S = \dfrac{\tau}{\gamma d}$ τ = predicted shear stress, γ = 62.4, d = existing depth

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis | Observers: **KP, AL**

Stream: **Lower Rush River** | Location: **Lower Rush River-1-1.10** | Date: **9/29/2011**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		0		0		0		0		0		0		0		0		0
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		100%

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	0
Materials less than:	mm

Be sure to add separate material weights to grand total

GRAND TOTAL: 0

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Lower Rush River**	Stream Type: **B6c**
Location: **Lower Rush River-1-1.10**	Valley Type: **X**
Observers: **KP, AL**	Date: **9/29/2011**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream:	**Lower Rush River**		Stream Type:	**B6c**	
Location:	**Lower Rush River-1-1.10**		Valley Type:	**X**	
Observers:	**KP, AL**		Date:	**9/29/2011**	

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 3-8)**	< 1.2 (2)	1.2 – 1.4 (4)	1.4 – 1.6 (6)	> 1.6 (8)	**2**
2 **Depositional pattern (Worksheet 3-5)**	B1, B2 (1)	B4, B8 (2)	B3 (3)	B5, B6, B7 (4)	**1**
3 **Meander pattern (Worksheet 3-4)**	M1, M3, M4 (1)		M2, M5, M6, M7, M8 (3)		**1**
4 **Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL (2)	M/L, M/M, M/H, L/Ex, H/L (4)	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL (6)	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex (8)	**4**
5 **Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.8 – 1.0 (1)	0.3 – 0.79 (2)	0.1 – 0.29 (3)	< 0.1 (4)	**1**
				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** ☐

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream: **Lower Rush River**			Stream Type: **B6c**		
Location: **Lower Rush River-1-1.10**			Valley Type: **X**		
Observers: **KP, AL**			Date: **9/29/2011**		
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 3-14)**	Sufficient depth and/or slope to transport largest size available **(2)**	Trend toward insufficient depth and/or slope-slightly incompetent **(4)**	Cannot move D_{35} of bed material and/or D_{100} of bar material **(6)**	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size **(8)**	**2**
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load **(2)**	Trend toward insufficient sediment capacity **(4)**	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand **(6)**	Reduction over 25% of annual sediment yield for bedload and/or suspended sand **(8)**	**2**
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	>1.6 **(8)**	**2**
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation **(2)**	(E→C) **(4)**	(C→High W/d C), (B→High W/d B), (C→F) **(6)**	(C→D), (F→D) **(8)**	**2**
5 **Depositional patterns (Worksheet 3-5)**	B1 **(1)**	B2, B4 **(2)**	B3, B5 **(3)**	B6, B7, B8 **(4)**	**1**
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 **(1)**	D4, D7 **(2)**	D5, D8 **(3)**	D6, D9, D10 **(4)**	**1**
				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** ☐	

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream: **Lower Rush River**			Stream Type:	**B6c**	
Location: **Lower Rush River-1-1.10**			Valley Type:	**X**	
Observers: **KP, AL**			Date:	**9/29/2011**	
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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	**2**
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	**2**
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	**8**
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	**4**
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	**1**
				Total points	**17**
	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** ☐	

Worksheet 3-20. Channel enlargement prediction summary.

Stream:	**Lower Rush River**	Stream Type:	**B6c**
Location:	**Lower Rush River-1-1.10**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**9/29/2011**

Channel enlargement prediction criteria (choose one stability category for each criterion 1–4)	**Channel Enlargement Prediction Categories**				**Selected points** (from each row)
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) (2)	(C→High W/d C), (E→C) (4)	(G→F), (F→D) (6)	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) (8)	2
2 **Lateral stability (Worksheet 3-17)**	Stable (2)	Moderately unstable (4)	Unstable (6)	Highly unstable (8)	2
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition (2)	Moderate deposition (4)	Excess deposition (6)	Aggradation (8)	2
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised (2)	Slightly incised (4)	Moderately incised (6)	Degradation (8)	4
				Total points	**10**

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

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream: **Lower Rush River**		Stream Type:	**B6c**
Location: **Lower Rush River-1-1.10**		Valley Type:	**X**
Observers: **KP, AL**		Date:	**9/29/2011**
Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	**Stability Rating**	**Points**	**Selected Points**
1 Lateral stability (Worksheet 3-17)	**Stable**	**1**	**1**
	Mod. unstable	**2**	
	Unstable	**3**	
	Highly unstable	**4**	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	**No deposition**	**1**	**1**
	Mod. deposition	**2**	
	Excess deposition	**3**	
	Aggradation	**4**	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	**Not incised**	**1**	**2**
	Slightly incised	**2**	
	Mod. Incised	**3**	
	Degradation	**4**	
4 Channel enlargement prediction (Worksheet 3-20)	**No increase**	**1**	**1**
	Slight increase	**2**	
	Mod. increase	**3**	
	Extensive	**4**	
5 Pfankuch channel stability (Worksheet 3-10)	**Good: stable**	**1**	**1**
	Fair: mod unstable	**2**	
	Poor: unstable	**4**	
		Total Points	**6**

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

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Lower Rush River**	Location:	**Lower Rush River-1-1.10**
Observers:	**KP, AL**	Date: **9/29/2011**	Stream Type: **B6c** Valley Type: **X**

Channel Dimension	Mean bankfull depth (ft):	**1.77**	Mean bankfull width (ft):	**45.32**	Cross-section area (ft^2):	**80.5**	Width of flood-prone area (ft):	**72.2**	Entrenchment ratio:	**1.6**
Channel Pattern	Mean: Range:	MWR:	**0.0**	Lm/W_{bkf}:	**0.0**	Rc/W_{bkf}:	**0.0**	Sinuosity:	**0**	

River Profile and Bed Features	Check: ☐ Riffle/pool ☐ Step/pool ☐ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed											
	Max bankfull depth (ft):	Riffle	Pool	Depth ratio (max/mean):	Riffle	Pool	Pool to pool spacing:	Ratio	Slope			
		2.9			**1.6**				Valley:		Average bankfull:	**0.00034**

Level III Stream Stability Indices	Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:				
	Flow regime: **E1, 2, 9**	Stream size and order: **S-5**	Meander pattern(s): **M1**	Depositional pattern(s): **N/A**	Debris/channel blockage(s): **D1**			
	Degree of incision (Bank-Height Ratio):	**1.7**	Degree of incision stability rating:	**Deeply Incised**	Modified Pfankuch stability rating (numeric and adjective rating):	**Good**		
	Width/depth ratio (W/d):	**25.5**	Reference W/d ratio (W/d_{ref}):	**25.5**	Width/depth ratio state $(W/d) / (W/d_{ref})$:	**1.0**	W/d ratio state stability rating:	**Stable**
	Meander Width Ratio (MWR):	**0.0**	Reference MWR_{ref}:	**0.0**	Degree of confinement (MWR / MWR_{ref}):	**1.0**	MWR / MWR_{ref} stability rating:	**Unconfined**

Bank Erosion Summary	Length of reach studied (ft):	**4744**	Annual streambank erosion rate: **211** (tons/yr)	**0.04** (tons/yr/ft)	Curve used: **Fig 3-9**	Remarks:	
Sediment Capacity (POWERSED)	☑ Sufficient capacity	☐ Insufficient capacity	☐ Excess capacity	Remarks:			
Entrainment/ Competence	Largest particle from bar sample (mm):	$\tau =$	$\tau^* =$	Existing $depth_{bkf}$:	Required $depth_{bkf}$:	Existing $slope_{bkf}$:	Required $slope_{bkf}$:
Successional Stage Shift	→ → → → →	Existing stream state (type):	**B6c**	Potential stream state (type):	**B6c**		
Lateral Stability	☑ Stable	☐ Mod. unstable	☐ Unstable	☐ Highly unstable	Remarks/causes:		
Vertical Stability (Aggradation)	☑ No deposition	☐ Mod. deposition	☐ Ex. deposition	☐ Aggradation	Remarks/causes:		
Vertical Stability (Degradation)	☐ Not incised	☑ Slightly incised	☐ Mod. incised	☐ Degradation	Remarks/causes:		
Channel Enlargement	☑ No increase	☐ Slight increase	☐ Mod. increase	☐ Extensive	Remarks/causes:		
Sediment Supply (Channel Source)	☐ Low	☑ Moderate	☐ High	☐ Very high	Remarks/causes:		

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Lower Rush River**	Location: **Lower Rush River-2-6.03**
Observers: **KP, AL**	Reference reach: [ ] / Disturbed (impacted reach): **X** / Date: **11/18/2010**
Existing species composition:	Potential species composition:

	Riparian cover categories	Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**1%**	**1%**		100%
2. Understory	Shrub layer		**14%**		100%
3. Ground level	Herbaceous		**84%**		100%
3. Ground level	Leaf or needle litter		**0%**		
3. Ground level	Bare ground		**1%**		
			Column total = 100%		

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

Remarks:
Condition, vigor and/or usage of existing reach:
None

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Lower Rush River**			Location: **Lower Rush River-2-6.03**					
Observers: **KP, AL**						Date: **11/18/2010**		
List ALL COMBINATIONS that APPLY..............☞	**E1**	**E2**	**E9**					

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order

Stream:	**Lower Rush River**
Location:	**Lower Rush River-2-6.03**
Observers:	**KP, AL**
Date:	**11/18/2010**
Stream Size Category and Order ☞	**S-7**

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).

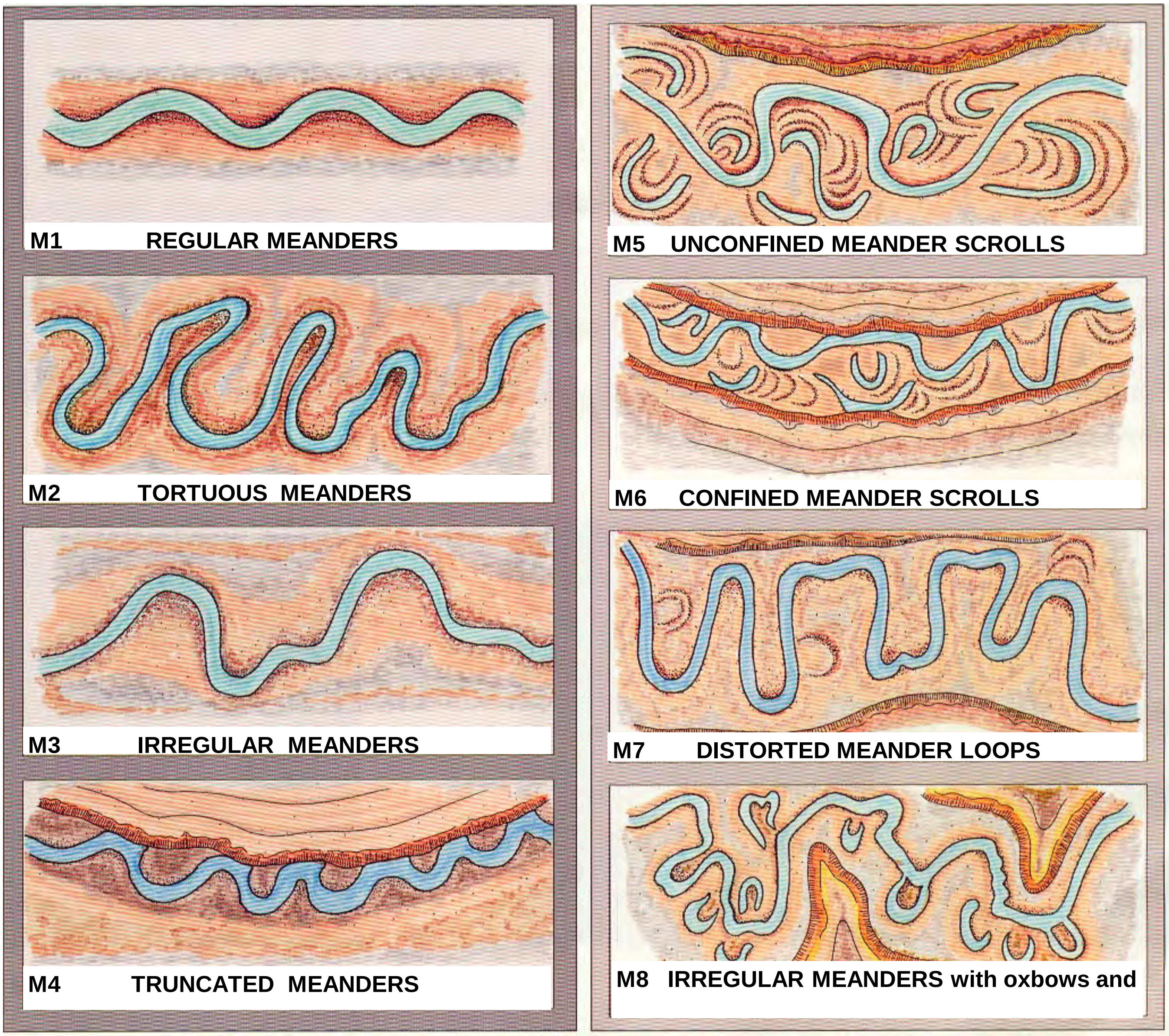
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Lower Rush River**	Reach:	**Lower Rush River-2-6.03**
Observers:	**KP, AL**	Date:	**11/18/2010**

List ALL CATEGORIES that APPLY ☞	**M1**				

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



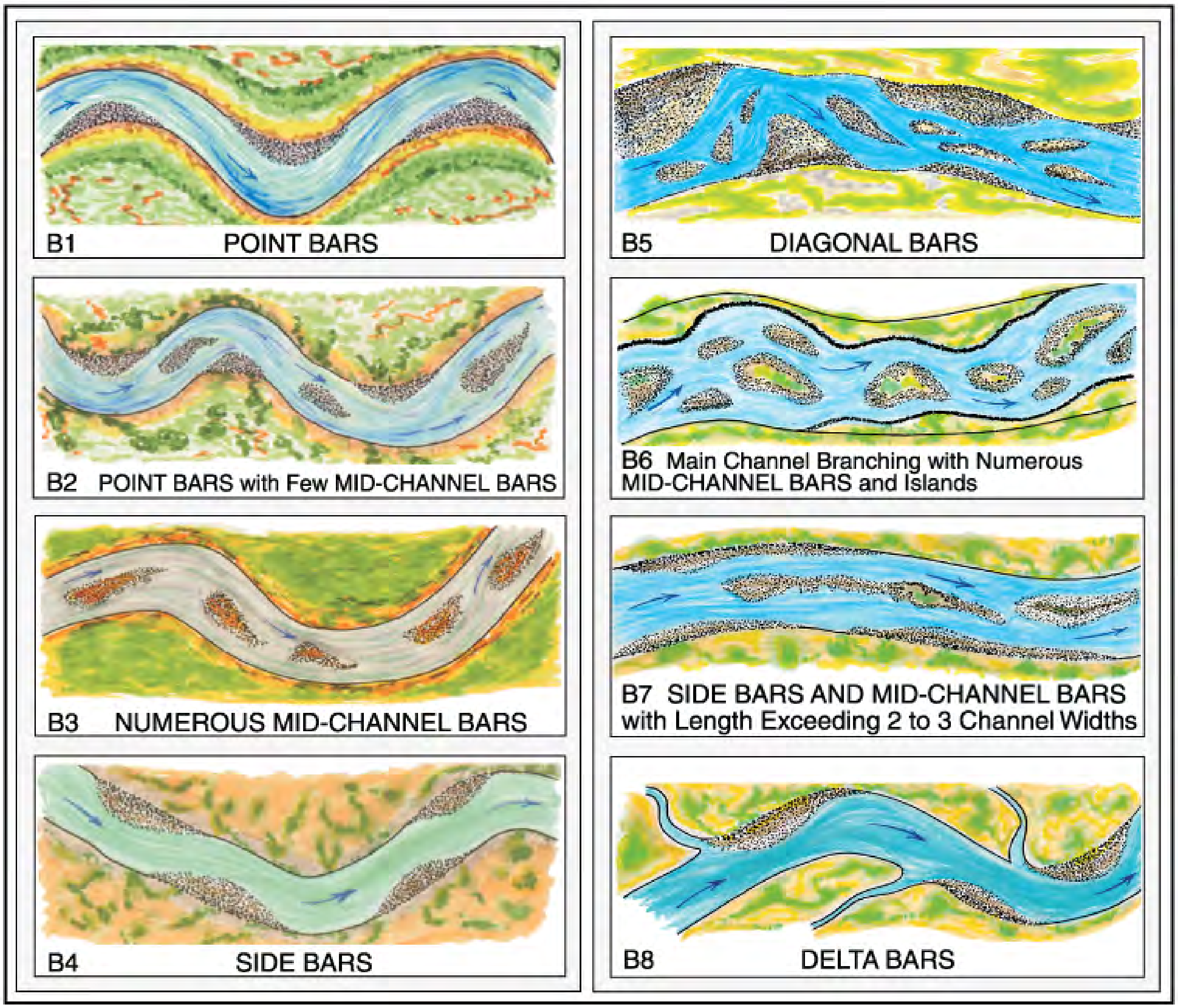
Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns

Stream:	**Lower Rush River**	Reach:	**Lower Rush River-2-6.03**
Observers:	**KP, AL**	Date:	**11/18/2010**

List ALL CATEGORIES that APPLY ☞	**NONE**				

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



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Lower Rush River**		Location: **Lower Rush River-2-6.03**	
Observers: **KP, AL**		Date: **11/18/2010**	
Description/extent		**Materials that 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.	☐

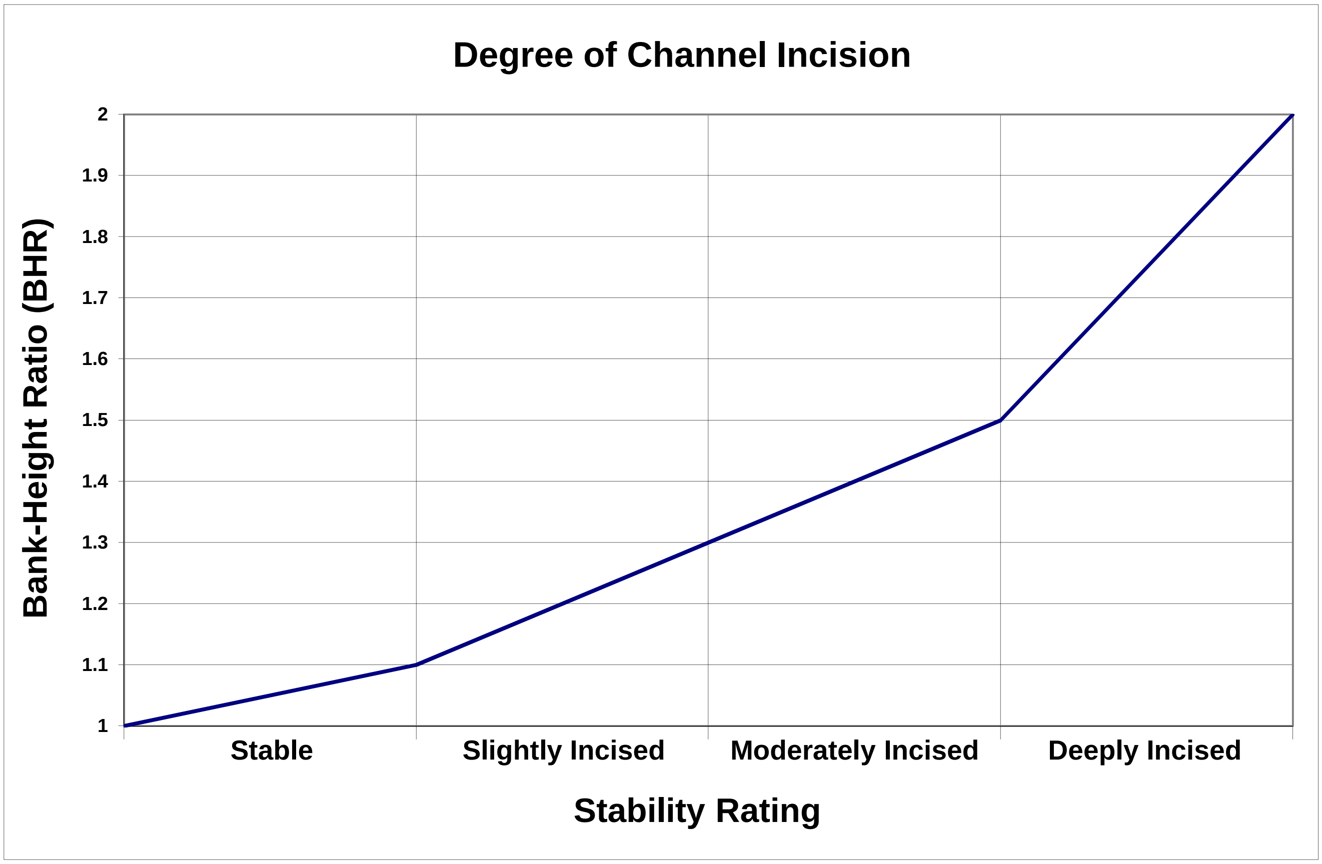
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision

Low Bank Height:	**6.2**
Max Bankfull Depth:	**2.89**

Bank-Height Ratio:	**2.1**

Degree of Channel Incision Stability Rating ☞	**Deeply Incised**

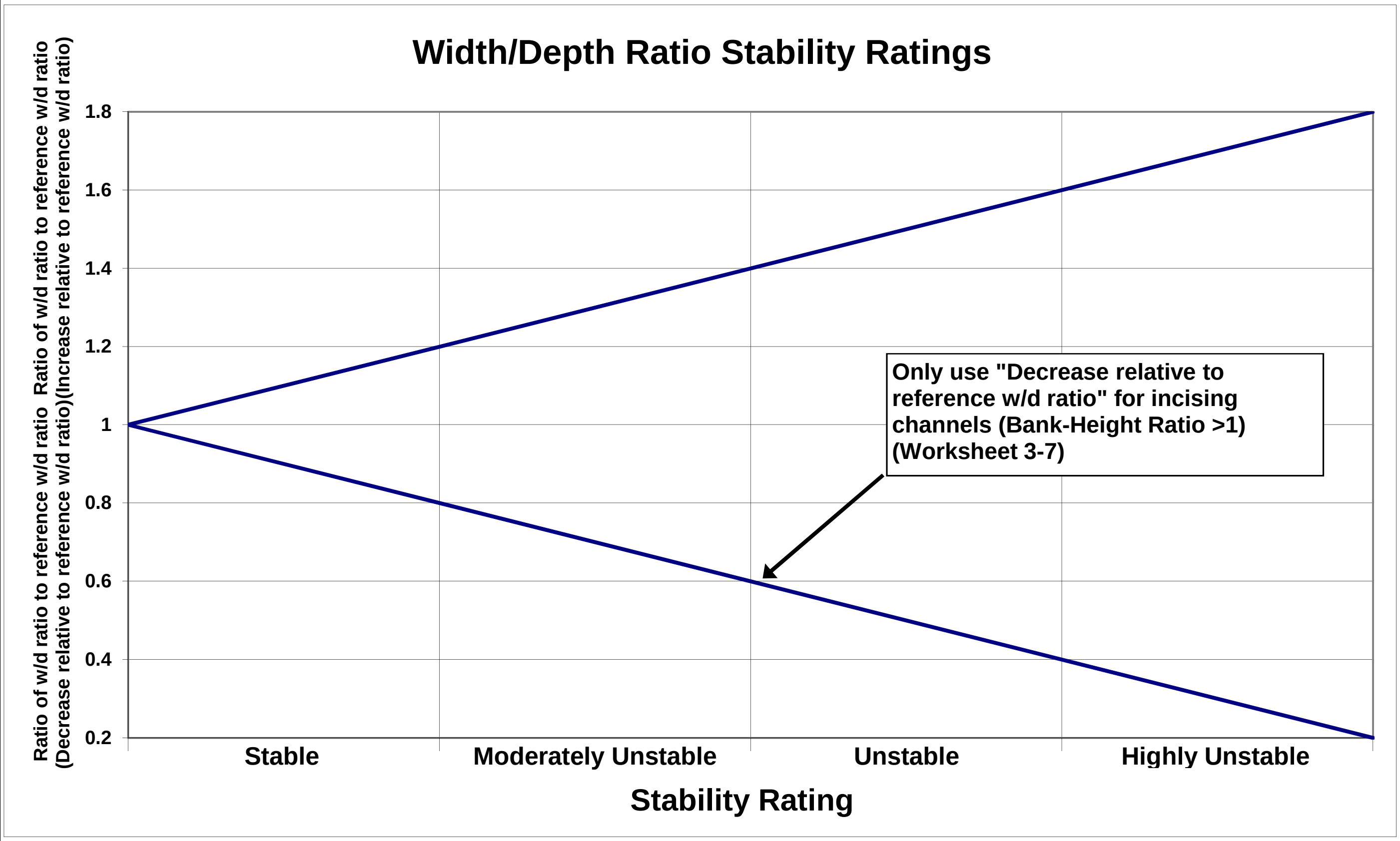


Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State

Existing Width/Depth Ratio:	38.7	Ratio of existing W/d to reference W/d:	0.881
Reference Width/Depth Ratio:	43.9		

Width/Depth Ratio State Stability Rating ☞ **Stable**

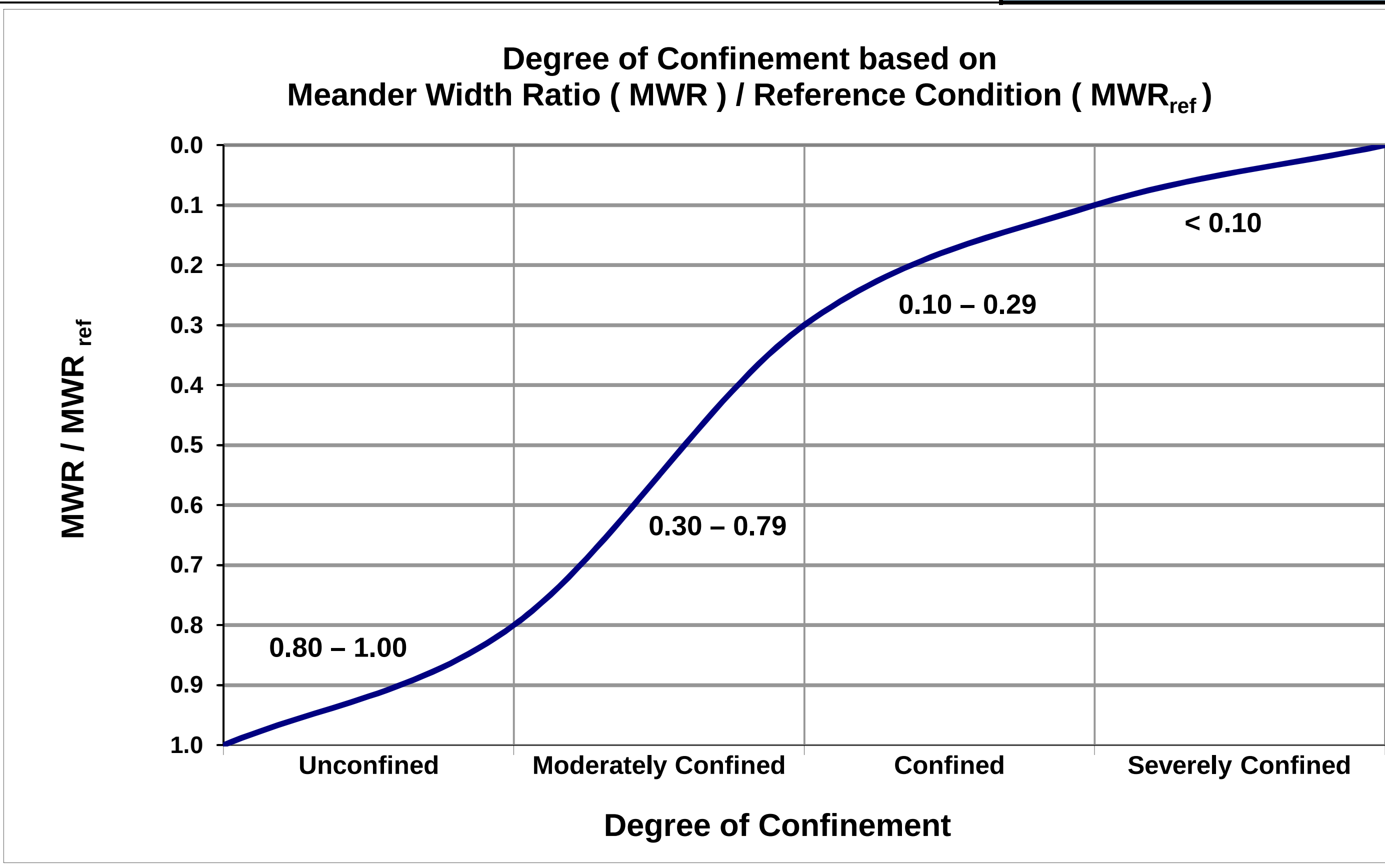


Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement

Existing Meander Width Ratio (MWR):	**24.3**	Ratio of MWR to MWR_{ref}:	**1.314**
Reference Meander Width Ratio (MWR_{ref}):	**18.5**		

Degree of Confinement Stability Rating ☞	**Unconfined**



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Lower Rush River **Location:** Lower Rush River-2-6. **Valley Type:** X **Observers:** KP, AL **Date:** 11/18/2010

Location	Key	Category	Excellent Description	Excellent Rating	Good Description	Good Rating	Fair Description	Fair Rating	Poor Description	Poor Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	**2**	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	**3**	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	**2**	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	**3**	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	**2**	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	**2**	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	**4**	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	**37**	**Good total =**	**0**	**Fair total =**	**0**	**Poor total =**	**4**

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	**41**
Existing stream type =	**B6c**
***Potential stream type =**	**B6c**
Modified channel stability rating =	**Good**

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream: **Lower Rush River** Location: **Lower Rush River-2-6.03**

Station: **6.26** Observers: **KP, AL**

Date: **11/18/2010** Stream Type: **B6c** Valley Type: **X**

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	**6.9** **(A)**	**Bankfull Height** (ft) =	**2.3** **(B)**	(A) / (B) =	**3.0** **(C)**	**9**

Root Depth / Study Bank Height (E)

Root Depth (ft) =	**1** **(D)**	**Study Bank Height** (ft) =	**6.9** **(A)**	(D) / (A) =	**0.1** **(E)**	**8**

Weighted Root Density (G)

Root Density as **%** =	**25%** **(F)**	(F) x (E) =	**4%** **(G)**	**10**

Bank Angle (H)

Bank Angle as *Degrees* =	**8** **(H)**	**1**

Surface Protection (I)

Surface Protection as **%** =	**0%** **(I)**	**10**

Bank Material Adjustment:

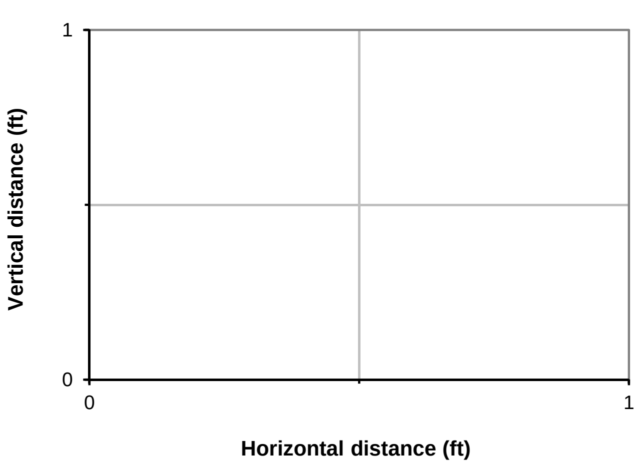
Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

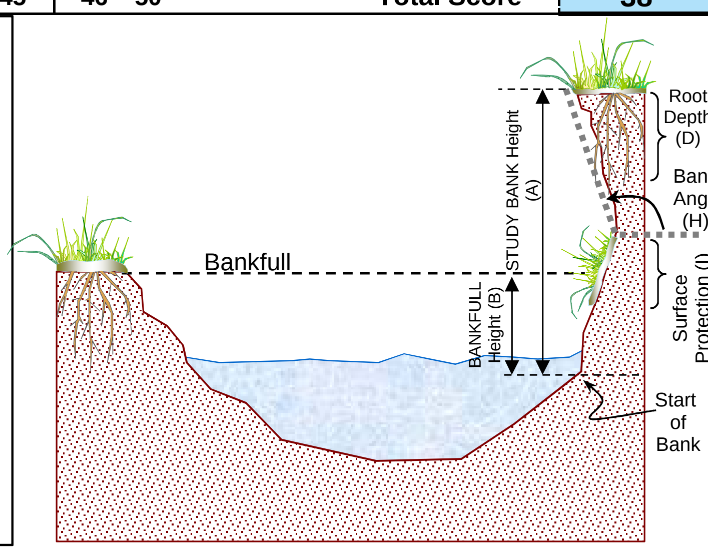
Bank Material Adjustment: **0**

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** **38**

Bank Sketch





Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Lower Rush River** | Location: **Lower Rush River-2-6.03**

Station: **6.26** | Stream Type: **B6c** | Valley Type: **X**

Observers: **KP, AL** | Date: **11/18/10**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})................................	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S)................................	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})................................	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf}).........................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient................................	Level IV	Validation

Level I

(1)
- Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
- Extensive deposition (continuous, cross-channel)................................ ....NBS = Extreme
- Chute cutoffs, down-valley meander migration, converging flow....................................NBS = Extreme

Level II

(2)

Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)

(3)

Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)

(4)

Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)

Dominant Near-Bank Stress
Very Low

Level III

(5)

Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)

(6)

Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)

Level IV

(7)

Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
	Very Low

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating | **Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	Lower Rush River			Location: Lower Rush River-2-6.03			
Graph Used:	Fig 3-9	Total Bank Length (ft): 4828.7				Date: 11/18/2010	
Observers:	KP, AL		Valley Type: X			Stream Type: B6c	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	High	Very Low	0.165	4828.7	6.9	5497	0.05
2.						0	#DIV/0!
3.						0	#DIV/0!
4.						0	#DIV/0!
5.						0	#DIV/0!
6.						0	#DIV/0!
7.						0	#DIV/0!
8.						0	#DIV/0!
9.						0	#DIV/0!
10.						0	#DIV/0!
11.						0	#DIV/0!
12.						0	#DIV/0!
13.						0	#DIV/0!
14.						0	#DIV/0!
15.						0	#DIV/0!
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	5497	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	204	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	265	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	0.05	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Lower Rush River**	Stream Type:	**B6c**
Location:	**Lower Rush River-2-6.03**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**11/18/2010**

Enter Required Information for Existing Condition

	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
0	D_{max}	Largest particle from bar sample (ft)		(mm)	304.8 mm/ft
0.00038	S	Existing bankfull water surface slope (ft/ft)			
0	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1: $\tau^* = 0.0834\ (D_{50}/\hat{D}_{50})^{-0.872}$	
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2: $\tau^* = 0.0384\ (D_{max}/D_{50})^{-0.887}$	
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	#DIV/0!

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	d	Required bankfull mean depth (ft) $d = \frac{\tau^* \gamma_s D_{max}}{S}$ (use D_{max} in ft)
		Check: ☐ Stable ☐ Aggrading ☐ Degrading

Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	S	Required bankfull water surface slope (ft/ft) $S = \frac{\tau^* \gamma_s D_{max}}{d}$ (use D_{max} in ft)
		Check: ☐ Stable ☐ Aggrading ☐ Degrading

Sediment Competence Using Dimensional Shear Stress

0	Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**
0	Predicted mean depth required to initiate movement of measured D_{max} (mm) $d = \frac{\tau}{\gamma S}$ τ = predicted shear stress, γ = 62.4, S = existing slope
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) $S = \frac{\tau}{\gamma d}$ τ = predicted shear stress, γ = 62.4, d = existing depth

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis

Observers: **KP, AL**

Stream: **Lower Rush River** | Location: **Lower Rush River-2-6.03** | Date: **11/18/2010**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																				
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				
11																				
12																				
13																				
14																				
15																				
Net wt. total		0		0		0		0		0		0		0		0		0		0
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		#####		100%

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	0
Materials less than:	mm

Be sure to add separate material weights to grand total

GRAND TOTAL: 0

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Lower Rush River**	Stream Type: **B6c**
Location: **Lower Rush River-2-6.03**	Valley Type: **X**
Observers: **KP, AL**	Date: **11/18/2010**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream:	**Lower Rush River**	Stream Type:	**B6c**
Location:	**Lower Rush River-2-6.03**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**11/18/2010**

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 3-8)**	< 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	> 1.6 **(8)**	**2**
2 **Depositional pattern (Worksheet 3-5)**	B1, B2 **(1)**	B4, B8 **(2)**	B3 **(3)**	B5, B6, B7 **(4)**	**1**
3 **Meander pattern (Worksheet 3-4)**	M1, M3, M4 **(1)**		M2, M5, M6, M7, M8 **(3)**		**1**
4 **Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL **(2)**	M/L, M/M, M/H, L/Ex, H/L **(4)**	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL **(6)**	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex **(8)**	**4**
5 **Degree of confinement (MWR / MWR$_{ref}$) (Worksheet 3-9)**	0.8 – 1.0 **(1)**	0.3 – 0.79 **(2)**	0.1 – 0.29 **(3)**	< 0.1 **(4)**	**1**
				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** ☐	

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Lower Rush River**			Stream Type:	**B6c**	
Location:	**Lower Rush River-2-6.03**			Valley Type:	**X**	
Observers:	**KP, AL**			Date:	**11/18/2010**	

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 3-14)**	Sufficient depth and/or slope to transport largest size available **(2)**	Trend toward insufficient depth and/or slope-slightly incompetent **(4)**	Cannot move D_{35} of bed material and/or D_{100} of bar material **(6)**	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size **(8)**	**2**
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load **(2)**	Trend toward insufficient sediment capacity **(4)**	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand **(6)**	Reduction over 25% of annual sediment yield for bedload and/or suspended sand **(8)**	**2**
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	>1.6 **(8)**	**2**
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation **(2)**	(E→C) **(4)**	(C→High W/d C), (B→High W/d B), (C→F) **(6)**	(C→D), (F→D) **(8)**	**2**
5 **Depositional patterns (Worksheet 3-5)**	B1 **(1)**	B2, B4 **(2)**	B3, B5 **(3)**	B6, B7, B8 **(4)**	**1**
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 **(1)**	D4, D7 **(2)**	D5, D8 **(3)**	D6, D9, D10 **(4)**	**1**
				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** ☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream:	**Lower Rush River**	Stream Type:	**B6c**
Location:	**Lower Rush River-2-6.03**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**11/18/2010**

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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	2
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	2
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	8
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	4
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	1
				Total points	**17**

	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 ☐

Worksheet 3-20. Channel enlargement prediction summary.

Stream:	**Lower Rush River**			Stream Type:	**B6c**
Location:	**Lower Rush River-2-6.03**			Valley Type:	**X**
Observers:	**KP, AL**			Date:	**11/18/2010**

Channel enlargement prediction criteria (choose one stability category for each criterion 1–4)	**Channel Enlargement Prediction Categories**				**Selected points** (from each row)
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) (2)	(C→High W/d C), (E→C) (4)	(G→F), (F→D) (6)	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) (8)	2
2 **Lateral stability (Worksheet 3-17)**	Stable (2)	Moderately unstable (4)	Unstable (6)	Highly unstable (8)	2
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition (2)	Moderate deposition (4)	Excess deposition (6)	Aggradation (8)	2
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised (2)	Slightly incised (4)	Moderately incised (6)	Degradation (8)	4
				Total points	**10**

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

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream:	**Lower Rush River**	Stream Type:	**B6c**
Location:	**Lower Rush River-2-6.03**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**11/18/2010**

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	Stability Rating	Points	Selected Points
1 Lateral stability (Worksheet 3-17)	Stable	1	1
	Mod. unstable	2	
	Unstable	3	
	Highly unstable	4	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition	1	1
	Mod. deposition	2	
	Excess deposition	3	
	Aggradation	4	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	2
	Slightly incised	2	
	Mod. Incised	3	
	Degradation	4	
4 Channel enlargement prediction (Worksheet 3-20)	No increase	1	1
	Slight increase	2	
	Mod. increase	3	
	Extensive	4	
5 Pfankuch channel stability (Worksheet 3-10)	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 ☐

Worksheet 3-22. Summary of stability condition categories.

Stream: **Lower Rush River**		Location: **Lower Rush River-2-6.03**	
Observers: **KP, AL**	Date: **11/18/2010**	Stream Type: **B6c**	Valley Type: **X**

Channel Dimension					
	Mean bankfull depth (ft): **1.63**	Mean bankfull width (ft): **63.11**	Cross-section area (ft^2): **108.6**	Width of flood-prone area (ft): **90.5**	Entrenchment ratio:

Channel Pattern				
Mean: / Range:	MWR: **24.3**	Lm/W_{bkf}: **24.3**	Rc/W_{bkf}: **3.6**	Sinuosity: **1.28**

River Profile and Bed Features

Check: ☐ Riffle/pool ☐ Step/pool ☑ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed

Max bankfull depth (ft):	Riffle	Pool	Depth ratio (max/mean):	Riffle	Pool	Pool to pool spacing:	Ratio	Slope	
	2.9			**1.8**				Valley:	Average bankfull: **6.6E-05**

Level III Stream Stability Indices

Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:

Flow regime: **E1, 2, 9**	Stream size and order: **S-7**	Meander pattern(s): **M1**	Depositional pattern(s): **NONE**	Debris/channel blockage(s): **D1**

Degree of incision (Bank-Height Ratio): **2.1**	Degree of incision stability rating: **Deeply Incised**	Modified Pfankuch stability rating (numeric and adjective rating): **Good**

Width/depth ratio (W/d): **38.7**	Reference W/d ratio (W/d_{ref}): **43.9**	Width/depth ratio state $(W/d) / (W/d_{ref})$: **0.9**	W/d ratio state stability rating: **Stable**
Meander Width Ratio (MWR): **24.3**	Reference MWR_{ref}: **18.5**	Degree of confinement (MWR / MWR_{ref}): **1.3**	MWR / MWR_{ref} stability rating: **Unconfined**

Bank Erosion Summary				
Length of reach studied (ft): **4829**	Annual streambank erosion rate: **265** (tons/yr)	**0.05** (tons/yr/ft)	Curve used: **Fig 3-9**	Remarks:

Sediment Capacity (POWERSED)

☑ Sufficient capacity ☐ Insufficient capacity ☐ Excess capacity — Remarks:

Entrainment/ Competence						
Largest particle from bar sample (mm):	$\tau =$	$\tau^* =$	Existing $depth_{bkf}$:	Required $depth_{bkf}$:	Existing $slope_{bkf}$:	Required $slope_{bkf}$:

Successional Stage Shift

→ → → → → Existing stream state (type): **B6c** Potential stream state (type): **B6c**

		Remarks/causes:
Lateral Stability	☑ Stable ☐ Mod. unstable ☐ Unstable ☐ Highly unstable	**None**
Vertical Stability (Aggradation)	☑ No deposition ☐ Mod. deposition ☐ Ex. deposition ☐ Aggradation	**None**
Vertical Stability (Degradation)	☐ Not incised ☑ Slightly incised ☐ Mod. incised ☐ Degradation	**None**
Channel Enlargement	☑ No increase ☐ Slight increase ☐ Mod. increase ☐ Extensive	**None**
Sediment Supply (Channel Source)	☐ Low ☑ Moderate ☐ High ☐ Very high	**None**

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Maple River**			Location: **Maple River-1-0.78**		
Observers: **KP, AL**		Reference reach [ ]	Disturbed (impacted reach) [X]	Date: **11/16/2010**	
Existing species composition:			Potential species composition:		

Riparian cover categories		Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**5%**	**1%**		
					100%
2. Understory	Shrub layer		**58%**		
					100%
3. Ground level	Herbaceous		**36%**		
					100%
	Leaf or needle litter				
	Bare ground		**5%**		
			Column total = 100%		

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

Remarks:
Condition, vigor and/or usage of existing reach:

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Maple River**	Location: **Maple River-1-0.78**							
Observers: **KP, AL**	Date: **11/16/2010**							
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P7**	**P9**				

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order

Stream:	**Maple River**
Location:	**Maple River-1-0.78**
Observers:	**KP, AL**
Date:	**11/16/2010**
Stream Size Category and Order ☞	**S-6**

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).

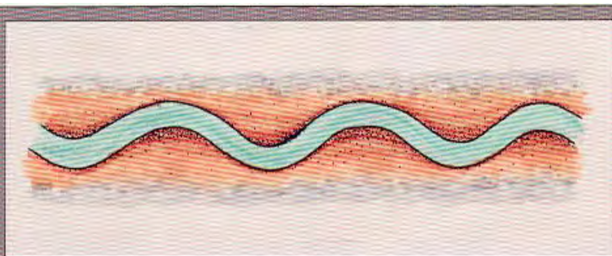
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Maple River**	Reach:	**Maple River-1-0.78**
Observers:	**KP, AL**	Date:	**11/16/2010**

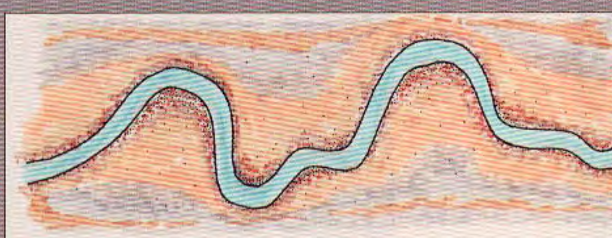
List ALL CATEGORIES that APPLY ☞	**M2**				

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

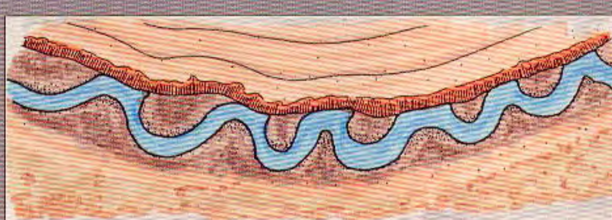


M1 REGULAR MEANDERS

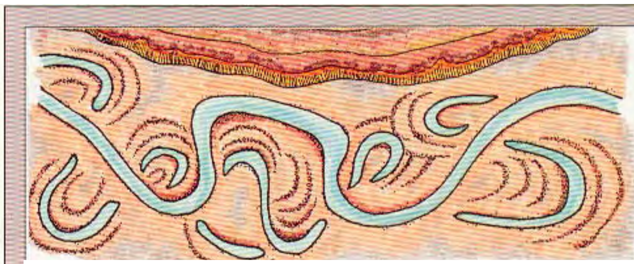
M2 TORTUOUS MEANDERS



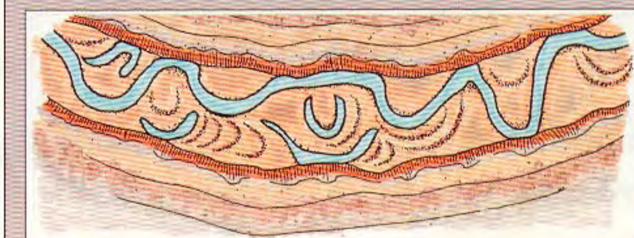
M3 IRREGULAR MEANDERS



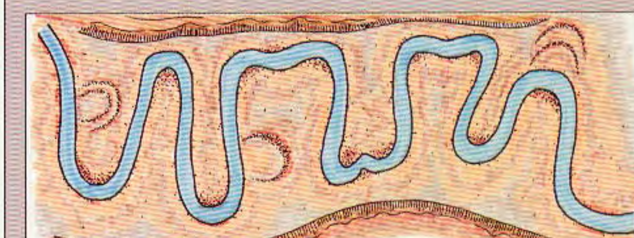
M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS



M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

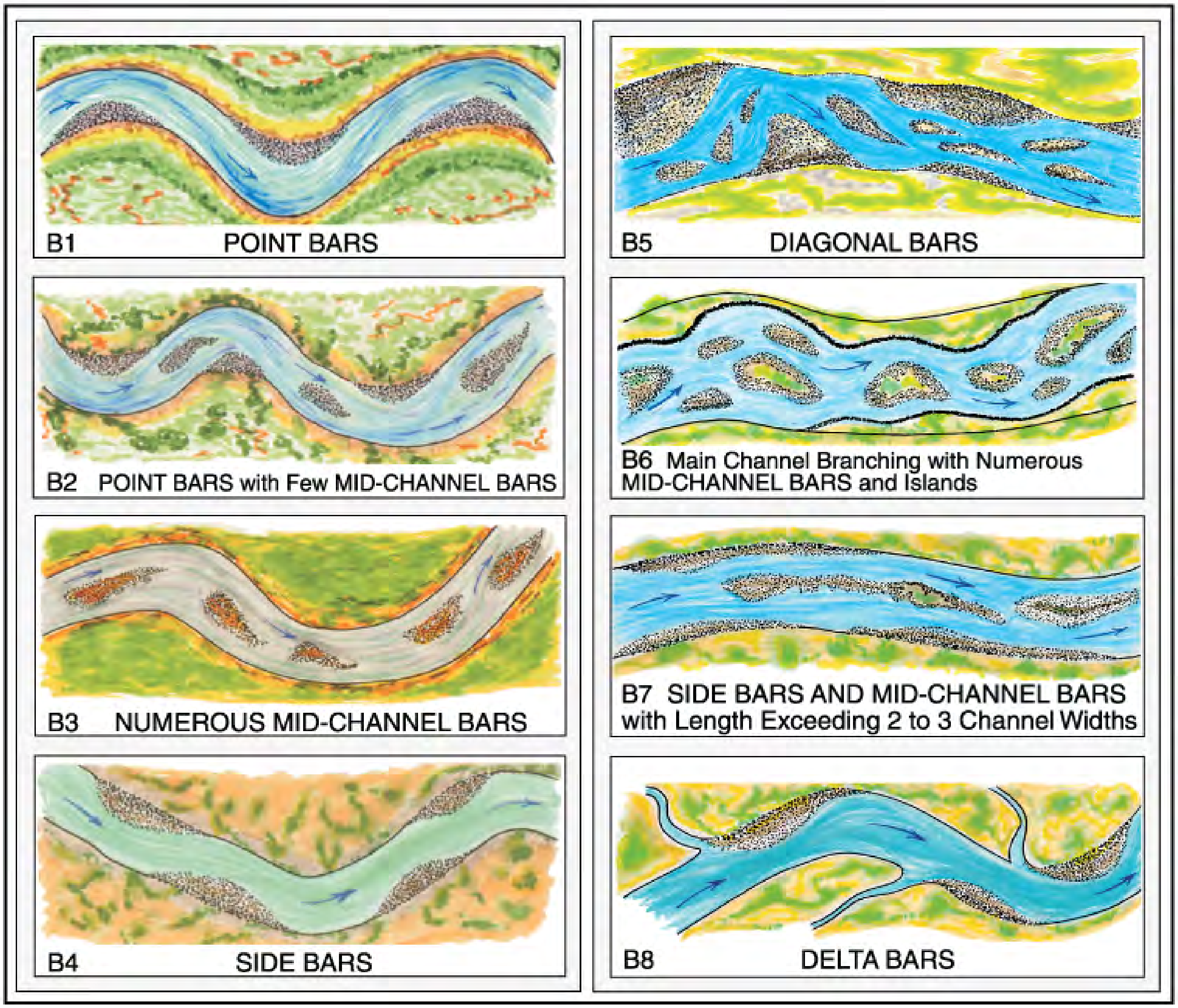
Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns

Stream:	**Maple River**	Reach:	**Maple River-1-0.78**
Observers:	**KP, AL**	Date:	**11/16/2010**

List ALL CATEGORIES that APPLY ☞	NONE				

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

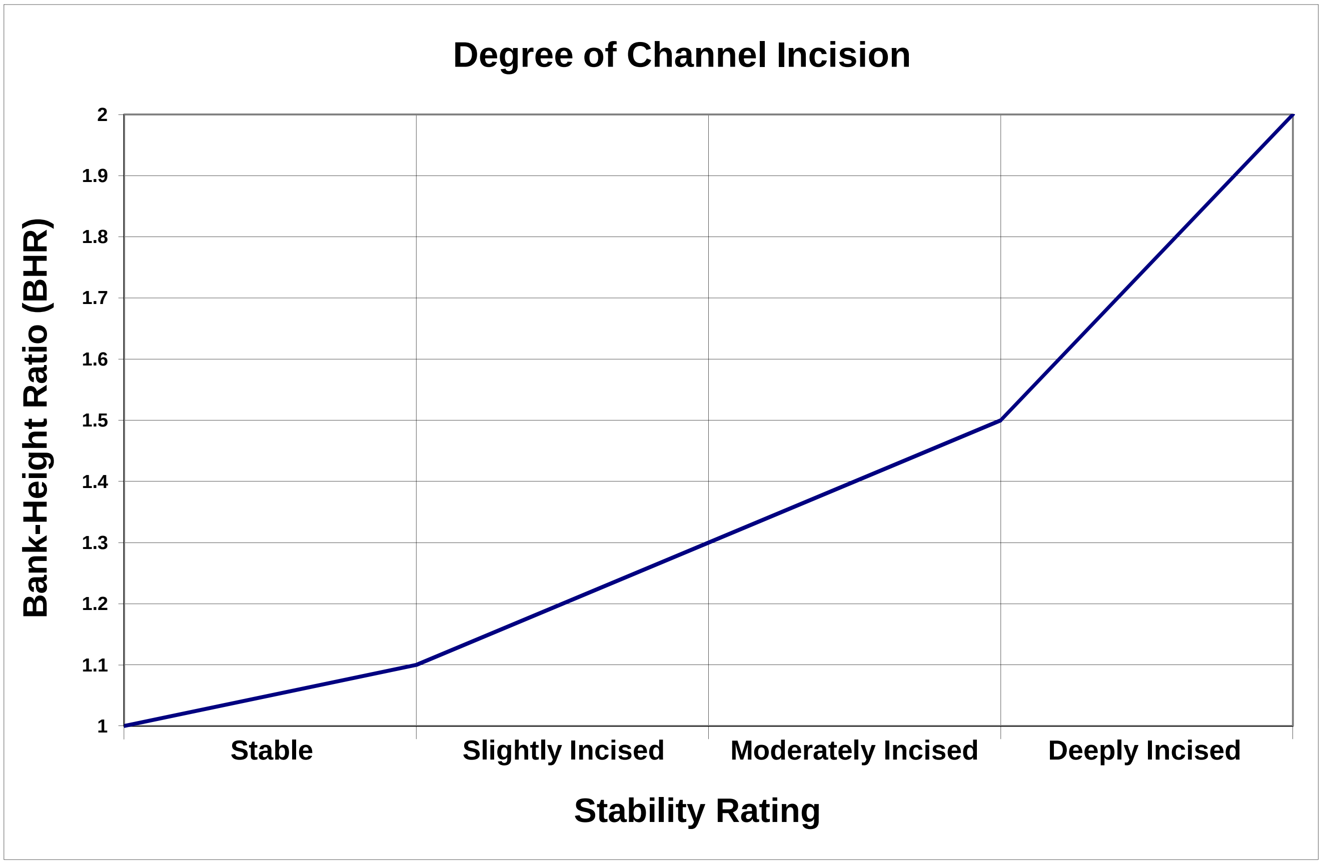


Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Maple River**		Location: **Maple River-1-0.78**	
Observers: **KP, AL**		Date: **11/16/2010**	
Description/extent		**Materials that 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.	☐

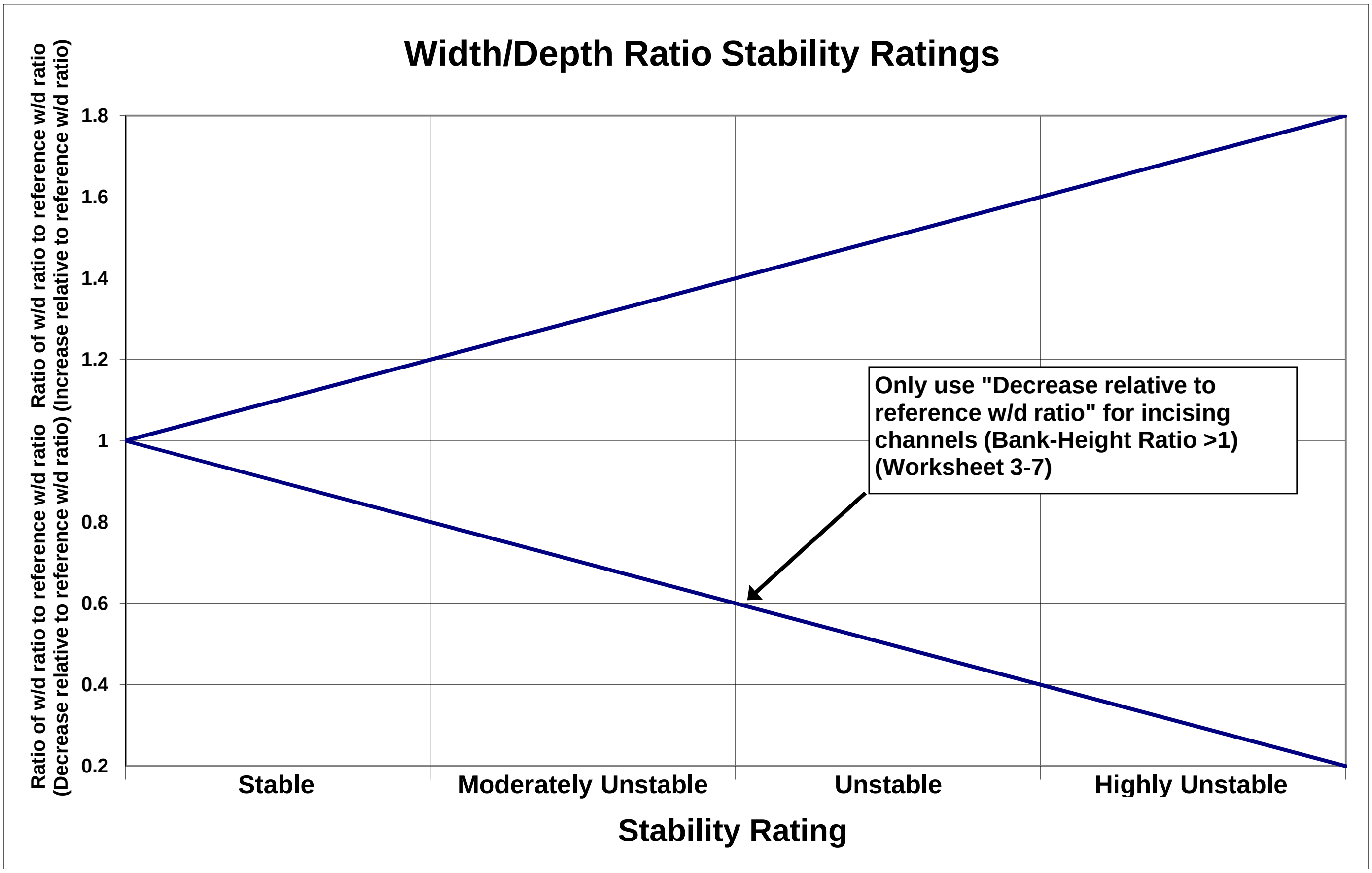
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision			
Low Bank Height:	**10.2**	Bank-Height Ratio:	**1.1**
Max Bankfull Depth:	**9.113**		
Degree of Channel Incision Stability Rating ☞		**Stable**	



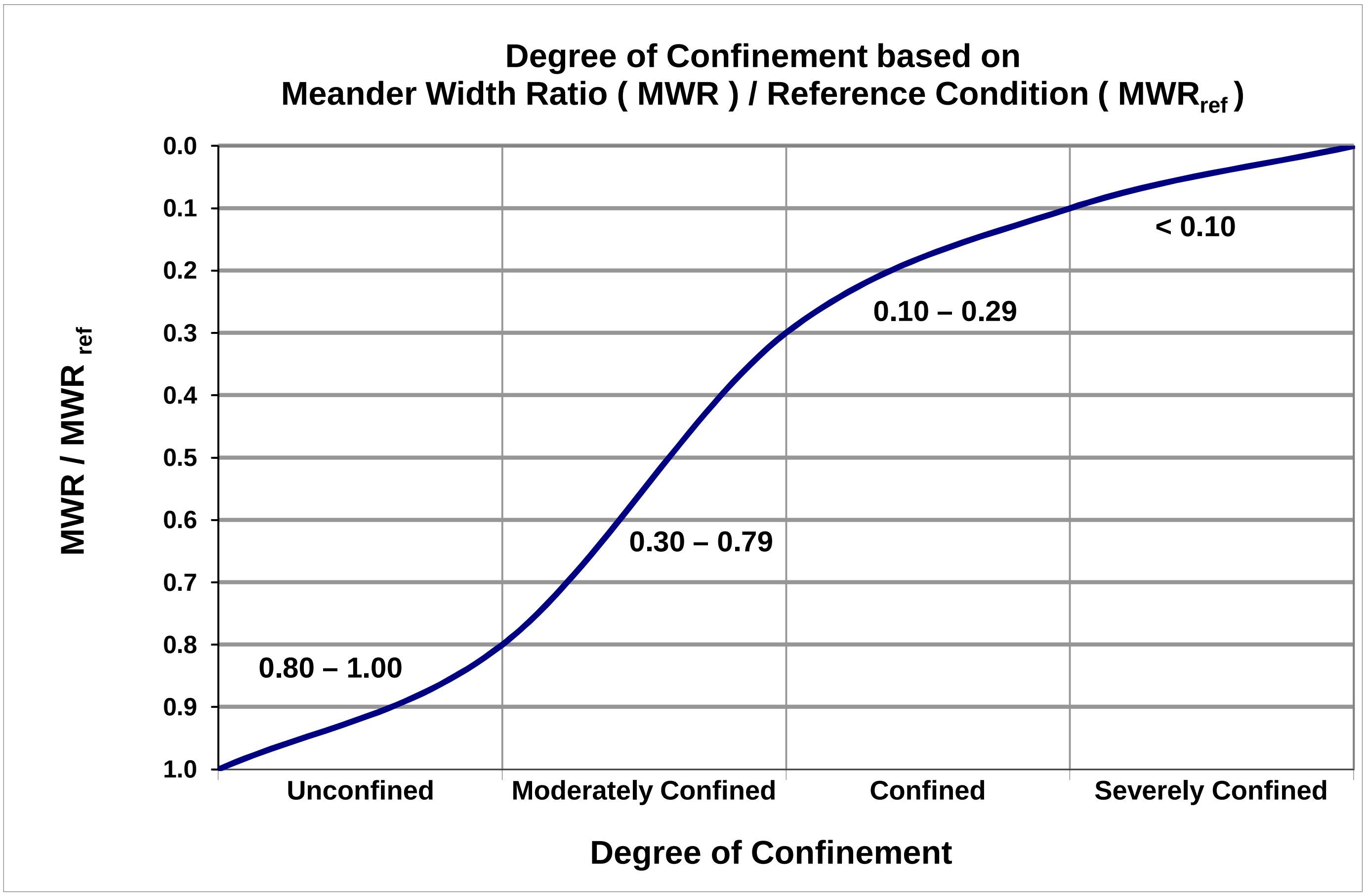
Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State			
Existing Width/Depth Ratio:	11.7	Ratio of existing W/d to reference W/d:	1.027
Reference Width/Depth Ratio:	11.4		
Width/Depth Ratio State Stability Rating ☞		Stable	



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	10.8	Ratio of MWR to MWR_{ref}:	0.977
Reference Meander Width Ratio (MWR_{ref}):	11.0		
Degree of Confinement Stability Rating ☞		Unconfined	



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Maple River | **Location:** Maple River-1-0.78 | **Valley Type:** | **Observers:** KP, AL | **Date:** ='WS 3-1'!N6

Location	Key	Category	Excellent Description	Excellent Rating	Good Description	Good Rating	Fair Description	Fair Rating	Poor Description	Poor Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	**6**	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	**9**	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	**4**	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	**6**	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	**2**	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	**4**	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	**12**	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	21	Good total =	14	Fair total =	27	Poor total =	4

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	66
Existing stream type =	E6
*Potential stream type =	E6
Modified channel stability rating =	Fair

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream:	**Maple River**	Location:	**Maple River-1-0.78**
Station:		Observers:	**KP, AL**
Date: **11/16/2010**	Stream Type: **E6**	Valley Type: **X**	

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	11.4 **(A)**	**Bankfull Height** (ft) =	6.9 **(B)**	(A) / (B) =	1.7 **(C)**	**7**

Root Depth / Study Bank Height (E)

Root Depth (ft) =	1.5 **(D)**	**Study Bank Height** (ft) =	11.4 **(A)**	(D) / (A) =	0.1 **(E)**	**8**

Weighted Root Density (G)

Root Density as **%** =	25% **(F)**	(F) x (E) =	3% **(G)**	**10**

Bank Angle (H)

Bank Angle as *Degrees* =	27 **(H)**	**2**

Surface Protection (I)

Surface Protection as **%** =	10% **(I)**	**10**

Bank Material Adjustment:

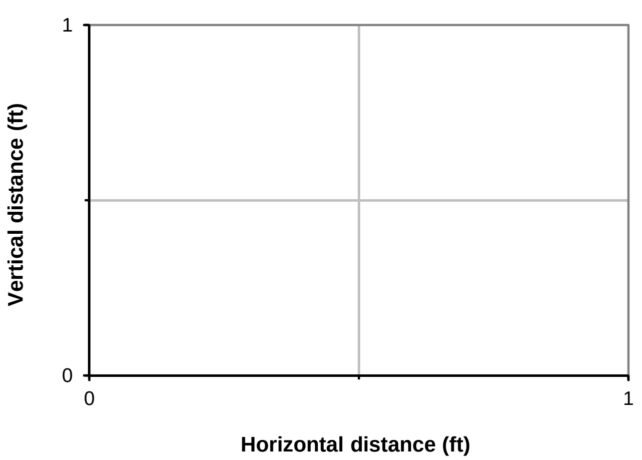
Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

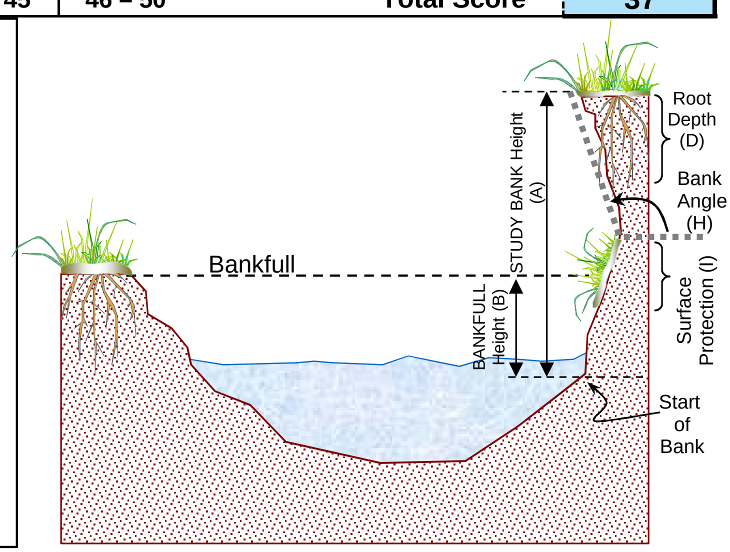
Bank Material Adjustment: **0**

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**	**High**
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50	**and Total Score**	**37**

Bank Sketch





Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Maple River** Location: **Maple River-1-0.78**

Station: **0** Stream Type: **E6** Valley Type: **X**

Observers: **KP, AL** Date: **11/16/10**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})...	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S).....................................	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})..	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})............................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient..	Level IV	Validation

Level I

(1)
- Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
- Extensive deposition (continuous, cross-channel)..................................... ....NBS = Extreme
- Chute cutoffs, down-valley meander migration, converging flow...NBS = Extreme

Level II

(2)

Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)

(3)

Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)

(4)

Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)

Dominant Near-Bank Stress
Very Low

Level III

(5)

Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)

(6)

Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)

Level IV

(7)

Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
	Very Low

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating **Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Maple River**			Location:	**Maple River-1-0.78**		
Graph Used:	**Fig 3-9**	Total Bank Length (ft):	**5624.5**			Date:	**11/16/2010**
Observers:	**KP, AL**	Valley Type:	**X**			Stream Type:	**E6**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**5624.5**	**11.4**	**10580**	**0.09**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**10580**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**392**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**509**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.09**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Maple River**			Stream Type:	**E6**
Location:	**Maple River-1-0.78**			Valley Type:	**X**
Observers:	**KP, AL**			Date:	**11/16/2010**
Enter Required Information for Existing Condition					
	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			
Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress					
#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\ (D_{50}/\hat{D}_{50})^{-0.872}$	
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\ (D_{max}/D_{50})^{-0.887}$	
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress		EQUATION USED:	**#DIV/0!**
Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample					
#DIV/0!	d	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)	
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample					
#DIV/0!	S	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)	
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Sediment Competence Using Dimensional Shear Stress					
0	Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope				
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**				
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**				
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope			$d = \dfrac{\tau}{\gamma S}$	
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth			$S = \dfrac{\tau}{\gamma d}$	

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis	Observers: **KP, AL**
Stream: **Maple River** — Location: **Maple River-1-0.78**	Date: **11/16/2010**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		0		0		0		0		0		0		0		0		0
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		100%

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	0
Materials less than:	mm

Be sure to add separate material weights to grand total

GRAND TOTAL: 0

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Maple River**	Stream Type: **E6**
Location: **Maple River-1-0.78**	Valley Type: **X**
Observers: **KP, AL**	Date: **11/16/2010**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream:	**Maple River**	Stream Type:	**E6**
Location:	**Maple River-1-0.78**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**11/16/2010**

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 3-8)**	< 1.2 (2)	1.2 – 1.4 (4)	1.4 – 1.6 (6)	> 1.6 (8)	2
2 **Depositional pattern (Worksheet 3-5)**	B1, B2 (1)	B4, B8 (2)	B3 (3)	B5, B6, B7 (4)	1
3 **Meander pattern (Worksheet 3-4)**	M1, M3, M4 (1)		M2, M5, M6, M7, M8 (3)		3
4 **Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL (2)	M/L, M/M, M/H, L/Ex, H/L (4)	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL (6)	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex (8)	4
5 **Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.8 – 1.0 (1)	0.3 – 0.79 (2)	0.1 – 0.29 (3)	< 0.1 (4)	1
				Total points	**11**

	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** ☐

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Maple River**	Stream Type:	**E6**
Location:	**Maple River-1-0.78**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**11/16/2010**

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 3-14)**	Sufficient depth and/or slope to transport largest size available **(2)**	Trend toward insufficient depth and/or slope-slightly incompetent **(4)**	Cannot move D_{35} of bed material and/or D_{100} of bar material **(6)**	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size **(8)**	**2**
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load **(2)**	Trend toward insufficient sediment capacity **(4)**	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand **(6)**	Reduction over 25% of annual sediment yield for bedload and/or suspended sand **(8)**	**2**
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	>1.6 **(8)**	**2**
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation **(2)**	(E→C) **(4)**	(C→High W/d C), (B→High W/d B), (C→F) **(6)**	(C→D), (F→D) **(8)**	**2**
5 **Depositional patterns (Worksheet 3-5)**	B1 **(1)**	B2, B4 **(2)**	B3, B5 **(3)**	B6, B7, B8 **(4)**	**1**
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 **(1)**	D4, D7 **(2)**	D5, D8 **(3)**	D6, D9, D10 **(4)**	**3**
				Total points	**12**

	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** ☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream:	**Maple River**	Stream Type:	**E6**
Location:	**Maple River-1-0.78**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**11/16/2010**

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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	2
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	2
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	2
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	2
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	1
				Total points	**9**

	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** ☐

Worksheet 3-20. Channel enlargement prediction summary.

Stream:	Maple River			Stream Type:	E6	
Location:	Maple River-1-0.78			Valley Type:	X	
Observers:	KP, AL			Date:	11/16/2010	
Channel enlargement prediction criteria (choose one stability category for each criterion 1–4)	**Channel Enlargement Prediction Categories**				**Selected points** (from each row)	
	No increase	**Slight increase**	**Moderate increase**	**Extensive**		
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) **(2)**	(C→High W/d C), (E→C) **(4)**	(G→F), (F→D) **(6)**	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) **(8)**	**2**	
2 **Lateral stability (Worksheet 3-17)**	Stable **(2)**	Moderately unstable **(4)**	Unstable **(6)**	Highly unstable **(8)**	**4**	
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition **(2)**	Moderate deposition **(4)**	Excess deposition **(6)**	Aggradation **(8)**	**2**	
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised **(2)**	Slightly incised **(4)**	Moderately incised **(6)**	Degradation **(8)**	**2**	
				Total points	**10**	
	Category point range					
Channel enlargement prediction (use total points and check stability rating)	**No increase 8 – 10** ☑	**Slight increase 11 – 16** ☐	**Moderate increase 17 – 24** ☐	**Extensive > 24** ☐		

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream: **Maple River**		Stream Type:	**E6**
Location: **Maple River-1-0.78**		Valley Type:	**X**
Observers: **KP, AL**		Date:	**11/16/2010**

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	Stability Rating	Points	Selected Points
1 Lateral stability (Worksheet 3-17)	Stable	1	3
	Mod. unstable	**2**	
	Unstable	3	
	Highly unstable	4	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	**No deposition**	**1**	1
	Mod. deposition	2	
	Excess deposition	3	
	Aggradation	4	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	**Not incised**	**1**	1
	Slightly incised	2	
	Mod. Incised	3	
	Degradation	4	
4 Channel enlargement prediction (Worksheet 3-20)	**No increase**	**1**	1
	Slight increase	2	
	Mod. increase	3	
	Extensive	4	
5 Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	2
	Fair: mod unstable	**2**	
	Poor: unstable	4	
		Total Points	8

	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 ☐

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Maple River**	Location:	**Maple River-1-0.78**
Observers:	**KP, AL**	Date: **11/16/2010**	Stream Type: **E6** Valley Type: **X**

Channel Dimension	Mean bankfull depth (ft): **5.84**	Mean bankfull width (ft): **68.49**	Cross-section area (ft^2): **399.1**	Width of flood-prone area (ft): **377.25**	Entrenchment ratio: **5.5**
Channel Pattern	Mean: Range: MWR: **10.8**	Lm/W_{bkf}: **10.8**	Rc/W_{bkf}: **2.2**	Sinuosity: **2.15**	

River Profile and Bed Features

Check: [ ] Riffle/pool [ ] Step/pool [x] Plane bed [ ] Convergence/divergence [x] Dunes/antidunes/smooth bed

Max bankfull depth (ft): Riffle	Pool	Depth ratio (max/mean): Riffle	Pool	Pool to pool spacing: Ratio	Slope: Valley	Slope: Average bankfull
9.1		**1.6**				**0.00011**

Level III Stream Stability Indices

Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:

Flow regime: **P1, 2, 7, 9**	Stream size and order: **S-6**	Meander pattern(s): **M2**	Depositional pattern(s): **NONE**	Debris/channel blockage(s): **D1, 5**
Degree of incision (Bank-Height Ratio): **0.8**	Degree of incision stability rating: **Stable**	Modified Pfankuch stability rating (numeric and adjective rating): **Fair**		
Width/depth ratio (W/d): **11.7**	Reference W/d ratio (W/d_{ref}): **11.4**	Width/depth ratio state (W/d) / (W/d_{ref}): **1.0**	W/d ratio state stability rating: **Stable**	
Meander Width Ratio (MWR): **10.8**	Reference MWR_{ref}: **11.0**	Degree of confinement (MWR / MWR_{ref}): **1.0**	MWR / MWR_{ref} stability rating: **Unconfined**	

Bank Erosion Summary	Length of reach studied (ft): **5625**	Annual streambank erosion rate: **509** (tons/yr) **0.09** (tons/yr/ft)	Curve used: **Fig 3-9**	Remarks:
Sediment Capacity (POWERSED)	[x] Sufficient capacity [ ] Insufficient capacity [ ] Excess capacity			Remarks:
Entrainment/ Competence	Largest particle from bar sample (mm):	$\tau =$	$\tau^* =$	Existing $depth_{bkf}$: Required $depth_{bkf}$: Existing $slope_{bkf}$: Required $slope_{bkf}$:
Successional Stage Shift	→ → → → →	Existing stream state (type): **E6**	Potential stream state (type): **E6**	
Lateral Stability	[ ] Stable [x] Mod. unstable [ ] Unstable [ ] Highly unstable		Remarks/causes: **None**	
Vertical Stability (Aggradation)	[x] No deposition [ ] Mod. deposition [ ] Ex. deposition [ ] Aggradation		Remarks/causes: **None**	
Vertical Stability (Degradation)	[x] Not incised [ ] Slightly incised [ ] Mod. incised [ ] Degradation		Remarks/causes: **None**	
Channel Enlargement	[x] No increase [ ] Slight increase [ ] Mod. increase [ ] Extensive		Remarks/causes: **None**	
Sediment Supply (Channel Source)	[ ] Low [x] Moderate [ ] High [ ] Very high		Remarks/causes: **None**	

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Maple River**			Location: **Maple River - 2 - 11.39**	
Observers: **KP, AL**	Reference reach [ ]	Disturbed (impacted reach) [X]	Date: **11/20/2010**	
Existing species composition:			Potential species composition:	

Riparian cover categories		Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer				
					100%
2. Understory	Shrub layer				
					100%
3. Ground level	Herbaceous				
					100%
	Leaf or needle litter				
	Bare ground				
			Column total = 100%		

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

Remarks:
Condition, vigor and/or usage of existing reach:
None

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Maple River**	Location: **Maple River - 2 - 11.39**							
Observers: **KP, AL**	Date: **11/20/2010**							
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P7**	**P9**				

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order

Stream:	**Maple River**
Location:	**Maple River - 2 - 11.39**
Observers:	**KP, AL**
Date:	**11/20/2010**
Stream Size Category and Order ☞	**S-6**

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).

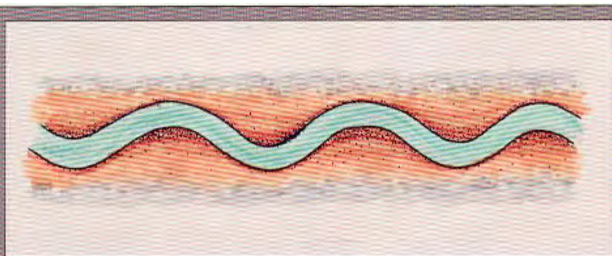
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Maple River**	Reach:	**Maple River - 2 - 11.39**
Observers:	**KP, AL**	Date:	**11/20/2010**

List ALL CATEGORIES that APPLY ☞	**M1**				

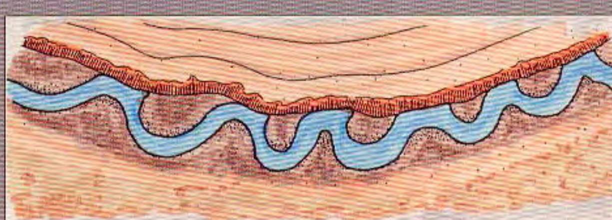
Various Meander Pattern variables modified from Galay et al. (1973)



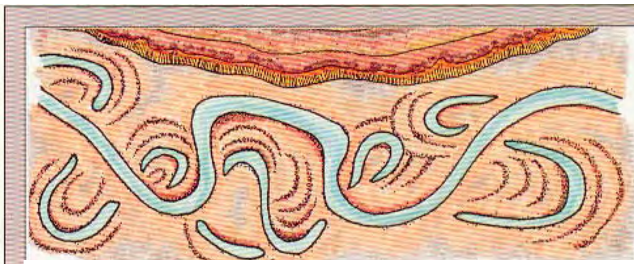
M1 REGULAR MEANDERS

M2 TORTUOUS MEANDERS

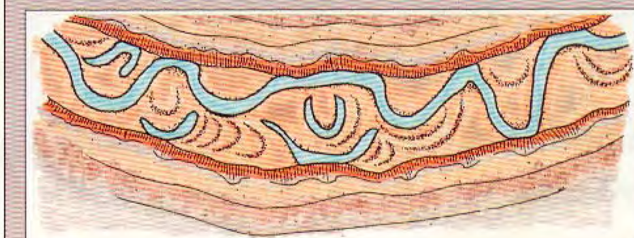
M3 IRREGULAR MEANDERS



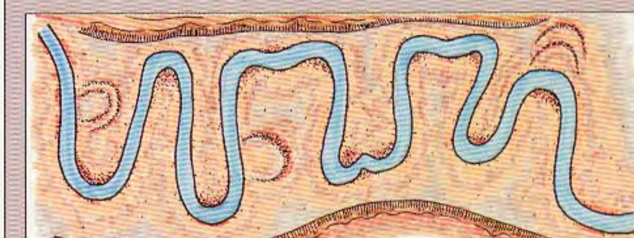
M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS



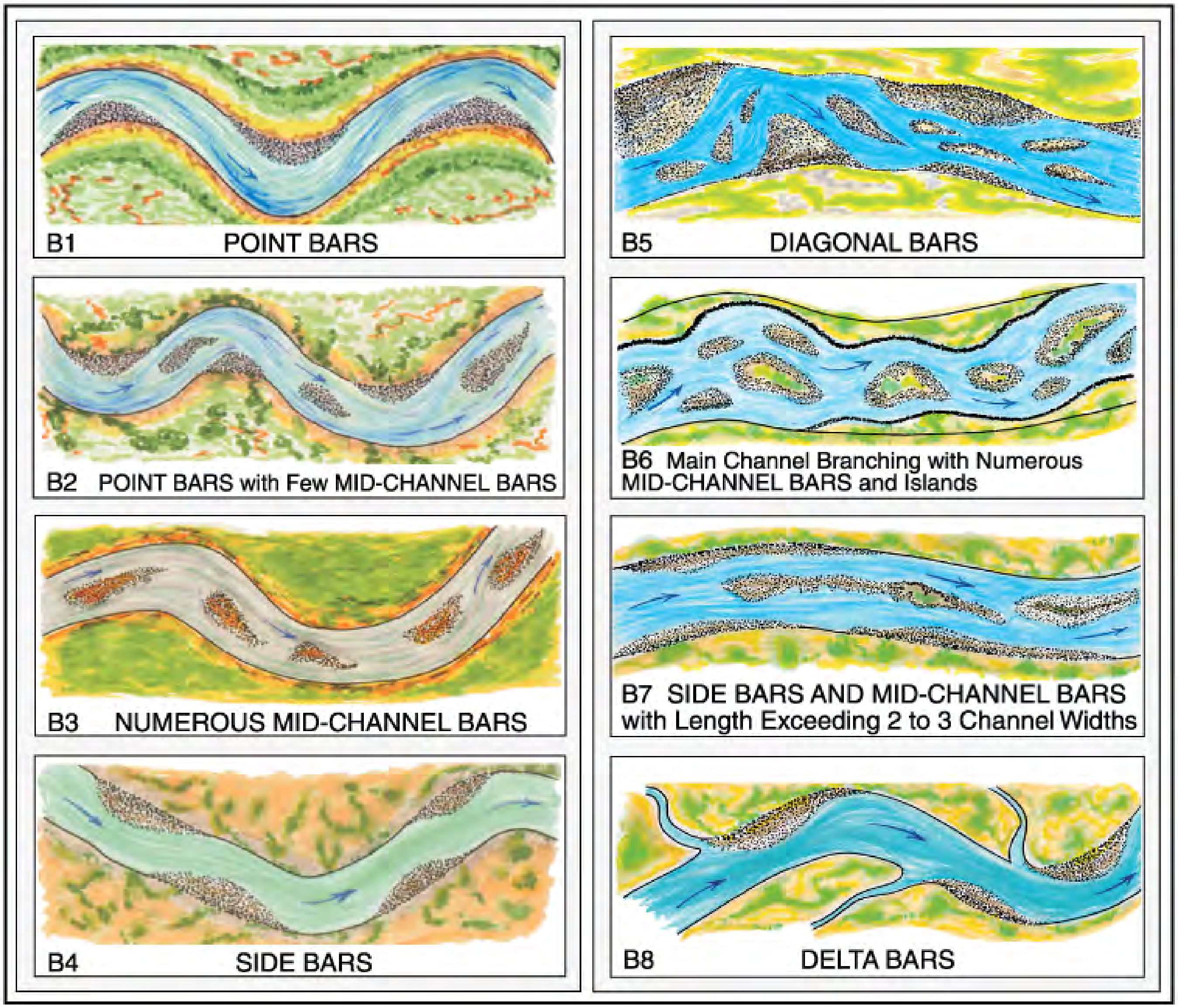
M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns					
Stream: **Maple River**			Reach: **Maple River - 2 - 11.39**		
Observers: **KP, AL**			Date: **11/20/2010**		
List ALL CATEGORIES that APPLY ☞	**NONE**				

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



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages				
Stream:	**Maple River**	Location: **Maple River - 2 - 11.39**		
Observers:	**KP, AL**	Date: **11/20/2010**		
Description/extent		**Materials that 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.	☐	

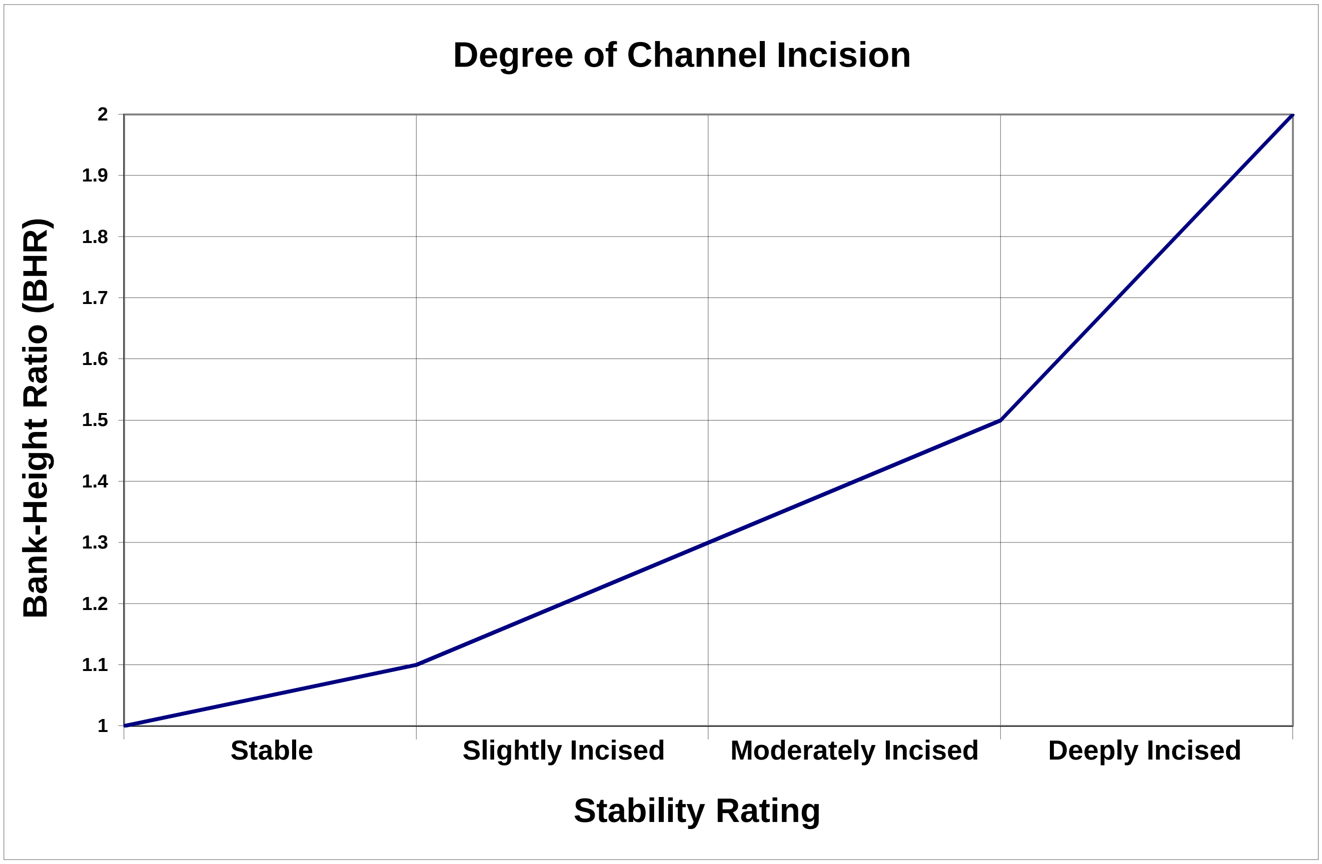
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision

Low Bank Height:	**9.3**
Max Bankfull Depth:	**9.03**

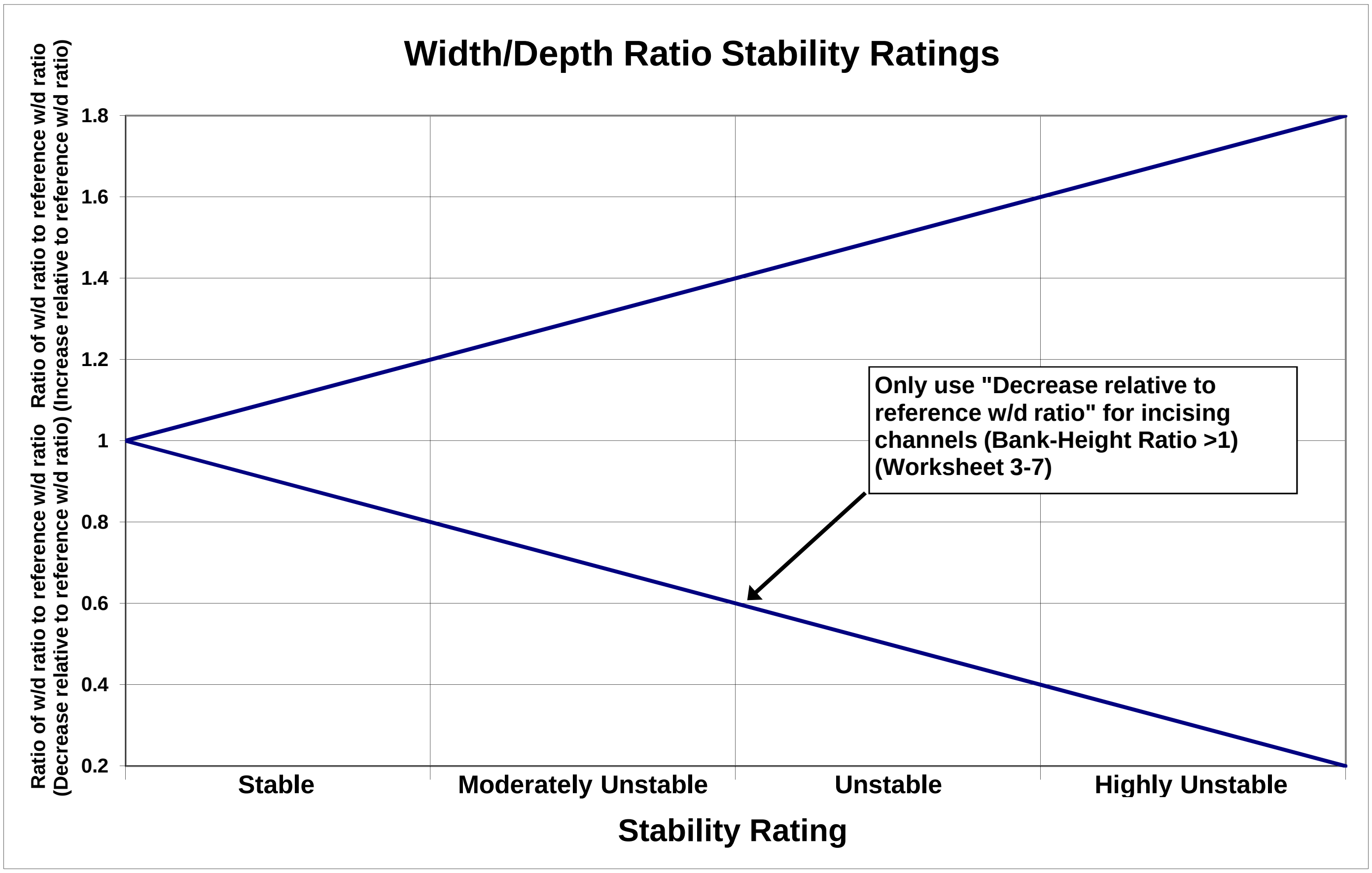
Bank-Height Ratio:	**1.0**

Degree of Channel Incision Stability Rating ☞	**Stable**



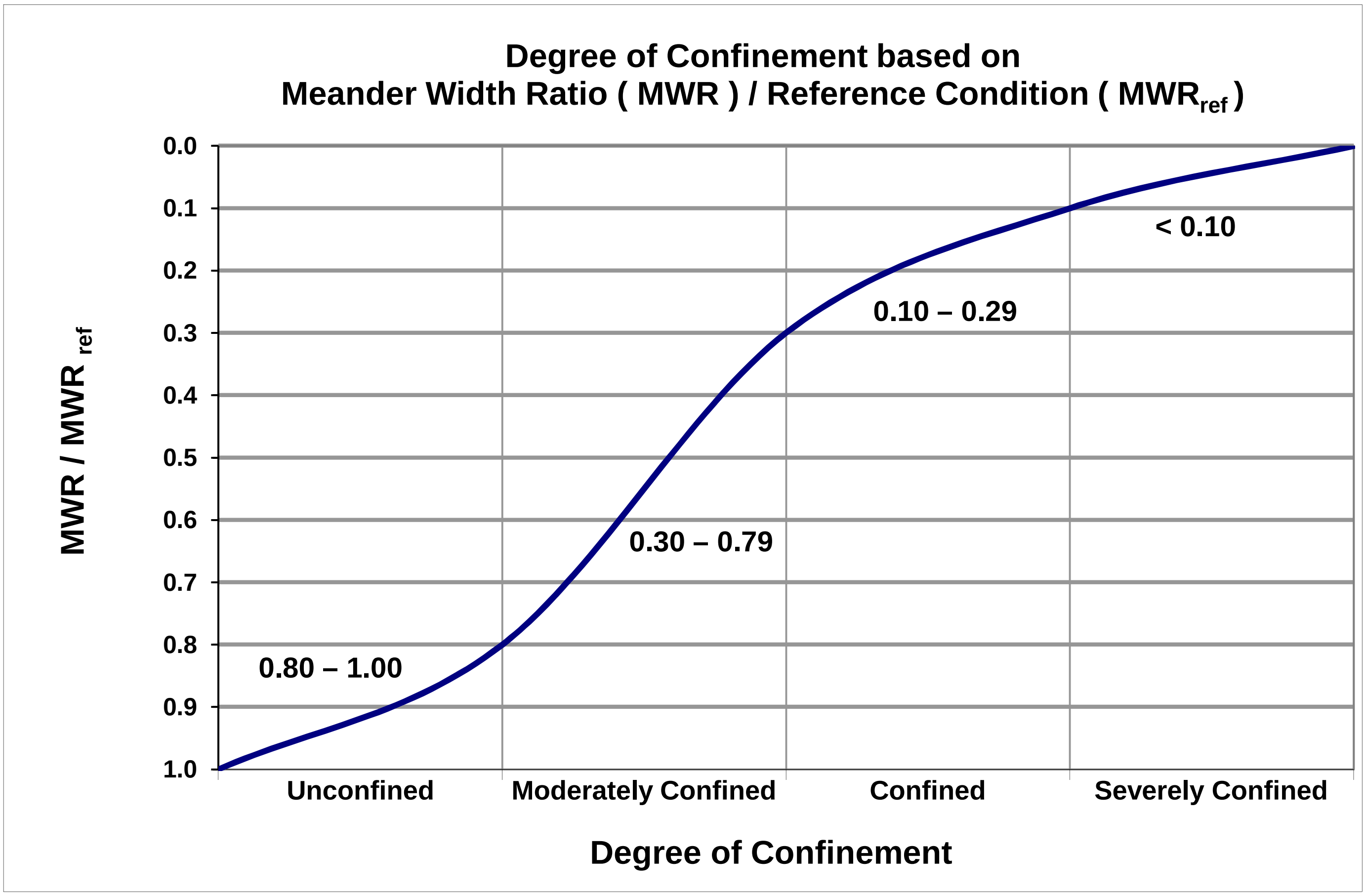
Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State			
Existing Width/Depth Ratio:	11.1	Ratio of existing W/d to reference W/d:	1.08
Reference Width/Depth Ratio:	10.3		
Width/Depth Ratio State Stability Rating ☞		Stable	



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	**25.4**	Ratio of MWR to MWR_{ref}:	**0.973**
Reference Meander Width Ratio (MWR_{ref}):	**26.1**		
Degree of Confinement Stability Rating ☞		**Unconfined**	



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Maple River | **Location:** Maple River - 2 - 11.39 | **Valley Type:** X | **Observers:** KP, AL | **Date:** 11/20/2010

Location	Key	Category	Excellent Description	Excellent Rating	Good Description	Good Rating	Fair Description	Fair Rating	Poor Description	Poor Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	**6**	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	**6**	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	**4**	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	**2**	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	**4**	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	**12**	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	21	Good total =	14	Fair total =	18	Poor total =	4

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	57
Existing stream type =	E6
*Potential stream type =	E6
Modified channel stability rating =	Good

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream: **Maple River**		Location: **Maple River - 2 - 11.39**	
Station:		Observers: **KP, AL**	
Date: **11/20/2010**	Stream Type: **E6**	Valley Type: **X**	

Study Bank Height / Bankfull Height (C) — BEHI Score (Fig. 3-7)

Study Bank Height (ft) =	12.6 (A)	Bankfull Height (ft) =	8 (B)	(A) / (B) =	1.6 (C)	6

Root Depth / Study Bank Height (E)

Root Depth (ft) =	1.5 (D)	Study Bank Height (ft) =	12.6 (A)	(D) / (A) =	0.1 (E)	8

Weighted Root Density (G)

Root Density as % =	20% (F)	(F) x (E) =	2% (G)	10

Bank Angle (H)

Bank Angle as *Degrees* =	33 (H)	2

Surface Protection (I)

Surface Protection as % =	10% (I)	10

Bank Material Adjustment:

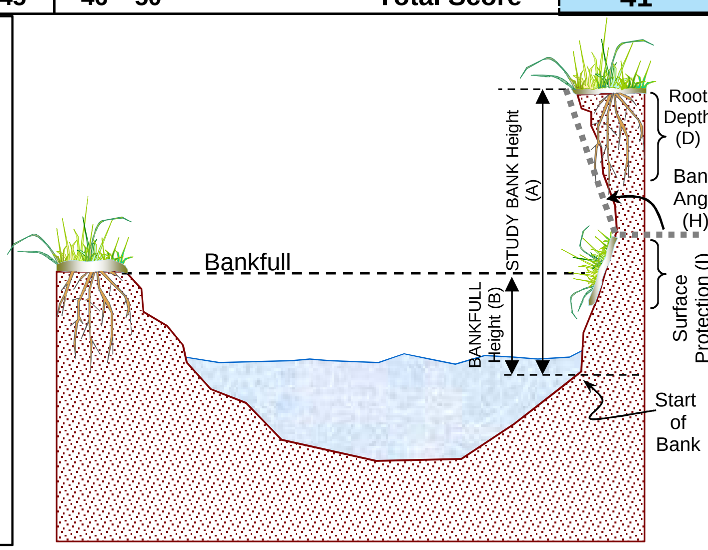
Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

Bank Material Adjustment: 0

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

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	**Very High** 41

Bank Sketch



Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Maple River** Location: **Maple River - 2 - 11.39**

Station: **0** Stream Type: **E6** Valley Type: **X**

Observers: **KP, AL** Date: **11/20/10**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})...	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S)..	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})...	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})...........................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient..	Level IV	Validation

Level I

(1)
- Transverse and/or central bars-short and/or discontinuous.......................NBS = High / Very High
- Extensive deposition (continuous, cross-channel).......................................NBS = Extreme
- Chute cutoffs, down-valley meander migration, converging flow.......................NBS = Extreme

Level II

	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)
(2)				

	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)
(3)				

	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)
(4)				

Dominant Near-Bank Stress
Very Low

Level III

	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)
(5)				

	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)
(6)								

Level IV

	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
(7)		**Very Low**

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating | **Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Maple River**			Location:	**Maple River - 2 - 11.39**		
Graph Used:	**Fig 3-9**	Total Bank Length (ft):	**9295**			Date:	**11/20/2010**
Observers:	**KP, AL**	Valley Type:	**X**			Stream Type:	**E6**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**Very High**	**Very Low**	**0.165**	**9295**	**12.6**	**19324**	**0.10**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**19324**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**716**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**930**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.10**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Maple River**		Stream Type:	**E6**
Location:	**Maple River - 2 - 11.39**		Valley Type:	**X**
Observers:	**KP, AL**		Date:	**11/20/2010**

Enter Required Information for Existing Condition

	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\ (D_{50}/\hat{D}_{50})^{-0.872}$	
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\ (D_{max}/D_{50})^{-0.887}$	
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress		EQUATION USED:	**#DIV/0!**

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	**d**	Required bankfull mean depth (ft)	$d = \frac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)
	Check: ☐ Stable ☐ Aggrading ☐ Degrading			

Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	**S**	Required bankfull water surface slope (ft/ft)	$S = \frac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)
	Check: ☐ Stable ☐ Aggrading ☐ Degrading			

Sediment Competence Using Dimensional Shear Stress

0	Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope	
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**	
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**	
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope	$d = \frac{\tau}{\gamma S}$
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth	$S = \frac{\tau}{\gamma d}$

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis

Observers: **KP, AL**

Stream: **Maple River** | Location: **Maple River - 2 - 11.39** | Date: **11/20/2010**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		**100%**

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	**0**
Materials less than:	mm

Be sure to add separate material weights to grand total

GRAND TOTAL **0**

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Maple River**	Stream Type: **E6**
Location: **Maple River - 2 - 11.39**	Valley Type: **X**
Observers: **KP, AL**	Date: **11/20/2010**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream:	**Maple River**			Stream Type:	**E6**
Location:	**Maple River - 2 - 11.39**			Valley Type:	**X**
Observers:	**KP, AL**			Date:	**11/20/2010**

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 3-8)**	< 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	> 1.6 **(8)**	**2**
2 **Depositional pattern (Worksheet 3-5)**	B1, B2 **(1)**	B4, B8 **(2)**	B3 **(3)**	B5, B6, B7 **(4)**	**1**
3 **Meander pattern (Worksheet 3-4)**	M1, M3, M4 **(1)**		M2, M5, M6, M7, M8 **(3)**		**1**
4 **Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL **(2)**	M/L, M/M, M/H, L/Ex, H/L **(4)**	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL **(6)**	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex **(8)**	**6**
5 **Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.8 – 1.0 **(1)**	0.3 – 0.79 **(2)**	0.1 – 0.29 **(3)**	< 0.1 **(4)**	**1**
				Total points	**11**

	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** ☐

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Maple River**	Stream Type:	**E6**
Location:	**Maple River - 2 - 11.39**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**11/20/2010**

	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 3-14)**	Sufficient depth and/or slope to transport largest size available **(2)**	Trend toward insufficient depth and/or slope-slightly incompetent **(4)**	Cannot move D_{35} of bed material and/or D_{100} of bar material **(6)**	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size **(8)**	2
2	**Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load **(2)**	Trend toward insufficient sediment capacity **(4)**	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand **(6)**	Reduction over 25% of annual sediment yield for bedload and/or suspended sand **(8)**	2
3	**W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	>1.6 **(8)**	2
4	**Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation **(2)**	(E→C) **(4)**	(C→High W/d C), (B→High W/d B), (C→F) **(6)**	(C→D), (F→D) **(8)**	2
5	**Depositional patterns (Worksheet 3-5)**	B1 **(1)**	B2, B4 **(2)**	B3, B5 **(3)**	B6, B7, B8 **(4)**	1
6	**Debris / blockages (Worksheet 3-6)**	D1, D2, D3 **(1)**	D4, D7 **(2)**	D5, D8 **(3)**	D6, D9, D10 **(4)**	1
					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** ☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream: **Maple River**			Stream Type:	**E6**	
Location: **Maple River - 2 - 11.39**			Valley Type:	**X**	
Observers: **KP, AL**			Date:	**11/20/2010**	
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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	**2**
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	**2**
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	**2**
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	**2**
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	**1**
				Total points	**9**
	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** ☐	

Worksheet 3-20. Channel enlargement prediction summary.

Stream: **Maple River**			Stream Type: **E6**		
Location: **Maple River - 2 - 11.39**			Valley Type: **X**		
Observers: **KP, AL**			Date: **11/20/2010**		
Channel enlargement prediction criteria (choose one stability category for each criterion 1–4)	**Channel Enlargement Prediction Categories**				**Selected points (from each row)**
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) **(2)**	(C→High W/d C), (E→C) **(4)**	(G→F), (F→D) **(6)**	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) **(8)**	**2**
2 **Lateral stability (Worksheet 3-17)**	Stable **(2)**	Moderately unstable **(4)**	Unstable **(6)**	Highly unstable **(8)**	**4**
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition **(2)**	Moderate deposition **(4)**	Excess deposition **(6)**	Aggradation **(8)**	**2**
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised **(2)**	Slightly incised **(4)**	Moderately incised **(6)**	Degradation **(8)**	**2**
				Total points	**10**
	Category point range				
Channel enlargement prediction (use total points and check stability rating)	**No increase 8 – 10** ☑	**Slight increase 11 – 16** ☐	**Moderate increase 17 – 24** ☐	**Extensive > 24** ☐	

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream: **Maple River**		Stream Type:	**E6**
Location: **Maple River - 2 - 11.39**		Valley Type:	**X**
Observers: **KP, AL**		Date:	**11/20/2010**

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	Stability Rating	Points	Selected Points
1 Lateral stability (Worksheet 3-17)	Stable	1	2
	Mod. unstable	2	
	Unstable	3	
	Highly unstable	4	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition	1	1
	Mod. deposition	2	
	Excess deposition	3	
	Aggradation	4	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	1
	Slightly incised	2	
	Mod. Incised	3	
	Degradation	4	
4 Channel enlargement prediction (Worksheet 3-20)	No increase	1	1
	Slight increase	2	
	Mod. increase	3	
	Extensive	4	
5 Pfankuch channel stability (Worksheet 3-10)	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 ☐

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Maple River**			Location: **Maple River - 2 - 11.39**			
Observers:	**KP, AL**	Date: **11/20/2010**		Stream Type: **E6**		Valley Type: **X**	
Channel Dimension	Mean bankfull depth (ft): **6.5**	Mean bankfull width (ft): **72.07**	Cross-section area (ft^2): **463**	Width of flood-prone area (ft): **672**		Entrenchment ratio: **9.3**	
Channel Pattern	Mean: Range: MWR: **25.4**	Lm/W_{bkf}: **25.4**		Rc/W_{bkf}: **3.6**		Sinuosity: **1.67**	
River Profile and Bed Features	Check: ☐ Riffle/pool ☐ Step/pool ☑ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed						
	Max bankfull depth (ft): Riffle **9.0**; Pool	Depth ratio (max/mean): Riffle **1.4**; Pool		Pool to pool spacing: Ratio		Slope: Valley: ; Average bankfull: **6.9E-05**	
Level III Stream Stability Indices	Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:			
	Flow regime: **P1, 2, 7, 9**	Stream size and order: **S-6**	Meander pattern(s): **M1**	Depositional pattern(s): **NONE**		Debris/channel blockage(s): **D2**	
	Degree of incision (Bank-Height Ratio): **1.0**	Degree of incision stability rating: **Stable**		Modified Pfankuch stability rating (numeric and adjective rating): **Good**			
	Width/depth ratio (W/d): **11.1**	Reference W/d ratio (W/d_{ref}): **10.3**	Width/depth ratio state $(W/d) / (W/d_{ref})$: **1.1**		W/d ratio state stability rating: **Stable**		
	Meander Width Ratio (MWR): **25.4**	Reference MWR_{ref}: **26.1**	Degree of confinement (MWR / MWR_{ref}): **1.0**		MWR / MWR_{ref} stability rating: **Unconfined**		
Bank Erosion Summary	Length of reach studied (ft): **9295**	Annual streambank erosion rate: **930** (tons/yr) **0.10** (tons/yr/ft)		Curve used: **Fig 3-9**	Remarks:		
Sediment Capacity (POWERSED)	☑ Sufficient capacity ☐ Insufficient capacity ☐ Excess capacity				Remarks:		
Entrainment/ Competence	Largest particle from bar sample (mm):	$\tau =$	$\tau^* =$	Existing $depth_{bkf}$:	Required $depth_{bkf}$:	Existing $slope_{bkf}$:	Required $slope_{bkf}$:
Successional Stage Shift	→ → → → →			Existing stream state (type): **E6**		Potential stream state (type): **E6**	
Lateral Stability	☐ Stable ☑ Mod. unstable ☐ Unstable ☐ Highly unstable				Remarks/causes: **None**		
Vertical Stability (Aggradation)	☑ No deposition ☐ Mod. deposition ☐ Ex. deposition ☐ Aggradation				Remarks/causes: **None**		
Vertical Stability (Degradation)	☑ Not incised ☐ Slightly incised ☐ Mod. incised ☐ Degradation				Remarks/causes: **None**		
Channel Enlargement	☑ No increase ☐ Slight increase ☐ Mod. increase ☐ Extensive				Remarks/causes: **None**		
Sediment Supply (Channel Source)	☐ Low ☑ Moderate ☐ High ☐ Very high			Remarks/causes: **None**			

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Red River**			Location: **Red River-1-410.65**	
Observers: **KD, JB**	Reference reach [ ]	Disturbed (impacted reach) [X]	Date: **9/28/2011**	
Existing species composition: **Trees, Brush**			Potential species composition:	

Riparian cover categories		Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**15%**	**1%**	**Trees**	**100%**
					100%
2. Understory	Shrub layer		**20%**	**Small Shrubs**	**100%**
					100%
3. Ground level	Herbaceous		**10%**	**Grass/Weeds**	**100%**
					100%
	Leaf or needle litter		**0%**		
	Bare ground		**69%**		
			Column total = 100%		

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

Remarks:
Condition, vigor and/or usage of existing reach:

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Red River**	Location: **Red River-1-410.65**							
Observers: **KD, JB**	Date: **9/28/2011**							
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P7**	**P9**				

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order

Stream:	**Red River**
Location:	**Red River-1-410.65**
Observers:	**KD, JB**
Date:	**9/28/2011**
Stream Size Category and Order ☞	**S-9**

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).

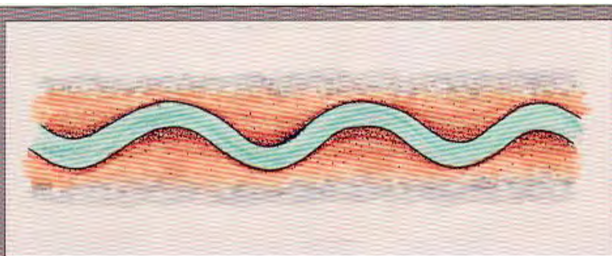
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Red River**	Reach:	**Red River-1-410.65**
Observers:	**KD, JB**	Date:	**9/28/2011**

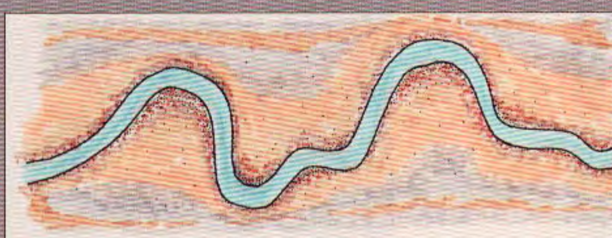
List ALL CATEGORIES that APPLY ☞	**M2**				

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

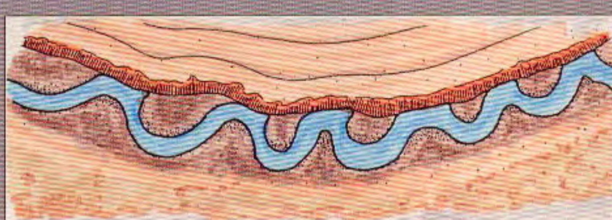


M1 REGULAR MEANDERS

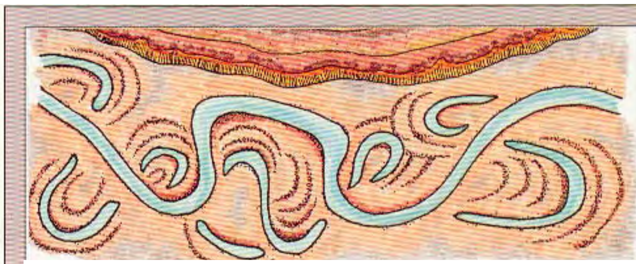
M2 TORTUOUS MEANDERS



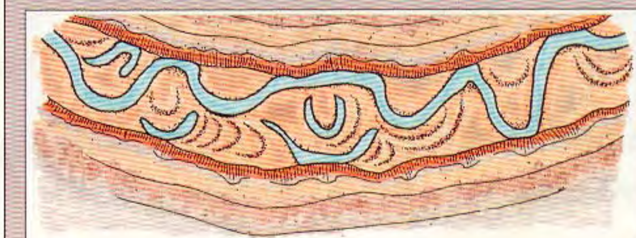
M3 IRREGULAR MEANDERS



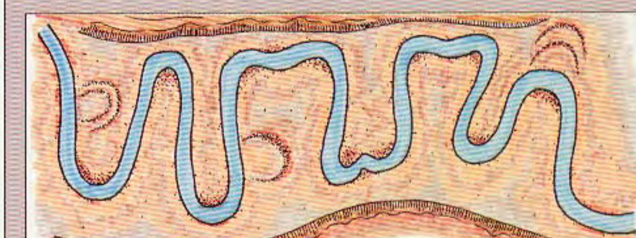
M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS



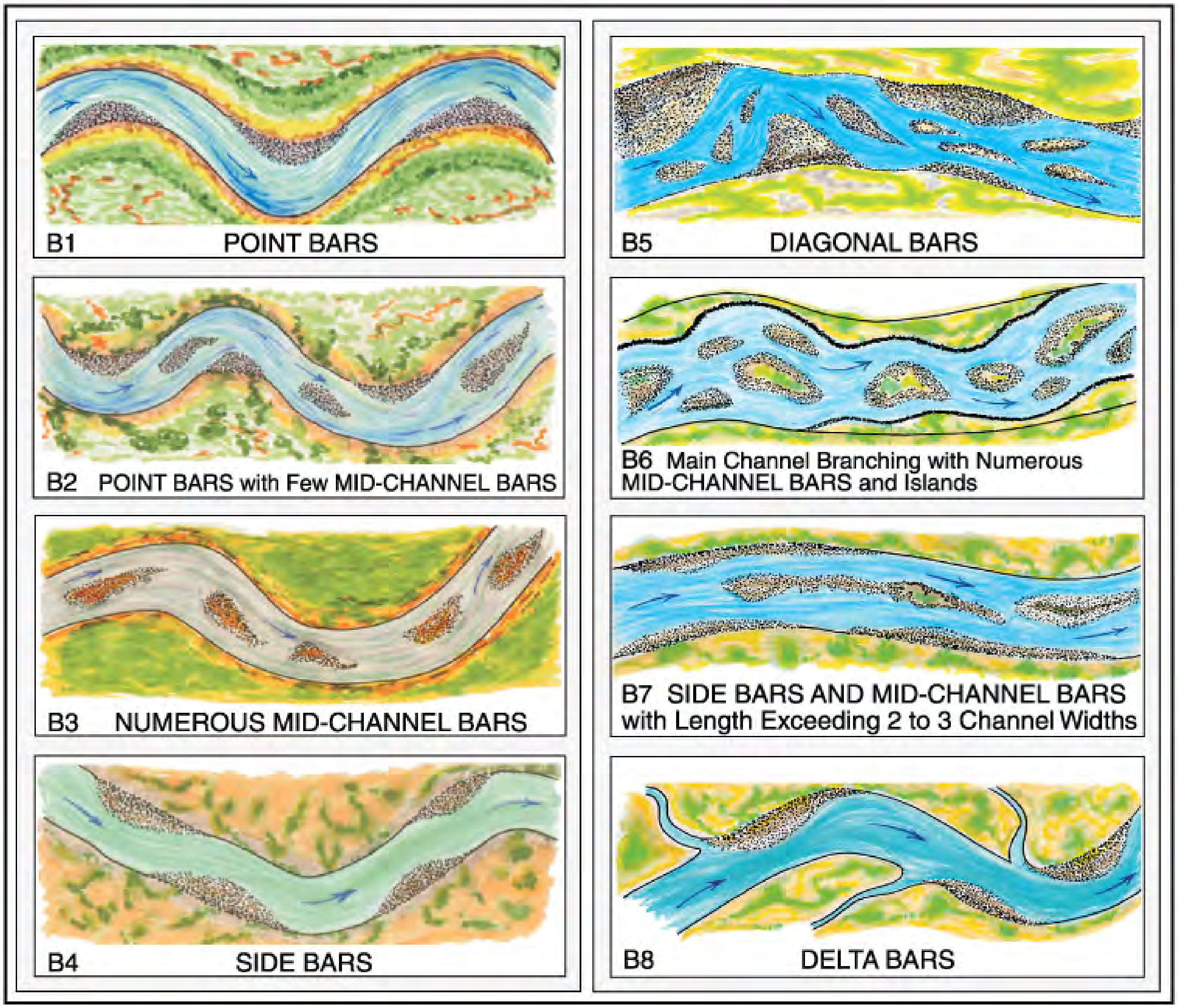
M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns					
Stream: **Red River**			Reach: **Red River-1-410.65**		
Observers: **KD, JB**			Date: **9/28/2011**		
List ALL CATEGORIES that APPLY ☞	**None**				

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

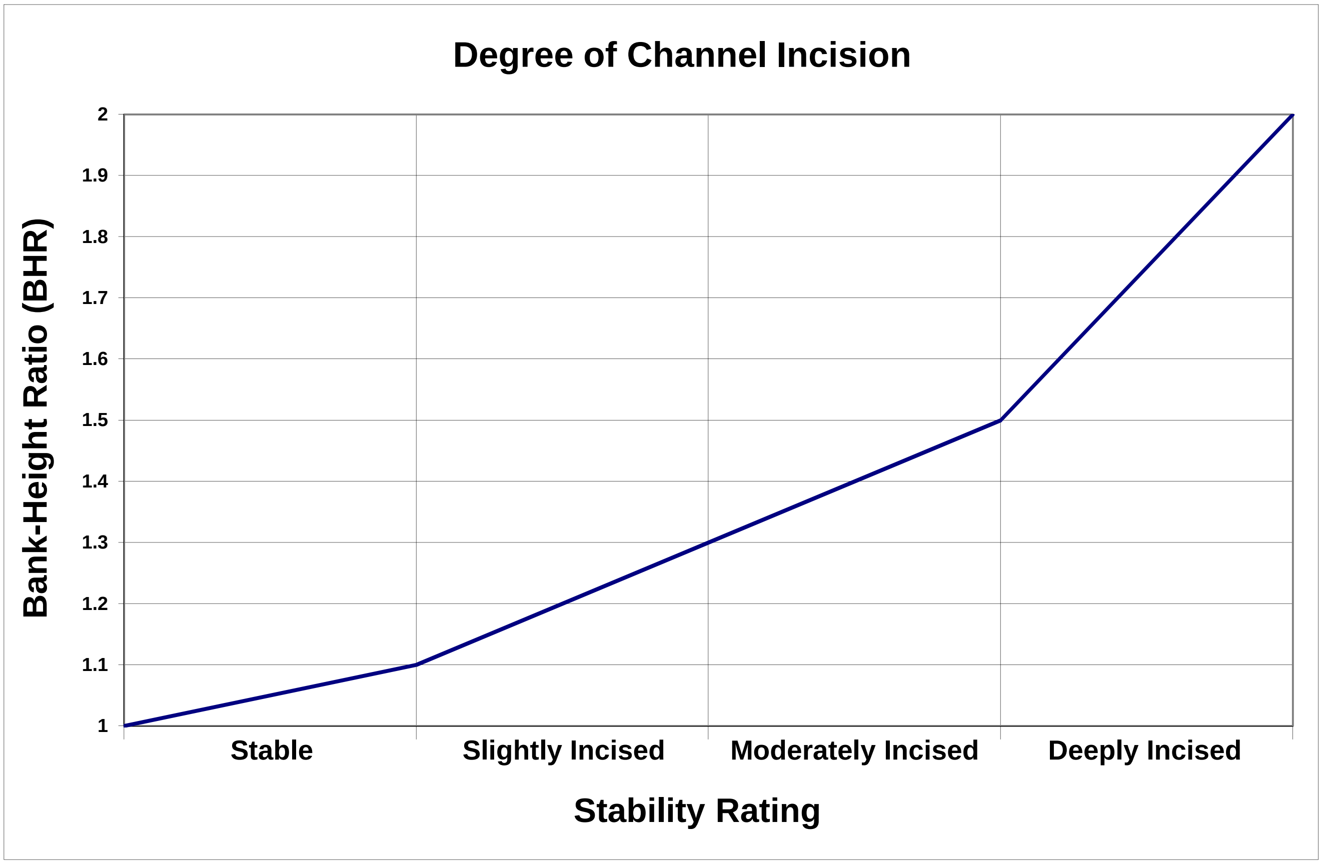


Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Red River**		Location: **Red River-1-410.65**	
Observers: **KD, JB**		Date: **9/28/2011**	
Description/extent		**Materials that 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.	☐

Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision			
Low Bank Height:	23.9	Bank-Height Ratio:	1.3
Max Bankfull Depth:	17.92		
Degree of Channel Incision Stability Rating ☞		Slightly Incised	

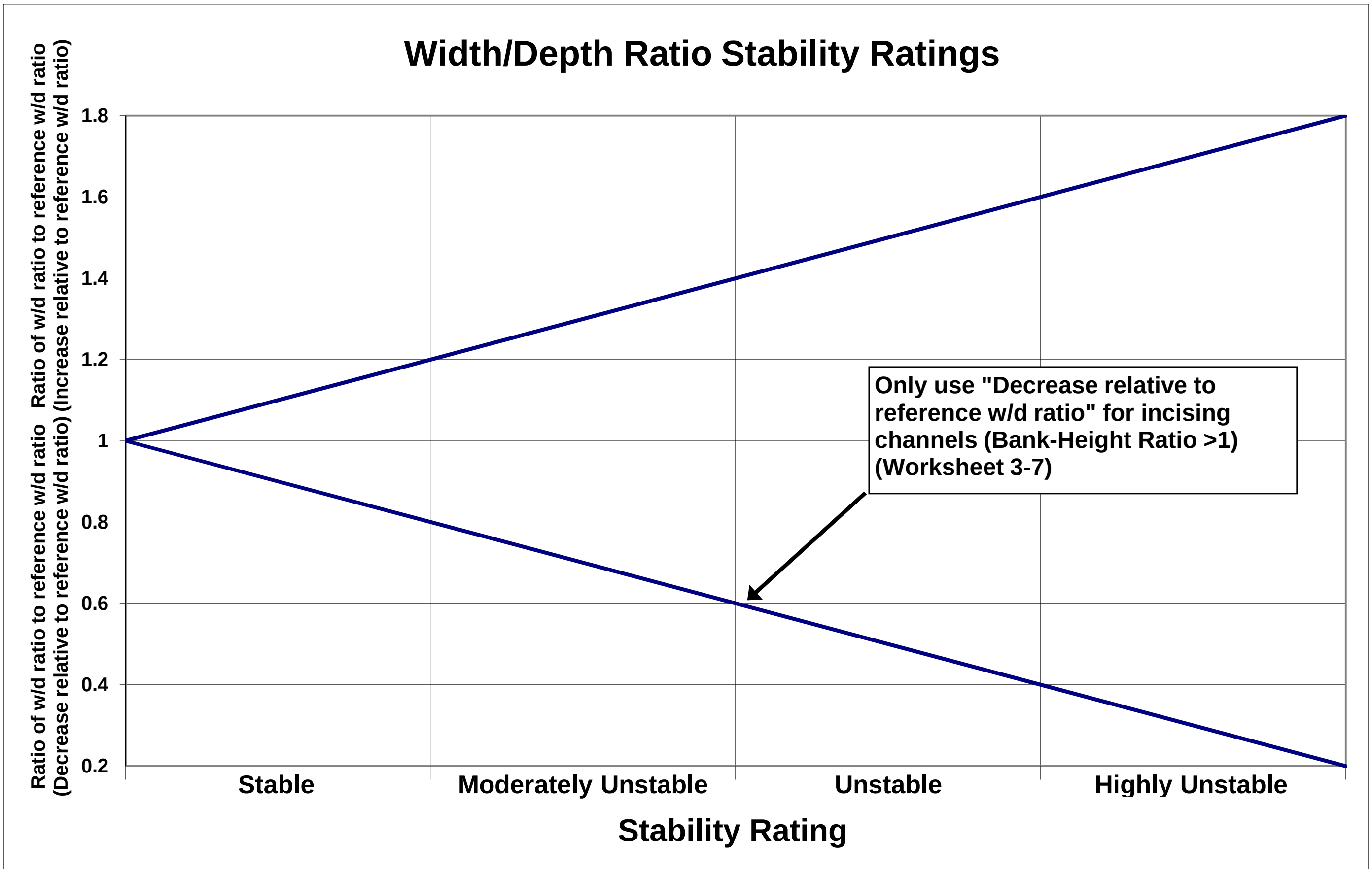


Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State

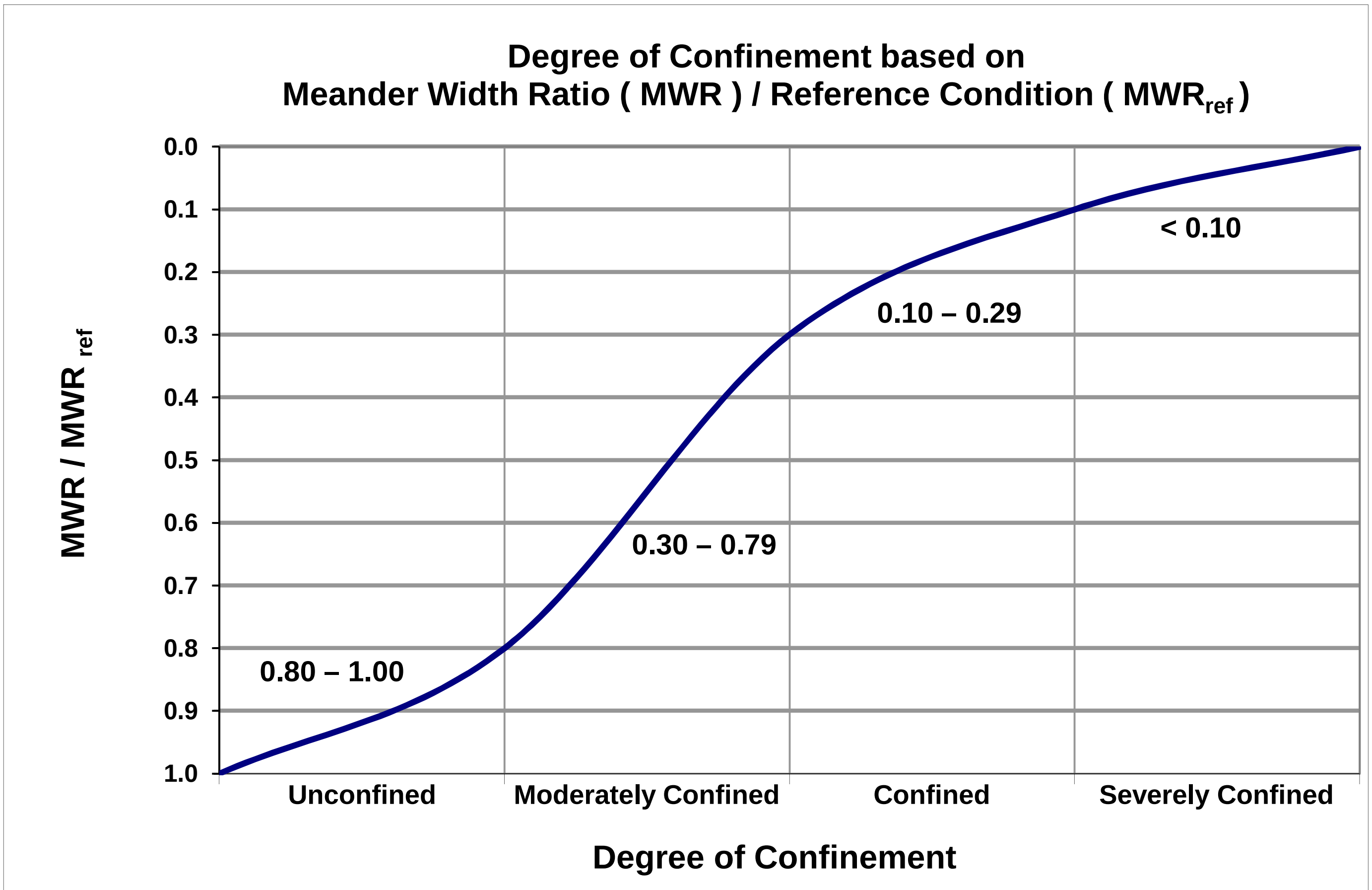
Existing Width/Depth Ratio:	**15.6**	Ratio of existing W/d to reference W/d:	**1**
Reference Width/Depth Ratio:	**15.6**		

Width/Depth Ratio State Stability Rating ☞	**Stable**



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	**11.2**	Ratio of MWR to MWR_{ref}:	**1**
Reference Meander Width Ratio (MWR_{ref}):	**11.2**		
Degree of Confinement Stability Rating ☞		**Unconfined**	



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Red River **Location:** Red River-1-410.65 **Valley Type:** X **Observers:** KD, JB **Date:** 9/28/2011

Location	Key	Category	Excellent: Description	Excellent: Rating	Good: Description	Good: Rating	Fair: Description	Fair: Rating	Poor: Description	Poor: Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	**2**	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	**12**
	3	Debris jam potential	Essentially absent from immediate channel area.	**2**	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	**12**
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	**2**	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	**2**	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	**16**
	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	6	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	**12**	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	21	Good total =	12	Fair total =	0	Poor total =	44

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	77
Existing stream type =	C6c-
*Potential stream type =	C6c-
Modified channel stability rating =	Good

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream: **Red River** Location: **Red River-1-410.65**

Station: Observers: **KD, JB**

Date: **9/28/2011** Stream Type: **C6c-** Valley Type: **X**

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	**27.7** **(A)**	**Bankfull Height** (ft) =	**10.2** **(B)**	(**A**) / (**B**) =	**2.7** **(C)**	**9**

Root Depth / Study Bank Height (E)

Root Depth (ft) =	**1** **(D)**	**Study Bank Height** (ft) =	**27.7** **(A)**	(**D**) / (**A**) =	**0.0** **(E)**	**10**

Weighted Root Density (G)

Root Density as **%** =	**2%** **(F)**	(**F**) x (**E**) =	**0%** **(G)**	**10**

Bank Angle (H)

Bank Angle as *Degrees* =	**9** **(H)**	**1**

Surface Protection (I)

Surface Protection as **%** =	**15%** **(I)**	**8**

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)

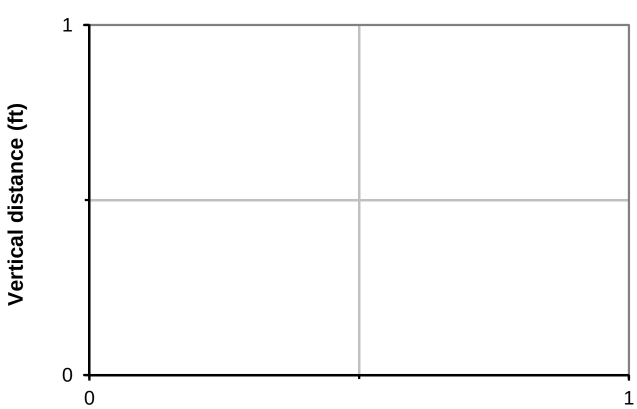
Bank Material Adjustment: **0**

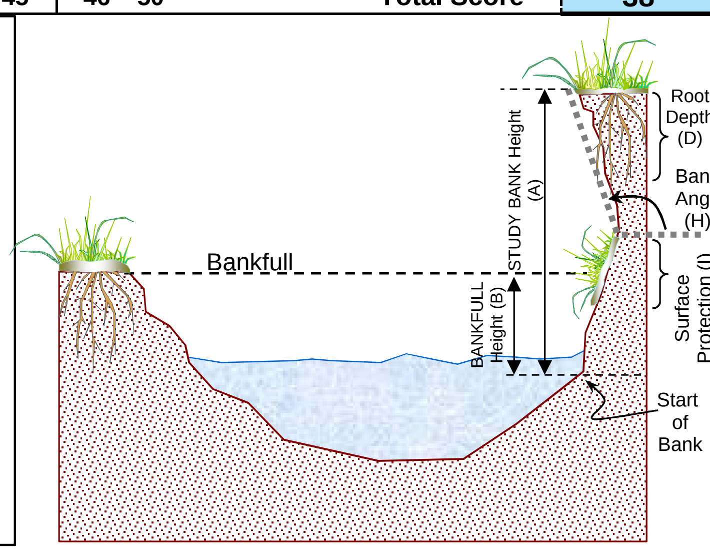
Stratification Adjustment
Add 5–10 points, depending on position of unstable layers in relation to bankfull stage: **0**

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: **High**
and
Total Score: **38**

Bank Sketch





Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Red River**	Location: **Red River-1-410.65**	
Station: **0**	Stream Type: **C6c-**	Valley Type: **X**
Observers: **KD, JB**		Date: **9/28/11**

Methods for Estimating Near-Bank Stress (NBS)

(1)	Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2)	Ratio of radius of curvature to bankfull width (R_c / W_{bkf})...	Level II	General prediction
(3)	Ratio of pool slope to average water surface slope (S_p / S).......................................	Level II	General prediction
(4)	Ratio of pool slope to riffle slope (S_p / S_{rif})..	Level II	General prediction
(5)	Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})..........................	Level III	Detailed prediction
(6)	Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})................................	Level III	Detailed prediction
(7)	Velocity profiles / Isovels / Velocity gradient..	Level IV	Validation

Level I

(1)	Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
	Extensive deposition (continuous, cross-channel).. ....NBS = Extreme
	Chute cutoffs, down-valley meander migration, converging flow...NBS = Extreme

Level II

	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)
(2)				

	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)
(3)				

	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)
(4)				

Dominant Near-Bank Stress
Very Low

Level III

	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)
(5)				

	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)
(6)								

Level IV

	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
(7)	**0.03**	**Very Low**

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating | **Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Red River**				Location:	**Red River-1-410.65**	
Graph Used:	**Fig 3-9**	Total Bank Length (ft):	**10739.3**			Date:	**9/28/2011**
Observers:	**KD, JB**		Valley Type:	**X**		Stream Type:	**C6c-**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**10739.3**	**27.7**	**49084**	**0.22**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**49084**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**1818**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**2363**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.22**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Red River**	Stream Type:	**C6c-**
Location:	**Red River-1-410.65**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**9/28/2011**

Enter Required Information for Existing Condition

	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
0	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	**#DIV/0!**

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	**d**	Required bankfull mean depth (ft)	$d = \frac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	**S**	Required bankfull water surface slope (ft/ft)	$S = \frac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Sediment Competence Using Dimensional Shear Stress

0	Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) $\quad d = \frac{\tau}{\gamma S}$ τ = predicted shear stress, γ = 62.4, S = existing slope
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) $\quad S = \frac{\tau}{\gamma d}$ τ = predicted shear stress, γ = 62.4, d = existing depth

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis

Observers: **KD, JB**

Stream: **Red River** | Location: **Red River-1-410.65** | Date: **9/28/2011**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		**100%**

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	**0**
Materials less than:	mm

Be sure to add separate material weights to grand total

0

GRAND TOTAL

Sample location notes		Sample location sketch	

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Red River**	Stream Type: **C6c-**
Location: **Red River-1-410.65**	Valley Type: **X**
Observers: **KD, JB**	Date: **9/28/2011**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream: **Red River**			Stream Type:	**C6c-**	
Location: **Red River-1-410.65**			Valley Type:	**X**	
Observers: **KD, JB**			Date:	**9/28/2011**	
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 3-8)**	< 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	> 1.6 **(8)**	**2**
2 **Depositional pattern (Worksheet 3-5)**	B1, B2 **(1)**	B4, B8 **(2)**	B3 **(3)**	B5, B6, B7 **(4)**	**1**
3 **Meander pattern (Worksheet 3-4)**	M1, M3, M4 **(1)**		M2, M5, M6, M7, M8 **(3)**		**3**
4 **Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL **(2)**	M/L, M/M, M/H, L/Ex, H/L **(4)**	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL **(6)**	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex **(8)**	**4**
5 **Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.8 – 1.0 **(1)**	0.3 – 0.79 **(2)**	0.1 – 0.29 **(3)**	< 0.1 **(4)**	**1**
				Total points	**11**
	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** ☐	

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Red River**	Stream Type:	**C6c-**
Location:	**Red River-1-410.65**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**9/28/2011**

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 3-14)**	Sufficient depth and/or slope to transport largest size available (2)	Trend toward insufficient depth and/or slope-slightly incompetent (4)	Cannot move D_{35} of bed material and/or D_{100} of bar material (6)	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size (8)	**2**
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load (2)	Trend toward insufficient sediment capacity (4)	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand (6)	Reduction over 25% of annual sediment yield for bedload and/or suspended sand (8)	**2**
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 (2)	1.2 – 1.4 (4)	1.4 – 1.6 (6)	>1.6 (8)	**2**
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation (2)	(E→C) (4)	(C→High W/d C), (B→High W/d B), (C→F) (6)	(C→D), (F→D) (8)	**2**
5 **Depositional patterns (Worksheet 3-5)**	B1 (1)	B2, B4 (2)	B3, B5 (3)	B6, B7, B8 (4)	**1**
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 (1)	D4, D7 (2)	D5, D8 (3)	D6, D9, D10 (4)	**1**
				Total points	**10**

Vertical stability for excess deposition / aggradation (use total points and check stability rating)	Vertical stability category point range for excess deposition / aggradation			
	No deposition 10 – 14 ☑	**Moderate deposition 15 – 20** ☐	**Excess deposition 21 – 30** ☐	**Aggradation > 30** ☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream:	**Red River**	Stream Type:	**C6c-**
Location:	**Red River-1-410.65**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**9/28/2011**

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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	2
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	2
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	4
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	4
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	1
				Total points	**13**

	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** ☐

Worksheet 3-20. Channel enlargement prediction summary.

Stream: **Red River**			Stream Type: **C6c-**		
Location: **Red River-1-410.65**			Valley Type: **X**		
Observers: **KD, JB**			Date: **9/28/2011**		
Channel enlargement prediction criteria (choose one stability category for each criterion 1–4)	**Channel Enlargement Prediction Categories**				**Selected points (from each row)**
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) **(2)**	(C→High W/d C), (E→C) **(4)**	(G→F), (F→D) **(6)**	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) **(8)**	**2**
2 **Lateral stability (Worksheet 3-17)**	Stable **(2)**	Moderately unstable **(4)**	Unstable **(6)**	Highly unstable **(8)**	**4**
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition **(2)**	Moderate deposition **(4)**	Excess deposition **(6)**	Aggradation **(8)**	**2**
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised **(2)**	Slightly incised **(4)**	Moderately incised **(6)**	Degradation **(8)**	**4**
				Total points	**12**
	Category point range				
Channel enlargement prediction (use total points and check stability rating)	**No increase 8 – 10** ☐	**Slight increase 11 – 16** ☑	**Moderate increase 17 – 24** ☐	**Extensive > 24** ☐	

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream: **Red River**		Stream Type:	**C6c-**
Location: **Red River-1-410.65**		Valley Type:	**X**
Observers: **KD, JB**		Date:	**9/28/2011**

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	Stability Rating	Points	Selected Points
1 Lateral stability (Worksheet 3-17)	Stable	1	3
	Mod. unstable	2	
	Unstable	3	
	Highly unstable	4	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition	1	1
	Mod. deposition	2	
	Excess deposition	3	
	Aggradation	4	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	2
	Slightly incised	2	
	Mod. Incised	3	
	Degradation	4	
4 Channel enlargement prediction (Worksheet 3-20)	No increase	1	2
	Slight increase	2	
	Mod. increase	3	
	Extensive	4	
5 Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	1
	Fair: mod unstable	2	
	Poor: unstable	4	
		Total Points	9

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

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Red River**		Location: **Red River-1-410.65**		
Observers:	**KD, JB**	Date: **9/28/2011**	Stream Type: **C6c-**	Valley Type: **X**	
Channel Dimension	Mean bankfull depth (ft): **11.9**	Mean bankfull width (ft): **185.2**	Cross-section area (ft^2): **2157**	Width of flood-prone area (ft): **683.3333**	Entrenchment ratio: **3.7**
Channel Pattern	Mean: Range:	MWR: **11.2**	Lm/W_{bkf}: **11.2**	Rc/W_{bkf}: **2.3**	Sinuosity: **1.96**
River Profile and Bed Features	Check: ☐ Riffle/pool	☐ Step/pool	☐ Plane bed	☐ Convergence/divergence	☑ Dunes/antidunes/smooth bed
	Max bankfull depth (ft): Riffle **17.9**; Pool	Depth ratio (max/mean): Riffle **1.5**; Pool	Pool to pool spacing:	Ratio	Slope: Valley: ; Average bankfull: **6.3E-05**
Level III Stream Stability Indices	Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:	
	Flow regime: **P1, 2, 7, 9**	Stream size and order: **S-9**	Meander pattern(s): **M2**	Depositional pattern(s): **NONE**	Debris/channel blockage(s): **D2, 3**
	Degree of incision (Bank-Height Ratio): **1.3**	Degree of incision stability rating: **Slightly Incised**	Modified Pfankuch stability rating (numeric and adjective rating): **Good**		
	Width/depth ratio (W/d): **15.6**	Reference W/d ratio (W/d_{ref}): **15.6**	Width/depth ratio state $(W/d) / (W/d_{ref})$: **1.0**	W/d ratio state stability rating: **Stable**	
	Meander Width Ratio (MWR): **11.2**	Reference MWR_{ref}: **11.2**	Degree of confinement (MWR / MWR_{ref}): **1.0**	MWR / MWR_{ref} stability rating: **Unconfined**	
Bank Erosion Summary	Length of reach studied (ft): **####**	Annual streambank erosion rate: **2363** (tons/yr) **0.22** (tons/yr/ft)	Curve used: **Fig 3-9**	Remarks:	
Sediment Capacity (POWERSED)	☑ Sufficient capacity	☐ Insufficient capacity	☐ Excess capacity	Remarks:	
Entrainment/ Competence	Largest particle from bar sample (mm):	$\tau =$	$\tau^* =$	Existing $depth_{bkf}$: ; Required $depth_{bkf}$:	Existing $slope_{bkf}$: ; Required $slope_{bkf}$:
Successional Stage Shift	→ → → → →		Existing stream state (type): **C6c-**	Potential stream state (type): **C6c-**	
Lateral Stability	☐ Stable	☑ Mod. unstable	☐ Unstable	☐ Highly unstable	Remarks/causes:
Vertical Stability (Aggradation)	☑ No deposition	☐ Mod. deposition	☐ Ex. deposition	☐ Aggradation	Remarks/causes:
Vertical Stability (Degradation)	☐ Not incised	☑ Slightly incised	☐ Mod. incised	☐ Degradation	Remarks/causes:
Channel Enlargement	☐ No increase	☑ Slight increase	☐ Mod. increase	☐ Extensive	Remarks/causes:
Sediment Supply (Channel Source)	☐ Low	☑ Moderate	☐ High	☐ Very high	Remarks/causes:

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream:	**Red River**			Location:	**Red River-2-419.14**		
Observers:	**KD, JB**	Reference reach		Disturbed (impacted reach)	X	Date:	**9/29/2011**
Existing species composition:	**Trees, Shrubs**			Potential species composition:			

	Riparian cover categories	Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**40%**	**2%**	**Trees**	**100%**
					100%
2. Understory	Shrub layer		**15%**	**Nettles**	**10%**
				Small shrubs	**90%**
					100%
3. Ground level	Herbaceous		**10%**	**Grass, weeds**	**100%**
					100%
	Leaf or needle litter		**0%**		
	Bare ground		**73%**		
			Column total = 100%		

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

Remarks:
Condition, vigor and/or usage of existing reach:

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Red River**			Location: **Red River-2-419.14**					
Observers: **KD, JB**						Date: **9/29/2011**		
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P7**	**P9**				

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order			
Stream:	Red River		
Location:	Red River-2-419.14		
Observers:	KD, JB		
Date:	9/29/2011		
Stream Size Category and Order ☞			**S-9**
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).			

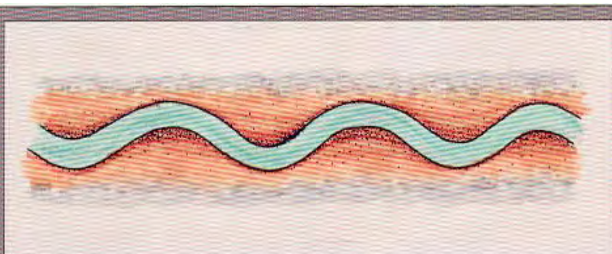
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Red River**	Reach:	**Red River-2-419.14**
Observers:	**KD, JB**	Date:	**9/29/2011**

List ALL CATEGORIES that APPLY ☞	**M2**				

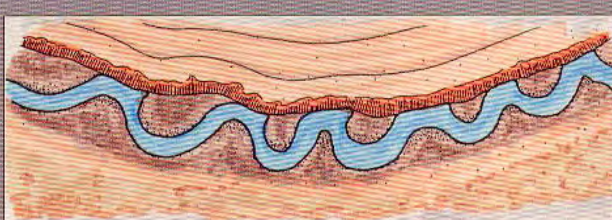
Various Meander Pattern variables modified from Galay et al. (1973)



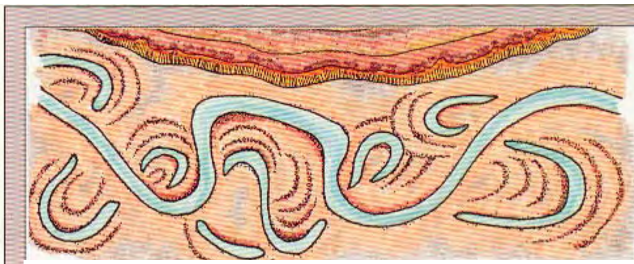
M1 REGULAR MEANDERS

M2 TORTUOUS MEANDERS

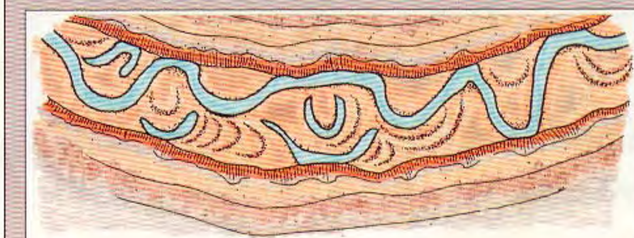
M3 IRREGULAR MEANDERS



M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS

M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

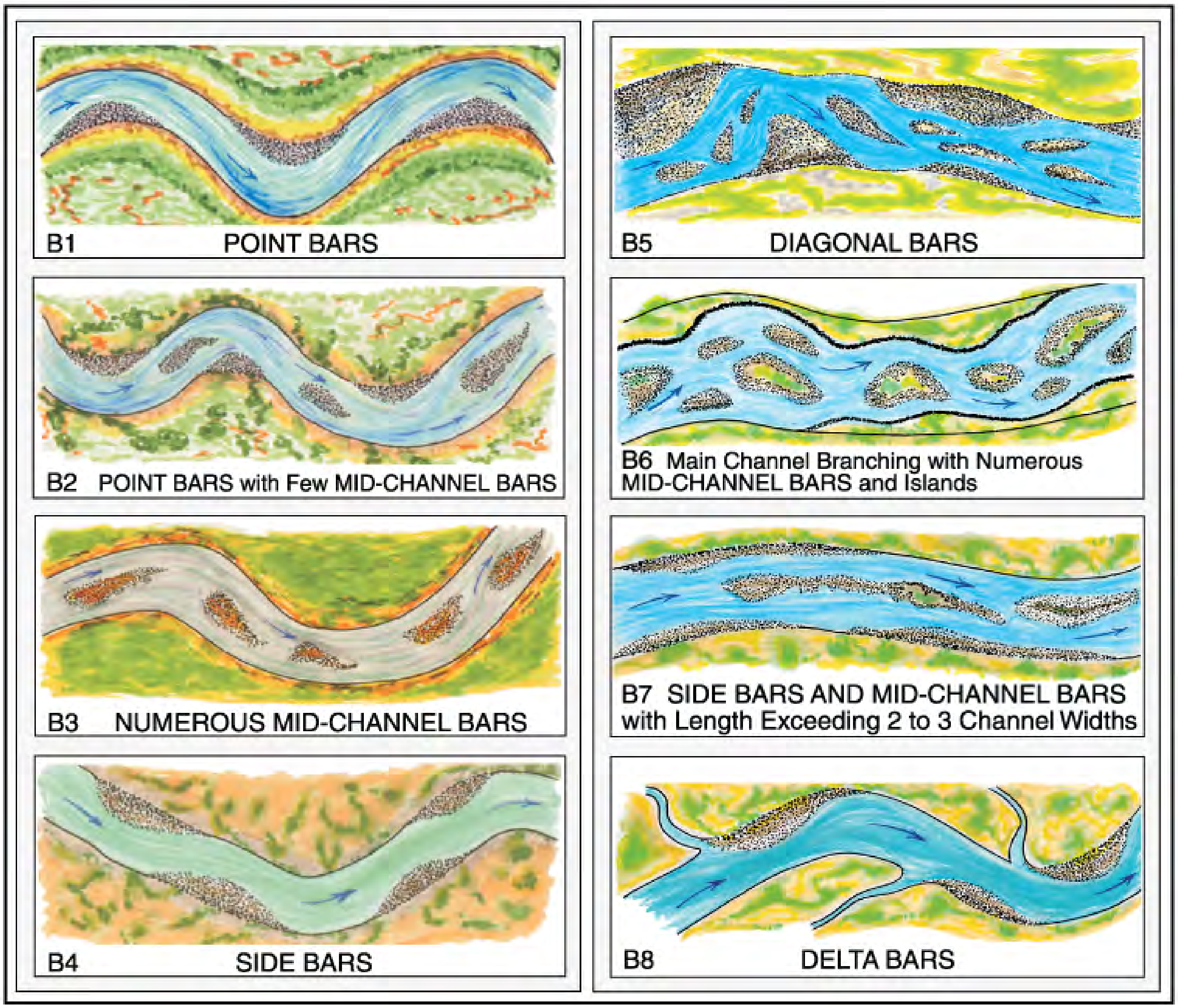
Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns

Stream:	**Red River**	Reach:	**Red River-2-419.14**
Observers:	**KD, JB**	Date:	**9/29/2011**

List ALL CATEGORIES that APPLY ☞	**None**				

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

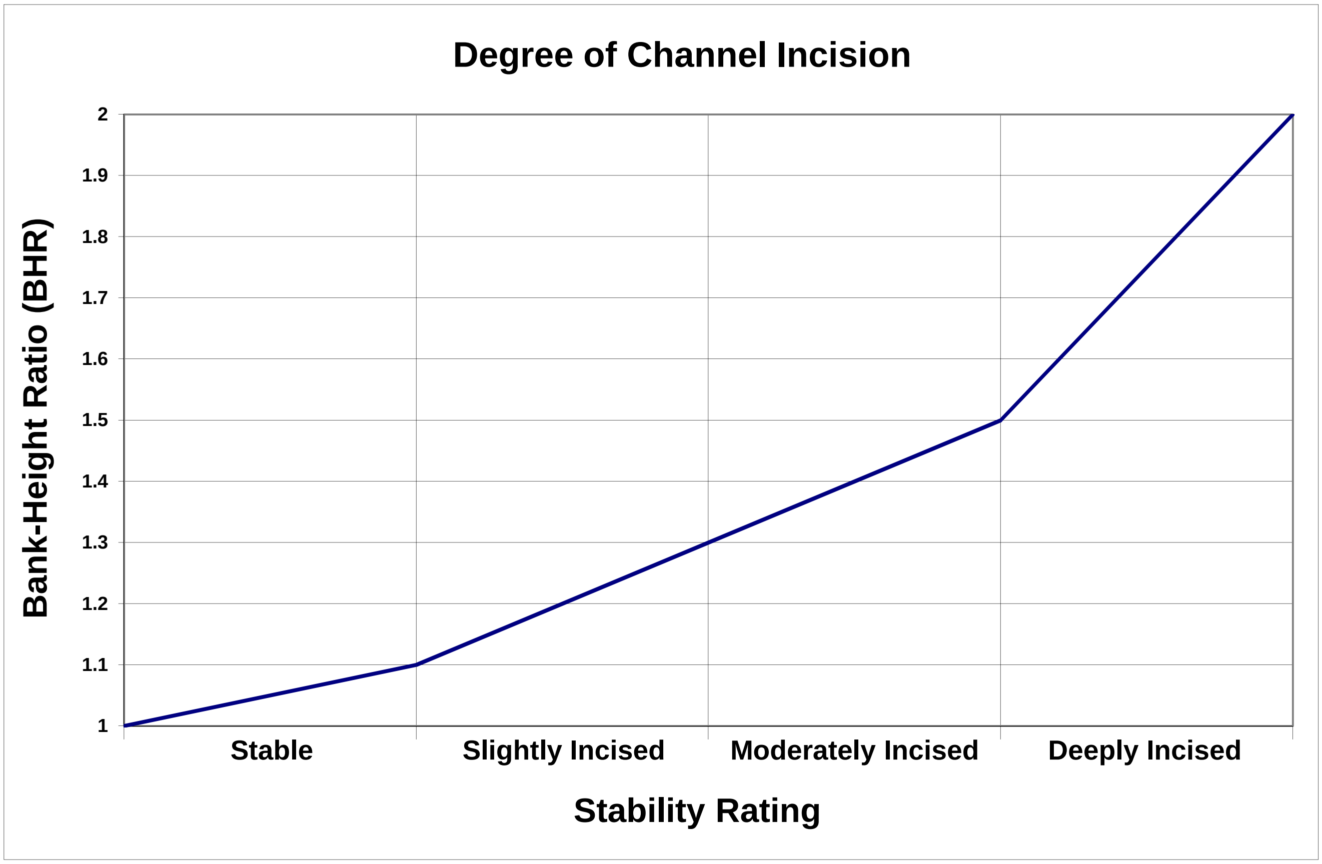


Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Red River**		Location: **Red River-2-419.14**	
Observers: **KD, JB**		Date: **9/29/2011**	
Description/extent		**Materials that 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.	☐

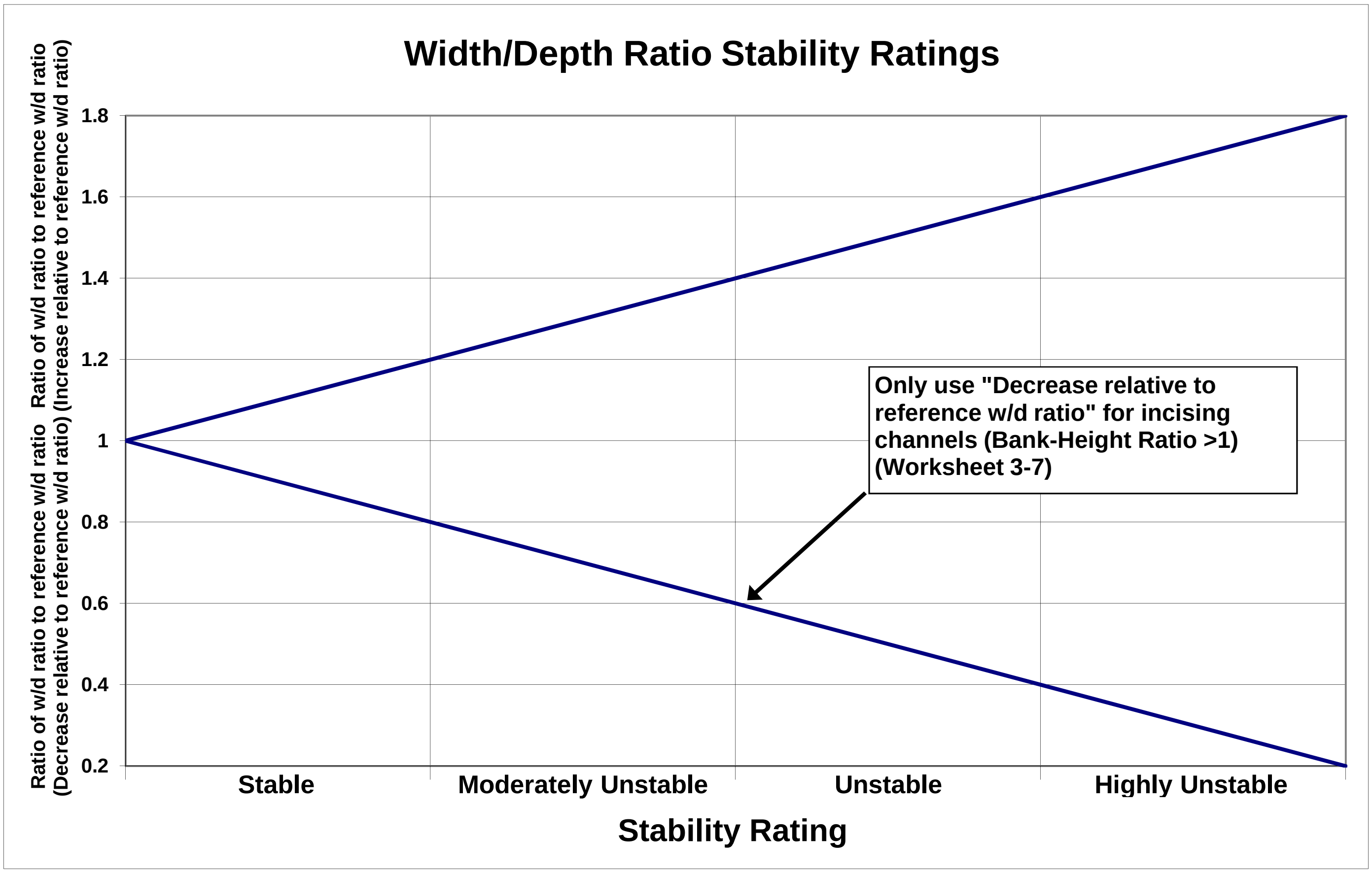
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision			
Low Bank Height:	31	Bank-Height Ratio:	1.9
Max Bankfull Depth:	16.6		
Degree of Channel Incision Stability Rating ☞			Deeply Incised



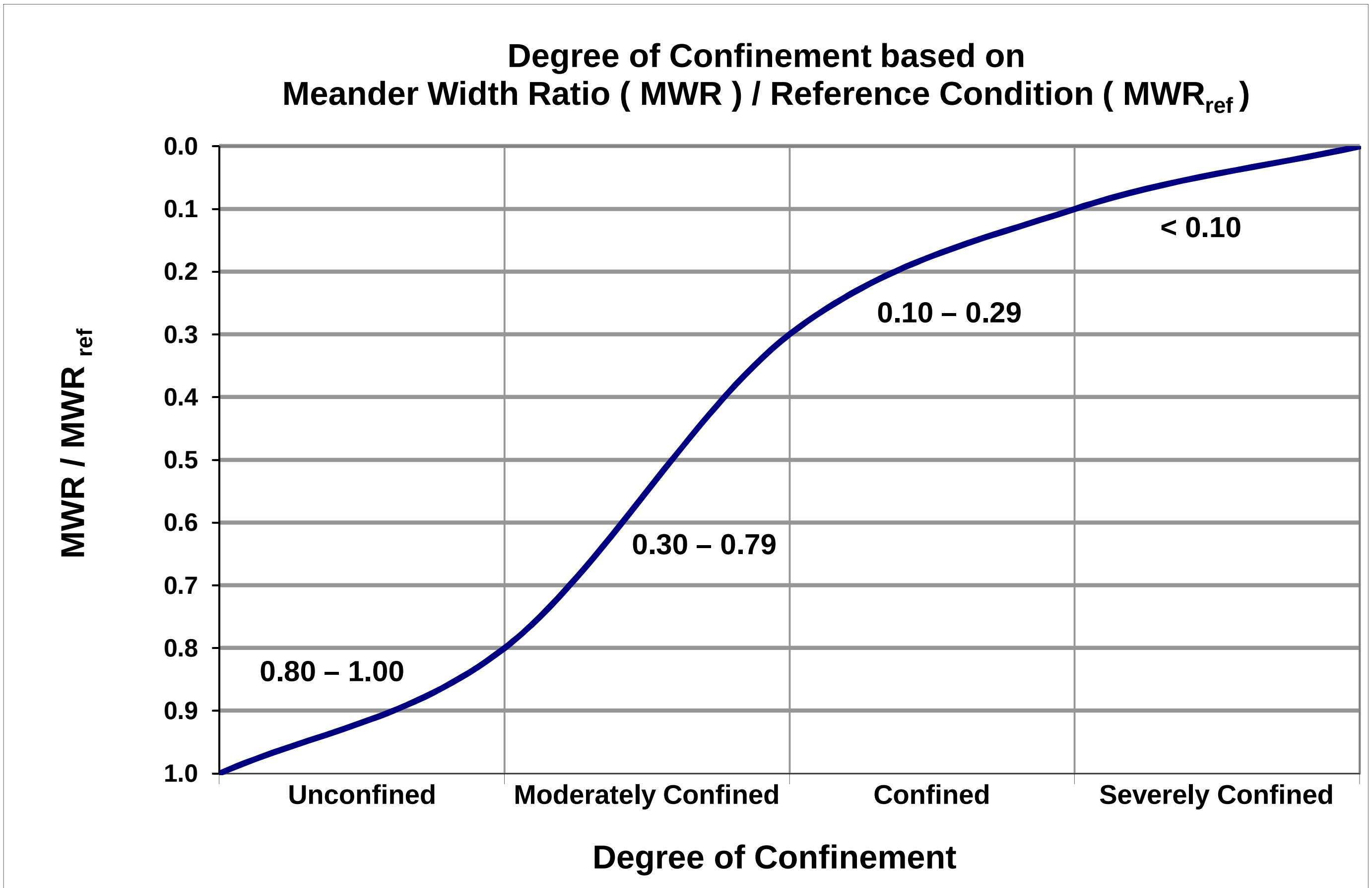
Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State			
Existing Width/Depth Ratio:	13.1	Ratio of existing W/d to reference W/d:	1
Reference Width/Depth Ratio:	13.1		
Width/Depth Ratio State Stability Rating ☞		**Stable**	



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	14.9	Ratio of MWR to MWR_{ref}:	1
Reference Meander Width Ratio (MWR_{ref}):	14.9		
Degree of Confinement Stability Rating ☞		**Unconfined**	



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Red River **Location:** Red River-2-419.14 **Valley Type:** X **Observers:** KD, JB **Date:** 9/29/2011

Location	Key	Category	Excellent Description	Rating	Good Description	Rating	Fair Description	Rating	Poor Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	**6**	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	**12**
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	**6**	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	**12**
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	**8**
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	**4**	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	**16**
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	19	Good total =	4	Fair total =	12	Poor total =	52

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	87
Existing stream type =	C6c-
*Potential stream type =	C6c-
Modified channel stability rating =	Fair

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream: **Red River** Location: **Red River-2-419.14**

Station: Observers: **KD, JB**

Date: **9/29/2011** Stream Type: **C6c-** Valley Type: **X**

						BEHI Score (Fig. 3-7)
Study Bank Height / Bankfull Height (C)						
Study Bank Height (ft) =	32.2 (A)	**Bankfull Height** (ft) =	15.5 (B)	(A) / (B) =	2.1 (C)	8
Root Depth / Study Bank Height (E)						
Root Depth (ft) =	3 (D)	**Study Bank Height** (ft) =	32.2 (A)	(D) / (A) =	0.1 (E)	8
Weighted Root Density (G)						
		Root Density as **%** =	5% (F)	(F) x (E) =	0% (G)	10
Bank Angle (H)						
				Bank Angle as *Degrees* =	22 (H)	2
Surface Protection (I)						
				Surface Protection as **%** =	2% (I)	10

Bank Material Adjustment:

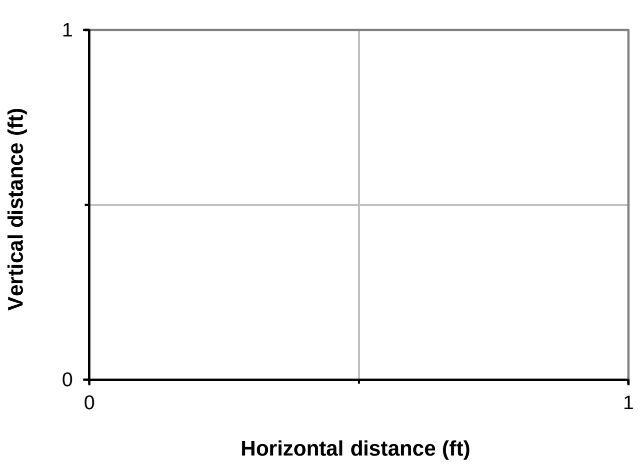
- **Bedrock** (Overall Very Low BEHI)
- **Boulders** (Overall Low BEHI)
- **Cobble** (Subtract 10 points if uniform medium to large cobble)
- **Gravel or Composite Matrix** (Add 5–10 points depending on percentage of bank material that is composed of sand)
- **Sand** (Add 10 points)
- **Silt/Clay** (no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

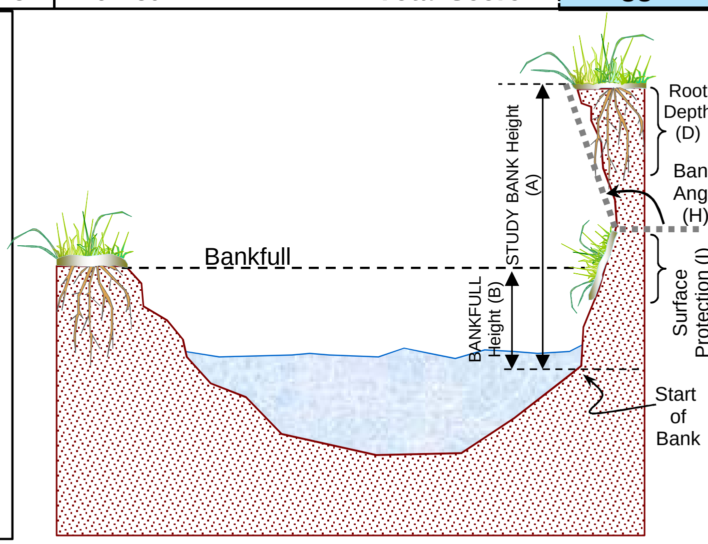
Bank Material Adjustment: 0

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 / 38

Bank Sketch





Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Red River**	Location: **Red River-2-419.14**	
Station: **0**	Stream Type: **C6c-**	Valley Type: **X**
Observers: **KD, JB**		Date: **9/29/11**

Methods for Estimating Near-Bank Stress (NBS)

(1)	Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2)	Ratio of radius of curvature to bankfull width (R_c / W_{bkf})..	Level II	General prediction
(3)	Ratio of pool slope to average water surface slope (S_p / S)..	Level II	General prediction
(4)	Ratio of pool slope to riffle slope (S_p / S_{rif})..	Level II	General prediction
(5)	Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6)	Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf}).........................	Level III	Detailed prediction
(7)	Velocity profiles / Isovels / Velocity gradient..	Level IV	Validation

Level I

(1)
- Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
- Extensive deposition (continuous, cross-channel).. ....NBS = Extreme
- Chute cutoffs, down-valley meander migration, converging flow..NBS = Extreme

Level II

(2)	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)

(3)	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)

(4)	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)

Dominant Near-Bank Stress
Very Low

Level III

(5)	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)
	16.6	**11.5**	**1.45**	**Low**

(6)	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)

Level IV

(7)	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
	0.04	**Very Low**

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating	**Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Red River**			Location:	**Red River-2-419.14**		
Graph Used:	**Fig 3-9**	Total Bank Length (ft):	**13635.2**			Date:	**9/29/2011**
Observers:	**KD, JB**	Valley Type:	**X**			Stream Type:	**C6c-**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**13635.2**	**32.2**	**72444**	**0.26**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**72444**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**2683**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**3488**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.26**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Red River**		Stream Type: **C6c-**		
Location:	**Red River-2-419.14**		Valley Type: **X**		
Observers:	**KD, JB**		Date: **9/29/2011**		
Enter Required Information for Existing Condition					
	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
0	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			
Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress					
#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1: $\tau^* = 0.0834\ (D_{50}/\hat{D}_{50})^{-0.872}$		
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2: $\tau^* = 0.0384\ (D_{max}/D_{50})^{-0.887}$		
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:		**#DIV/0!**
Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample					
#DIV/0!	**d**	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)	
	Check:	☐ Stable ☐ Aggrading ☐ Degrading			
Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample					
#DIV/0!	**S**	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)	
	Check:	☐ Stable ☐ Aggrading ☐ Degrading			
Sediment Competence Using Dimensional Shear Stress					
0	Bankfull shear stress $\tau = \gamma d S$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope				
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**				
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**				
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope		$d = \dfrac{\tau}{\gamma S}$		
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth		$S = \dfrac{\tau}{\gamma d}$		

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis

Observers: **KD, JB**

Stream: **Red River** | Location: **Red River-2-419.14** | Date: **9/29/2011**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		0		0		0		0		0		0		0		0		0
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		100%

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	0
Materials less than:	mm

Be sure to add separate material weights to grand total

GRAND TOTAL: 0

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Red River**	Stream Type: **C6c-**
Location: **Red River-2-419.14**	Valley Type: **X**
Observers: **KD, JB**	Date: **9/29/2011**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream:	**Red River**			Stream Type:	**C6c-**	
Location:	**Red River-2-419.14**			Valley Type:	**X**	
Observers:	**KD, JB**			Date:	**9/29/2011**	

	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 3-8)**	< 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	> 1.6 **(8)**	**2**
2	**Depositional pattern (Worksheet 3-5)**	B1, B2 **(1)**	B4, B8 **(2)**	B3 **(3)**	B5, B6, B7 **(4)**	**1**
3	**Meander pattern (Worksheet 3-4)**	M1, M3, M4 **(1)**		M2, M5, M6, M7, M8 **(3)**		**3**
4	**Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL **(2)**	M/L, M/M, M/H, L/Ex, H/L **(4)**	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL **(6)**	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex **(8)**	**4**
5	**Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.8 – 1.0 **(1)**	0.3 – 0.79 **(2)**	0.1 – 0.29 **(3)**	< 0.1 **(4)**	**1**
					Total points	**11**

	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** ☐

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Red River**	Stream Type:	**C6c-**
Location:	**Red River-2-419.14**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**9/29/2011**

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 3-14)**	Sufficient depth and/or slope to transport largest size available (2)	Trend toward insufficient depth and/or slope-slightly incompetent (4)	Cannot move D_{35} of bed material and/or D_{100} of bar material (6)	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size (8)	**2**
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load (2)	Trend toward insufficient sediment capacity (4)	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand (6)	Reduction over 25% of annual sediment yield for bedload and/or suspended sand (8)	**2**
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 (2)	1.2 – 1.4 (4)	1.4 – 1.6 (6)	>1.6 (8)	**2**
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation (2)	(E→C) (4)	(C→High W/d C), (B→High W/d B), (C→F) (6)	(C→D), (F→D) (8)	**2**
5 **Depositional patterns (Worksheet 3-5)**	B1 (1)	B2, B4 (2)	B3, B5 (3)	B6, B7, B8 (4)	**1**
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 (1)	D4, D7 (2)	D5, D8 (3)	D6, D9, D10 (4)	**1**
				Total points	**10**

Vertical stability for excess deposition / aggradation (use total points and check stability rating)	**Vertical stability category point range for excess deposition / aggradation**			
	No deposition 10 – 14 ☑	**Moderate deposition 15 – 20** ☐	**Excess deposition 21 – 30** ☐	**Aggradation > 30** ☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream:	**Red River**	Stream Type:	**C6c-**
Location:	**Red River-2-419.14**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**9/29/2011**

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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	2
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	2
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	8
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	4
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	1
				Total points	**17**

	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** ☐

Worksheet 3-20. Channel enlargement prediction summary.

Stream: **Red River**				Stream Type: **C6c-**	
Location: **Red River-2-419.14**				Valley Type: **X**	
Observers: **KD, JB**				Date: **9/29/2011**	
Channel enlargement prediction criteria **(choose one stability category for each criterion 1–4)**	**Channel Enlargement Prediction Categories**				**Selected points (from each row)**
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) **(2)**	(C→High W/d C), (E→C) **(4)**	(G→F), (F→D) **(6)**	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) **(8)**	**2**
2 **Lateral stability (Worksheet 3-17)**	Stable **(2)**	Moderately unstable **(4)**	Unstable **(6)**	Highly unstable **(8)**	**4**
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition **(2)**	Moderate deposition **(4)**	Excess deposition **(6)**	Aggradation **(8)**	**2**
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised **(2)**	Slightly incised **(4)**	Moderately incised **(6)**	Degradation **(8)**	**4**
				Total points	**12**
	Category point range				
Channel enlargement prediction **(use total points and check stability rating)**	**No increase 8 – 10** ☐	**Slight increase 11 – 16** ☑	**Moderate increase 17 – 24** ☐	**Extensive > 24** ☐	

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream: **Red River**		Stream Type:	**C6c-**
Location: **Red River-2-419.14**		Valley Type:	**X**
Observers: **KD, JB**		Date:	**9/29/2011**

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	**Stability Rating**	**Points**	**Selected Points**
1 Lateral stability (Worksheet 3-17)	Stable	1	2
	Mod. unstable	2	
	Unstable	3	
	Highly unstable	4	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition	1	1
	Mod. deposition	2	
	Excess deposition	3	
	Aggradation	4	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	2
	Slightly incised	2	
	Mod. Incised	3	
	Degradation	4	
4 Channel enlargement prediction (Worksheet 3-20)	No increase	1	2
	Slight increase	2	
	Mod. increase	3	
	Extensive	4	
5 Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	2
	Fair: mod unstable	2	
	Poor: unstable	4	
		Total Points	**9**

	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 ☐

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Red River**	Location:	**Red River-2-419.14**
Observers:	**KD, JB**	Date: **9/29/2011**	Stream Type: **C6c-** Valley Type: **X**

Channel Dimension	Mean bankfull depth (ft): **11.5**	Mean bankfull width (ft): **150.6**	Cross-section area (ft^2): **1725**	Width of flood-prone area (ft): **790.5**	Entrenchment ratio: **5.2**
Channel Pattern	Mean: Range: MWR: **14.9**	Lm/W_{bkf}: **14.9**	Rc/W_{bkf}: **5.1**	Sinuosity: **2.18**	

River Profile and Bed Features

Check: ☐ Riffle/pool ☐ Step/pool ☐ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed

Max bankfull depth (ft):	Riffle	Pool	Depth ratio (max/mean):	Riffle	Pool	Pool to pool spacing:	Ratio	Slope Valley:	Slope Average bankfull:
	16.6			**1.4**					**7E-05**

Level III Stream Stability Indices

Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:

Flow regime: **P1, 2, 7, 9**	Stream size and order: **S-9**	Meander pattern(s): **M2**	Depositional pattern(s): **NONE**	Debris/channel blockage(s): **D1-3**
Degree of incision (Bank-Height Ratio): **1.9**	Degree of incision stability rating: **Deeply Incised**	Modified Pfankuch stability rating (numeric and adjective rating): **Fair**		
Width/depth ratio (W/d): **13.1**	Reference W/d ratio (W/d_{ref}): **13.1**	Width/depth ratio state $(W/d) / (W/d_{ref})$: **1.0**	W/d ratio state stability rating: **Stable**	
Meander Width Ratio (MWR): **14.9**	Reference MWR_{ref}: **14.9**	Degree of confinement (MWR / MWR_{ref}): **1.0**	MWR / MWR_{ref} stability rating: **Unconfined**	

Bank Erosion Summary	Length of reach studied (ft): **####**	Annual streambank erosion rate: **3488** (tons/yr) **0.26** (tons/yr/ft)	Curve used: **Fig 3-9**	Remarks:
Sediment Capacity (POWERSED)	☑ Sufficient capacity ☐ Insufficient capacity ☐ Excess capacity			Remarks:
Entrainment/ Competence	Largest particle from bar sample (mm):	$\tau =$	$\tau^* =$	Existing $depth_{bkf}$: Required $depth_{bkf}$: Existing $slope_{bkf}$: Required $slope_{bkf}$:
Successional Stage Shift	→ → → → →	Existing stream state (type): **C6c-**	Potential stream state (type): **C6c-**	
Lateral Stability	☐ Stable ☑ Mod. unstable ☐ Unstable ☐ Highly unstable			Remarks/causes:
Vertical Stability (Aggradation)	☑ No deposition ☐ Mod. deposition ☐ Ex. deposition ☐ Aggradation			Remarks/causes:
Vertical Stability (Degradation)	☐ Not incised ☑ Slightly incised ☐ Mod. incised ☐ Degradation			Remarks/causes:
Channel Enlargement	☐ No increase ☑ Slight increase ☐ Mod. increase ☐ Extensive			Remarks/causes:
Sediment Supply (Channel Source)	☐ Low ☑ Moderate ☐ High ☐ Very high			Remarks/causes:

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Red River**	Location: **Red River - 3 - 440.57**
Observers: **KD, JB**	Reference reach [ ] / Disturbed (impacted reach) [X] / Date: **11/21/2010**
Existing species composition: **small shrubs**	Potential species composition: **small shrubs**

	Riparian cover categories	Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**5% without leaves, 70% with leaves**	**1%**	**trees**	**100%**
					100%
2. Understory	Shrub layer		**5%**	**small shrubs**	**95%**
				cocklebur bushes	**5%**
					100%
3. Ground level	Herbaceous		**2%**	**grass**	**100%**
					100%
	Leaf or needle litter		**1%**		
	Bare ground		**91%**		
			Column total = 100%		

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

Remarks:
Condition, vigor and/or usage of existing reach:
None

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Red River**		Location: **Red River - 3 - 440.57**						
Observers: **KD, JB**					Date: **11/21/2010**			
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P7**	**P8**	**P9**			

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order			
Stream:	Red River		
Location:	Red River - 3 - 440.57		
Observers:	KD, JB		
Date:	11/21/2010		
Stream Size Category and Order ☞			**S-8**
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).			

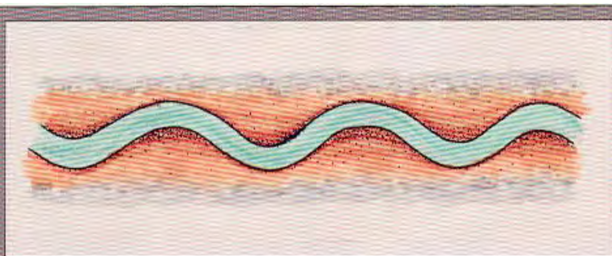
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Red River**	Reach:	**Red River - 3 - 440.57**
Observers:	**KD, JB**	Date:	**11/21/2010**

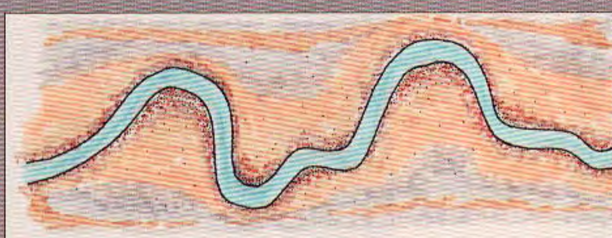
List ALL CATEGORIES that APPLY ☞	**M2**				

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

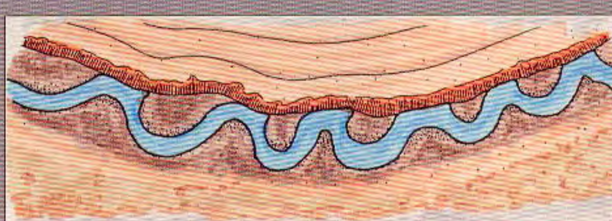


M1 REGULAR MEANDERS

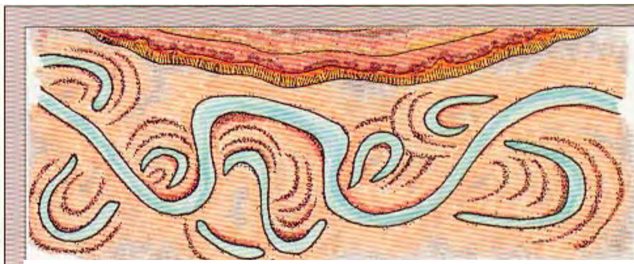
M2 TORTUOUS MEANDERS



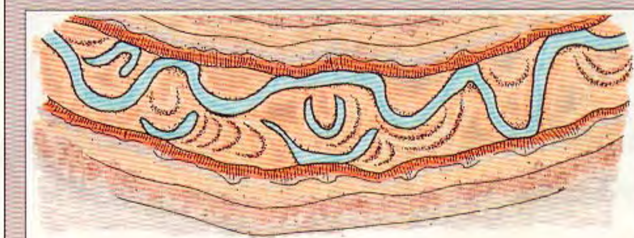
M3 IRREGULAR MEANDERS



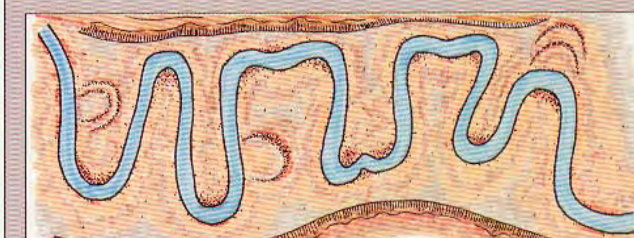
M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS



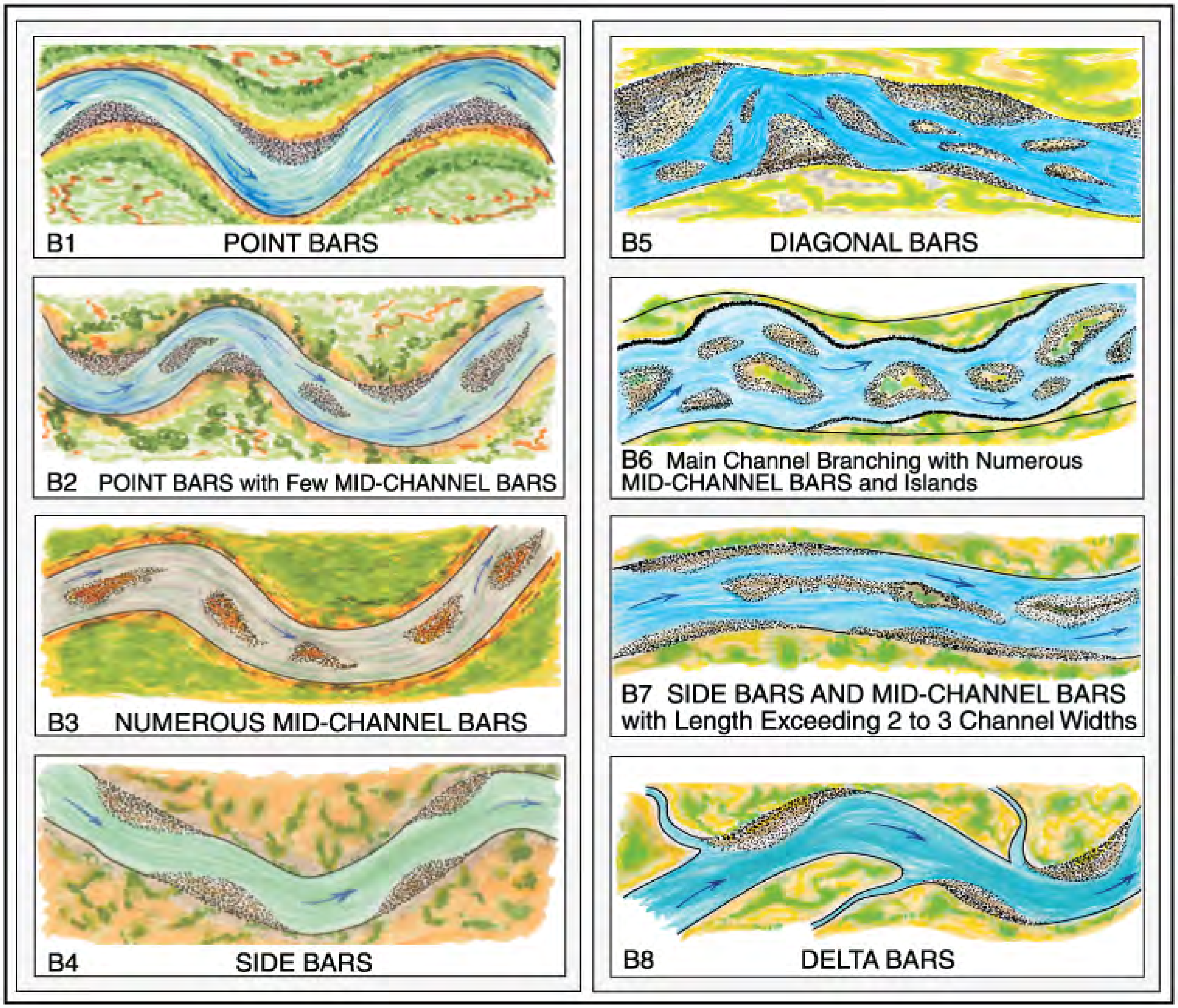
M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns					
Stream: **Red River**			Reach: **Red River - 3 - 440.57**		
Observers: **KD, JB**			Date: **11/21/2010**		
List ALL CATEGORIES that APPLY ☞	**NONE**				

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



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Red River**		Location: **Red River - 3 - 440.57**	
Observers: **KD, JB**		Date: **11/21/2010**	
Description/extent		**Materials that 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.	☐

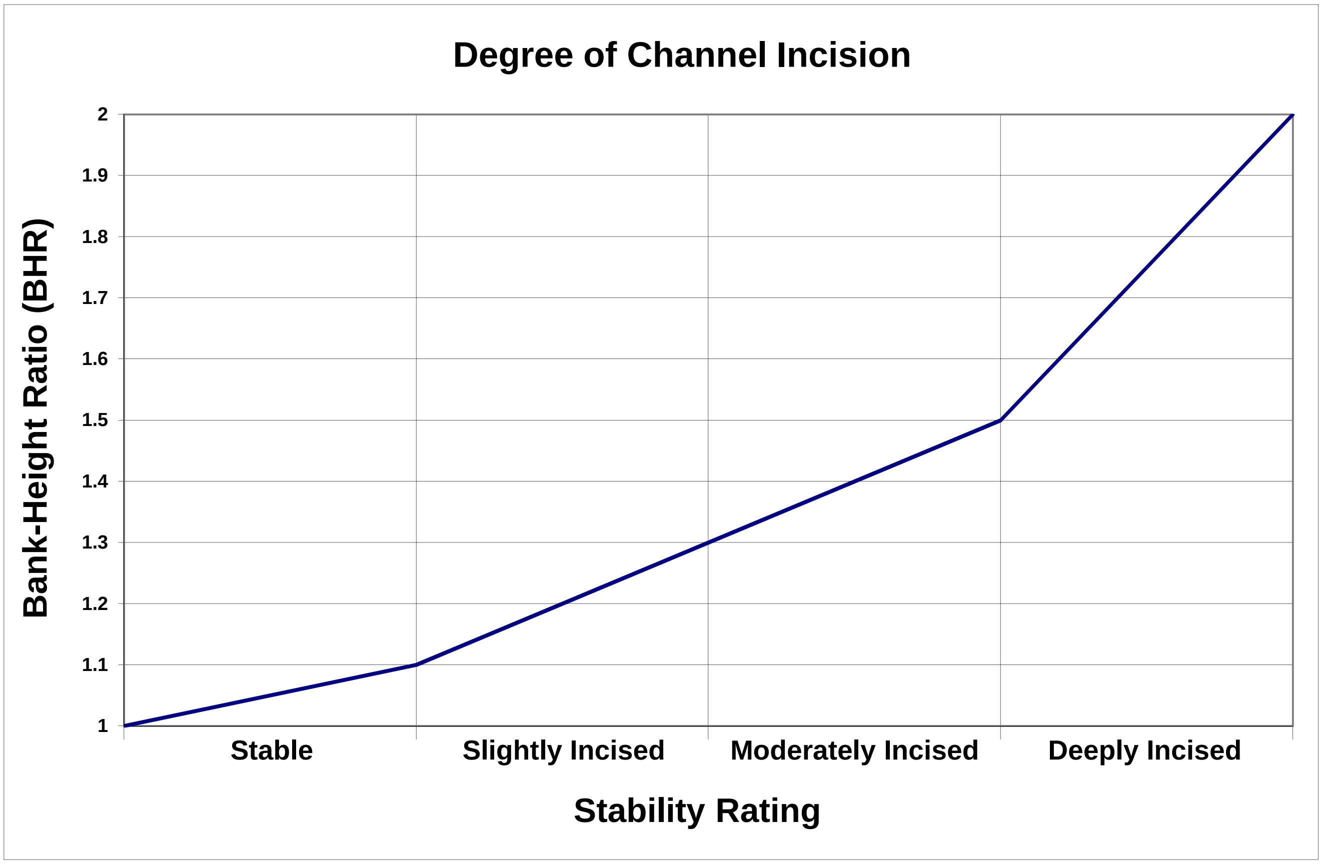
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision

Low Bank Height:	**18**
Max Bankfull Depth:	**13.46**

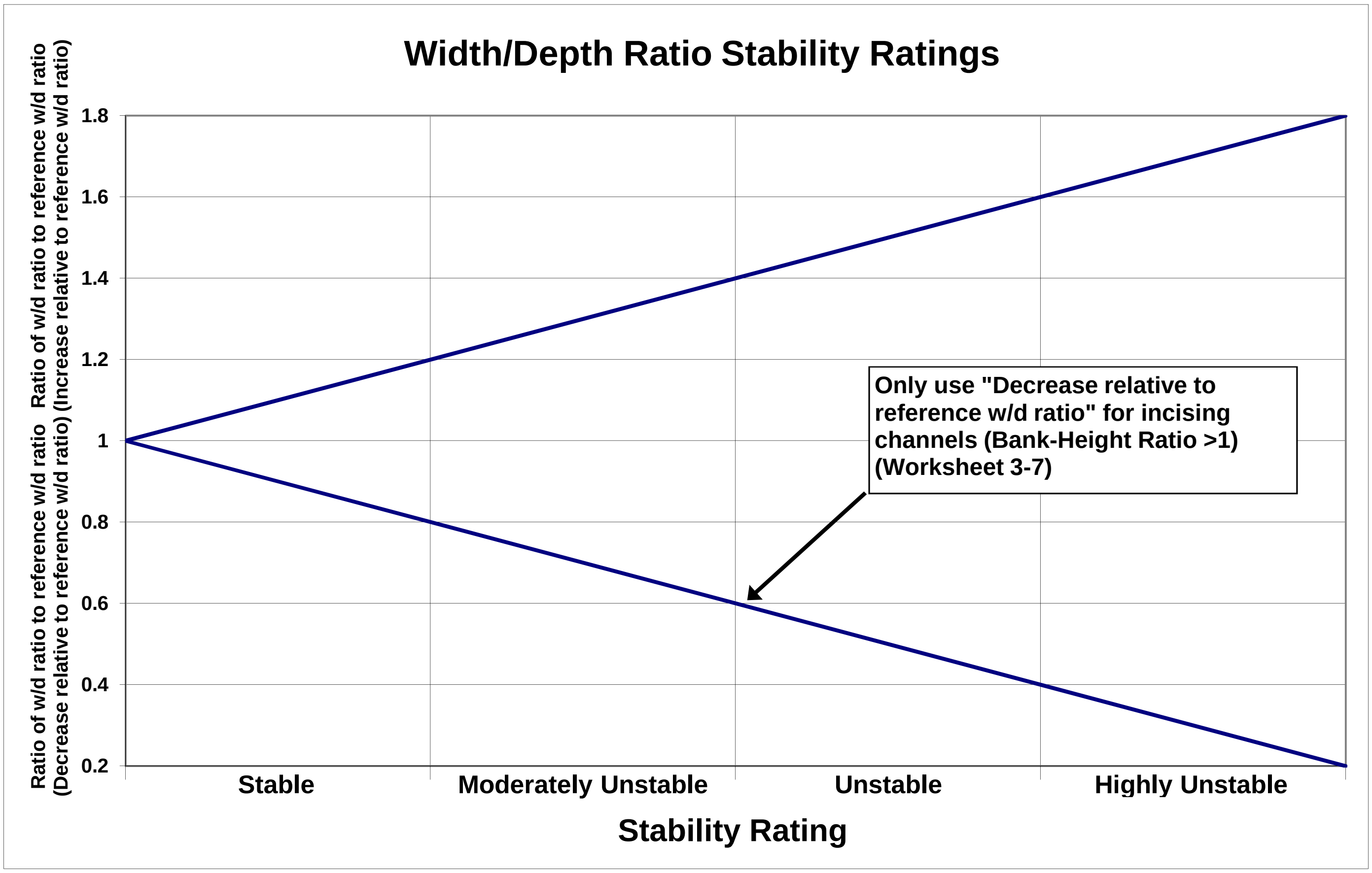
Bank-Height Ratio:	**1.3**

Degree of Channel Incision Stability Rating ☞	**Slightly Incised**



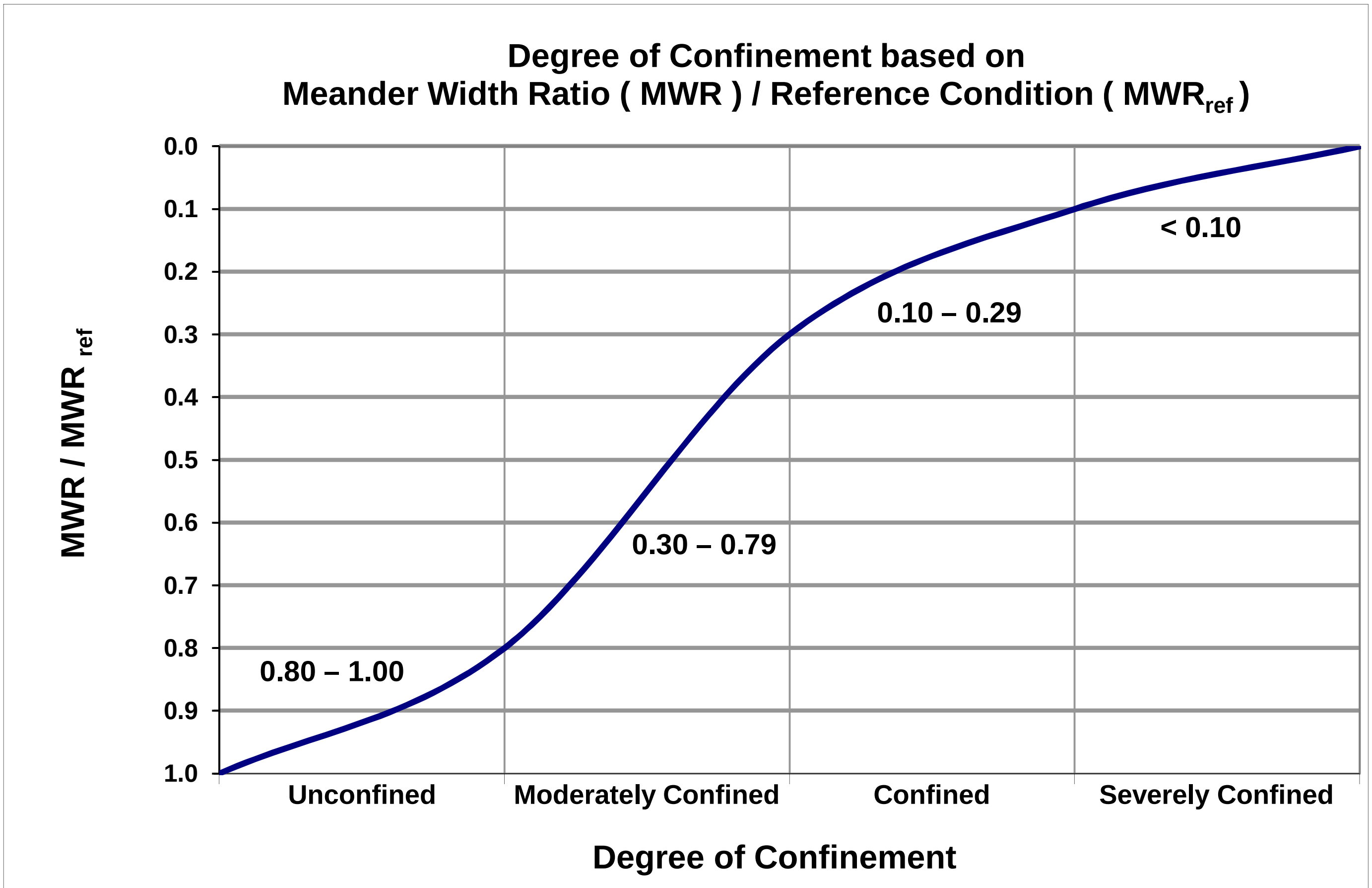
Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State			
Existing Width/Depth Ratio:	13.9	Ratio of existing W/d to reference W/d:	1.019
Reference Width/Depth Ratio:	13.6		
Width/Depth Ratio State Stability Rating ☞		Stable	



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	14.0	Ratio of MWR to MWR_{ref}:	0.984
Reference Meander Width Ratio (MWR_{ref}):	14.2		
Degree of Confinement Stability Rating ☞		Unconfined	



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Red River **Location:** Red River - 3 - 440.57 **Valley Type:** X **Observers:** KD, JB **Date:** 11/21/2010

Location	Key	Category	Excellent: Description	Excellent: Rating	Good: Description	Good: Rating	Fair: Description	Fair: Rating	Poor: Description	Poor: Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	**2**	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	**9**	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	**4**	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	**6**	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	**2**	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	**4**	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	**16**
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	23	Good total =	14	Fair total =	9	Poor total =	20

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	66
Existing stream type =	C6c-
*Potential stream type =	C6c-
Modified channel stability rating =	Good

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream: **Red River**	Location: **Red River - 3 - 440.57**
Station:	Observers: **KD, JB**
Date: **11/21/2010** Stream Type: **C6c-**	Valley Type: **X**

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	19.1 (A)	Bankfull Height (ft) =	12.2 (B)	(A) / (B) =	1.6 (C)	6

Root Depth / Study Bank Height (E)

Root Depth (ft) =	1 (D)	Study Bank Height (ft) =	19.1 (A)	(D) / (A) =	0.1 (E)	8

Weighted Root Density (G)

Root Density as % =	40% (F)	(F) x (E) =	2% (G)	10

Bank Angle (H)

Bank Angle as *Degrees* =	22 (H)	2

Surface Protection (I)

Surface Protection as % =	3% (I)	10

Bank Material Adjustment:

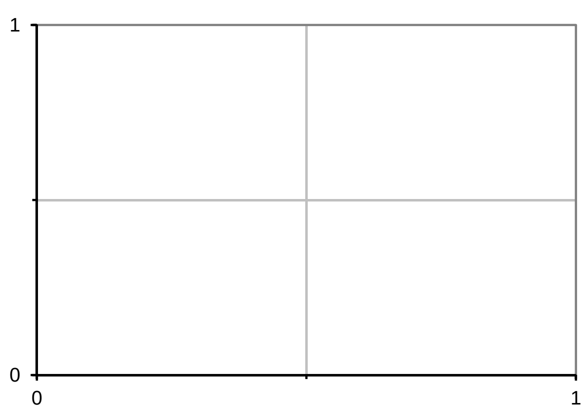
Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

Bank Material Adjustment: 0

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

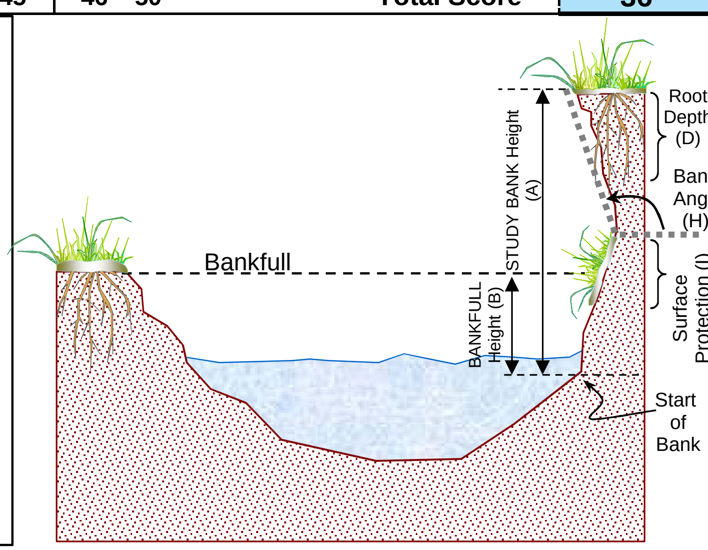
Very Low	Low	Moderate	High	Very High	Extreme	Adjective Rating	High
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50	and Total Score	36

Bank Sketch



Vertical distance (ft)

Horizontal distance (ft)



Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Red River**	Location: **Red River - 3 - 440.57**
Station: **0**	Stream Type: **C6c-** Valley Type: **X**
Observers: **KD, JB**	Date: **11/21/10**

Methods for Estimating Near-Bank Stress (NBS)

(1)	Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2)	Ratio of radius of curvature to bankfull width (R_c / W_{bkf})...	Level II	General prediction
(3)	Ratio of pool slope to average water surface slope (S_p / S)......................................	Level II	General prediction
(4)	Ratio of pool slope to riffle slope (S_p / S_{rif})..	Level II	General prediction
(5)	Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6)	Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})............................	Level III	Detailed prediction
(7)	Velocity profiles / Isovels / Velocity gradient..	Level IV	Validation

Level I

(1)
- Transverse and/or central bars-short and/or discontinuous........................NBS = High / Very High
- Extensive deposition (continuous, cross-channel)..NBS = Extreme
- Chute cutoffs, down-valley meander migration, converging flow.................................NBS = Extreme

Level II

	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)
(2)				

	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)
(3)				

	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)
(4)				

Dominant Near-Bank Stress
Very Low

Level III

	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)
(5)				

	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)
(6)								

Level IV

	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
(7)	0	Very Low

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating: Very Low

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream: **Red River**				Location: **Red River - 3 - 440.57**			
Graph Used: **Fig 3-9**		Total Bank Length (ft): **10364.3**				Date: **11/21/2010**	
Observers: **KD, JB**			Valley Type: **X**			Stream Type: **C6c-**	
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**10364.3**	**19.1**	**32663**	**0.15**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**32663**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**1210**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**1573**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.15**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Red River**		Stream Type:	**C6c-**
Location:	**Red River - 3 - 440.57**		Valley Type:	**X**
Observers:	**KD, JB**		Date:	**11/21/2010**

Enter Required Information for Existing Condition

	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	**#DIV/0!**

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	d	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	S	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Sediment Competence Using Dimensional Shear Stress

0	Bankfull shear stress $\tau = \gamma d S$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope	
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**	
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**	
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope	$d = \dfrac{\tau}{\gamma S}$
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth	$S = \dfrac{\tau}{\gamma d}$

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis

Observers: **KD, JB**

Stream: **Red River**

Location: **Red River - 3 - 440.57**

Date: **11/21/2010**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																				
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				
11																				
12																				
13																				
14																				
15																				
Net wt. total		0		0		0		0		0		0		0		0		0		0
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		#####		100%

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	0
Materials less than:	mm

Be sure to add separate material weights to grand total

GRAND TOTAL: 0

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Red River**	Stream Type: **C6c-**
Location: **Red River - 3 - 440.57**	Valley Type: **X**
Observers: **KD, JB**	Date: **11/21/2010**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream: **Red River**			Stream Type:	**C6c-**	
Location: **Red River - 3 - 440.57**			Valley Type:	**X**	
Observers: **KD, JB**			Date:	**11/21/2010**	
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 3-8)**	< 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	> 1.6 **(8)**	**2**
2 **Depositional pattern (Worksheet 3-5)**	B1, B2 **(1)**	B4, B8 **(2)**	B3 **(3)**	B5, B6, B7 **(4)**	**1**
3 **Meander pattern (Worksheet 3-4)**	M1, M3, M4 **(1)**		M2, M5, M6, M7, M8 **(3)**		**3**
4 **Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL **(2)**	M/L, M/M, M/H, L/Ex, H/L **(4)**	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL **(6)**	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex **(8)**	**4**
5 **Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.8 – 1.0 **(1)**	0.3 – 0.79 **(2)**	0.1 – 0.29 **(3)**	< 0.1 **(4)**	**1**
				Total points	**11**
	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** ☐	

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Red River**	Stream Type:	**C6c-**
Location:	**Red River - 3 - 440.57**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**11/21/2010**

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 3-14)**	Sufficient depth and/or slope to transport largest size available **(2)**	Trend toward insufficient depth and/or slope-slightly incompetent **(4)**	Cannot move D_{35} of bed material and/or D_{100} of bar material **(6)**	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size **(8)**	**2**
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load **(2)**	Trend toward insufficient sediment capacity **(4)**	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand **(6)**	Reduction over 25% of annual sediment yield for bedload and/or suspended sand **(8)**	**2**
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	>1.6 **(8)**	**2**
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation **(2)**	(E→C) **(4)**	(C→High W/d C), (B→High W/d B), (C→F) **(6)**	(C→D), (F→D) **(8)**	**2**
5 **Depositional patterns (Worksheet 3-5)**	B1 **(1)**	B2, B4 **(2)**	B3, B5 **(3)**	B6, B7, B8 **(4)**	**1**
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 **(1)**	D4, D7 **(2)**	D5, D8 **(3)**	D6, D9, D10 **(4)**	**1**
				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** ☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream:	**Red River**	Stream Type:	**C6c-**
Location:	**Red River - 3 - 440.57**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**11/21/2010**

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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	**2**
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	**2**
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	**4**
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	**4**
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	**1**
				Total points	**13**

	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** ☐

Worksheet 3-20. Channel enlargement prediction summary.

Stream: **Red River**			Stream Type: **C6c-**		
Location: **Red River - 3 - 440.57**			Valley Type: **X**		
Observers: **KD, JB**			Date: **11/21/2010**		
Channel enlargement prediction criteria (choose one stability category for each criterion 1–4)	**Channel Enlargement Prediction Categories**				**Selected points (from each row)**
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) **(2)**	(C→High W/d C), (E→C) **(4)**	(G→F), (F→D) **(6)**	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) **(8)**	**2**
2 **Lateral stability (Worksheet 3-17)**	Stable **(2)**	Moderately unstable **(4)**	Unstable **(6)**	Highly unstable **(8)**	**4**
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition **(2)**	Moderate deposition **(4)**	Excess deposition **(6)**	Aggradation **(8)**	**2**
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised **(2)**	Slightly incised **(4)**	Moderately incised **(6)**	Degradation **(8)**	**4**
				Total points	**12**
	Category point range				
Channel enlargement prediction (use total points and check stability rating)	**No increase 8 – 10** ☐	**Slight increase 11 – 16** ☑	**Moderate increase 17 – 24** ☐	**Extensive > 24** ☐	

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream: **Red River**		Stream Type:	**C6c-**
Location: **Red River - 3 - 440.57**		Valley Type:	**X**
Observers: **KD, JB**		Date:	**11/21/2010**

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	Stability Rating	Points	Selected Points
1 Lateral stability (Worksheet 3-17)	Stable	1	2
	Mod. unstable	2	
	Unstable	3	
	Highly unstable	4	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition	1	1
	Mod. deposition	2	
	Excess deposition	3	
	Aggradation	4	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	2
	Slightly incised	2	
	Mod. Incised	3	
	Degradation	4	
4 Channel enlargement prediction (Worksheet 3-20)	No increase	1	2
	Slight increase	2	
	Mod. increase	3	
	Extensive	4	
5 Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	1
	Fair: mod unstable	2	
	Poor: unstable	4	
		Total Points	8

	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 ☐

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Red River**		Location: **Red River - 3 - 440.57**		
Observers:	**KD, JB**	Date: **11/21/2010**	Stream Type: **C6c-**	Valley Type: **X**	
Channel Dimension	Mean bankfull depth (ft): **9.79**	Mean bankfull width (ft): **136**	Cross-section area (ft^2): **1334**	Width of flood-prone area (ft): **619.25**	Entrenchment ratio: **4.6**
Channel Pattern	Mean: Range: MWR: **14.0**	Lm/W_{bkf}: **14.0**	Rc/W_{bkf}: **2.1**	Sinuosity: **2.15**	
River Profile and Bed Features	Check: ☐ Riffle/pool ☐ Step/pool ☑ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed				
	Max bankfull depth (ft): Riffle **13.5**, Pool	Depth ratio (max/mean): Riffle **1.4**, Pool	Pool to pool spacing: Ratio	Slope: Valley: ; Average bankfull: **6.8E-05**	
Level III Stream Stability Indices	Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:	
	Flow regime: **P1, 2, 7, 8, 9**	Stream size and order: **S-8**	Meander pattern(s): **M2**	Depositional pattern(s): **NONE**	Debris/channel blockage(s): **D2**
	Degree of incision (Bank-Height Ratio): **1.3**	Degree of incision stability rating: **Slightly Incised**	Modified Pfankuch stability rating (numeric and adjective rating): **Good**		
	Width/depth ratio (W/d): **13.9**	Reference W/d ratio (W/d_{ref}): **13.6**	Width/depth ratio state $(W/d) / (W/d_{ref})$: **1.0**	W/d ratio state stability rating: **Stable**	
	Meander Width Ratio (MWR): **14.0**	Reference MWR_{ref}: **14.2**	Degree of confinement (MWR / MWR_{ref}): **1.0**	MWR / MWR_{ref} stability rating: **Unconfined**	
Bank Erosion Summary	Length of reach studied (ft): **####**	Annual streambank erosion rate: **1573** (tons/yr) **0.15** (tons/yr/ft)	Curve used: **Fig 3-9**	Remarks:	
Sediment Capacity (POWERSED)	☑ Sufficient capacity ☐ Insufficient capacity ☐ Excess capacity			Remarks:	
Entrainment/ Competence	Largest particle from bar sample (mm):	$\tau =$	$\tau^* =$	Existing $depth_{bkf}$: ; Required $depth_{bkf}$:	Existing $slope_{bkf}$: ; Required $slope_{bkf}$:
Successional Stage Shift	→ → → → →			Existing stream state (type): **C6c-**	Potential stream state (type): **C6c-**
Lateral Stability	☐ Stable ☑ Mod. unstable ☐ Unstable ☐ Highly unstable			Remarks/causes: **None**	
Vertical Stability (Aggradation)	☑ No deposition ☐ Mod. deposition ☐ Ex. deposition ☐ Aggradation			Remarks/causes: **None**	
Vertical Stability (Degradation)	☐ Not incised ☑ Slightly incised ☐ Mod. incised ☐ Degradation			Remarks/causes: **None**	
Channel Enlargement	☐ No increase ☑ Slight increase ☐ Mod. increase ☐ Extensive			Remarks/causes: **None**	
Sediment Supply (Channel Source)	☐ Low ☑ Moderate ☐ High ☐ Very high			Remarks/causes: **None**	

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Red River**	Location: **Red River - 4 - 452.52**
Observers: **KD, JB**	Reference reach: [ ] Disturbed (impacted reach): **X** Date: **11/16/2010**
Existing species composition: **Trees, briar bushes, grass**	Potential species composition: **Trees, briar bushes, grass**

	Riparian cover categories	Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**5% without leaves, 80% with leaves**	**1%**	**trees**	**100%**
					100%
2. Understory	Shrub layer		**2%**	**briars**	**100%**
					100%
3. Ground level	Herbaceous		**5%**	**grass**	**100%**
					100%
	Leaf or needle litter		**1%**		
	Bare ground		**91%**		
			Column total = 100%		

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

Remarks:
Condition, vigor and/or usage of existing reach:
NONE

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Red River**			Location: **Red River - 4 - 452.52**					
Observers: **KD, JB**						Date: **11/16/2010**		
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P7**	**P8**	**P9**			

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order

Stream:	**Red River**
Location:	**Red River - 4 - 452.52**
Observers:	**KD, JB**
Date:	**11/16/2010**

Stream Size Category and Order ☞ **S-9**

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).

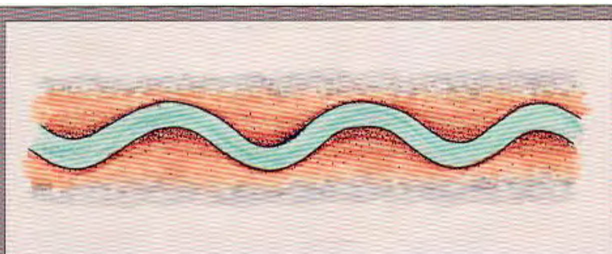
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Red River**	Reach:	**Red River - 4 - 452.52**
Observers:	**KD, JB**	Date:	**11/16/2010**

List ALL CATEGORIES that APPLY ☞	**M2**				

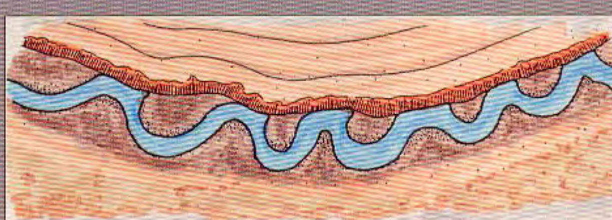
Various Meander Pattern variables modified from Galay et al. (1973)



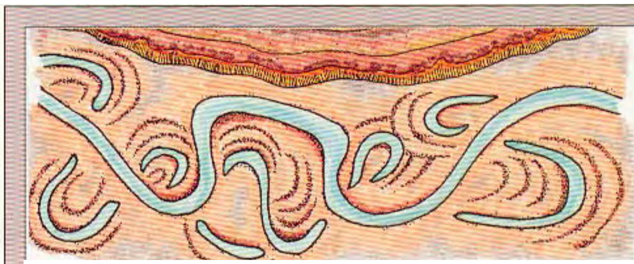
M1 REGULAR MEANDERS

M2 TORTUOUS MEANDERS

M3 IRREGULAR MEANDERS

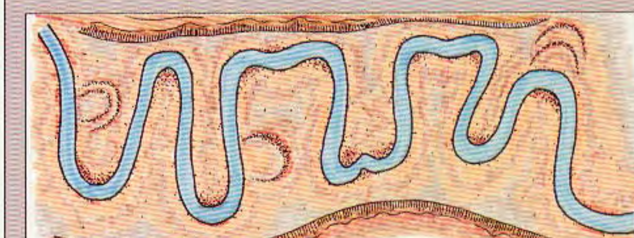


M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS

M6 CONFINED MEANDER SCROLLS



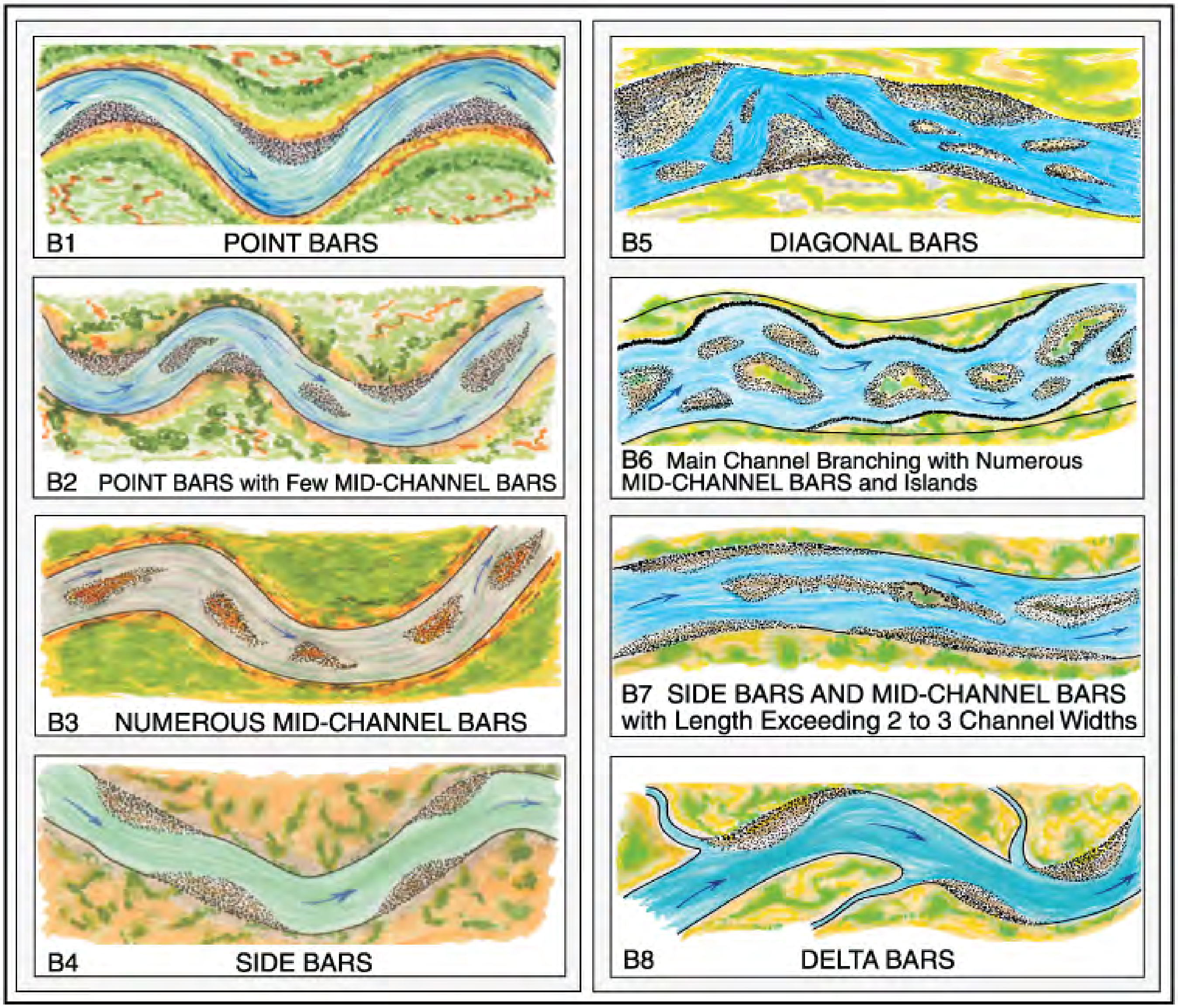
M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns					
Stream: **Red River**			Reach: **Red River - 4 - 452.52**		
Observers: **KD, JB**			Date: **11/16/2010**		
List ALL CATEGORIES that APPLY ☞	**NONE**				

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

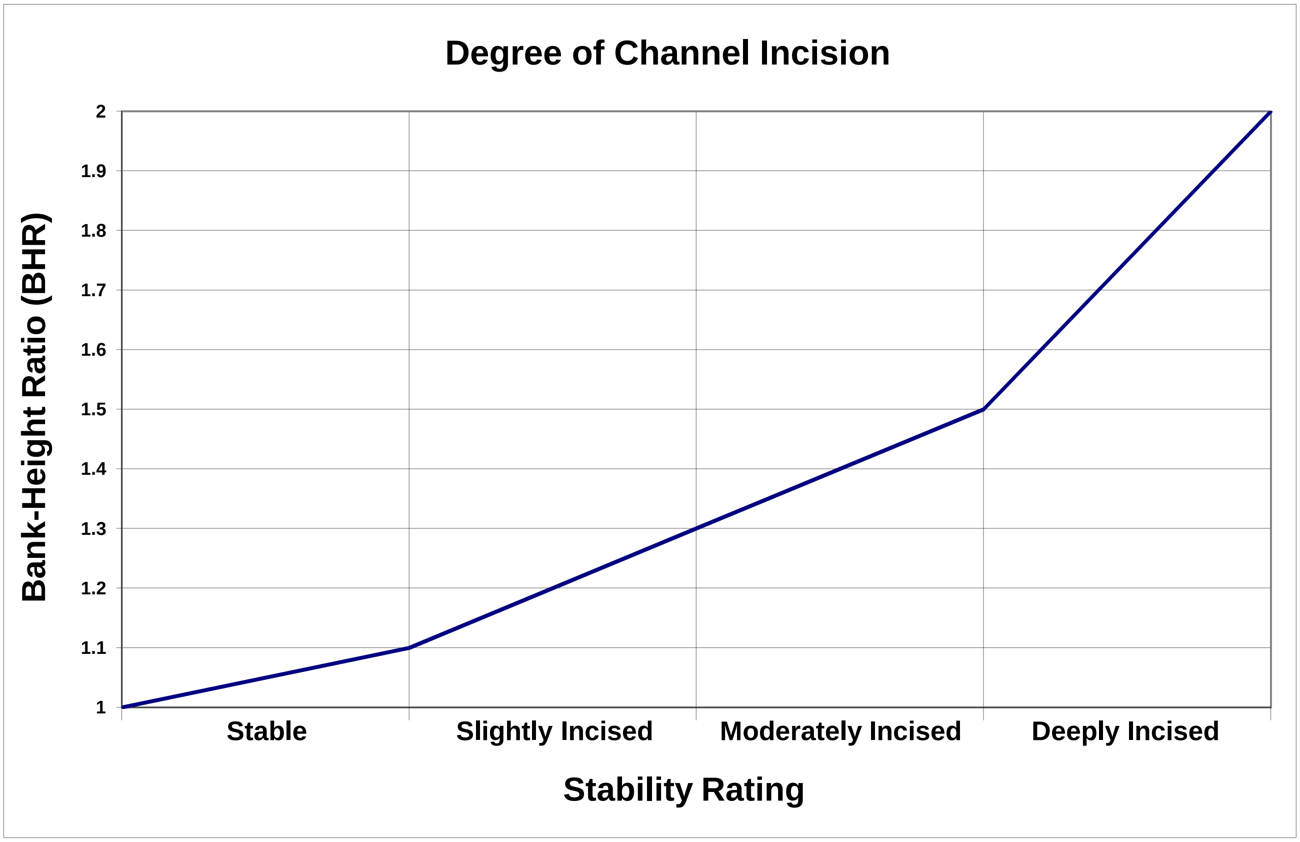


Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Red River**		Location: **Red River - 4 - 452.52**	
Observers: **KD, JB**		Date: **11/16/2010**	
Description/extent		**Materials that 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.	☐

Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision			
Low Bank Height:	16	Bank-Height Ratio:	1.1
Max Bankfull Depth:	14.99		
Degree of Channel Incision Stability Rating ☞		Stable	

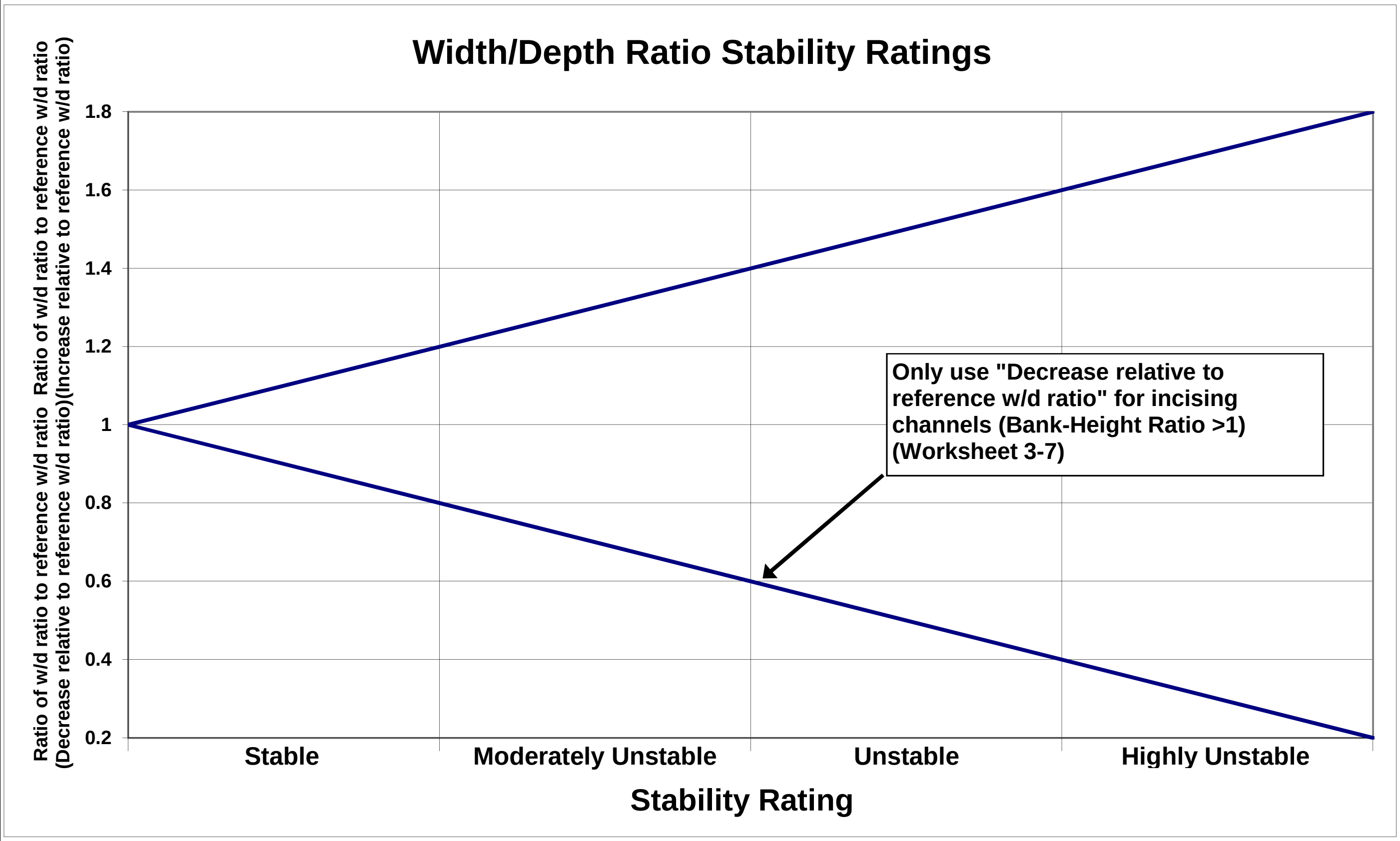


Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State

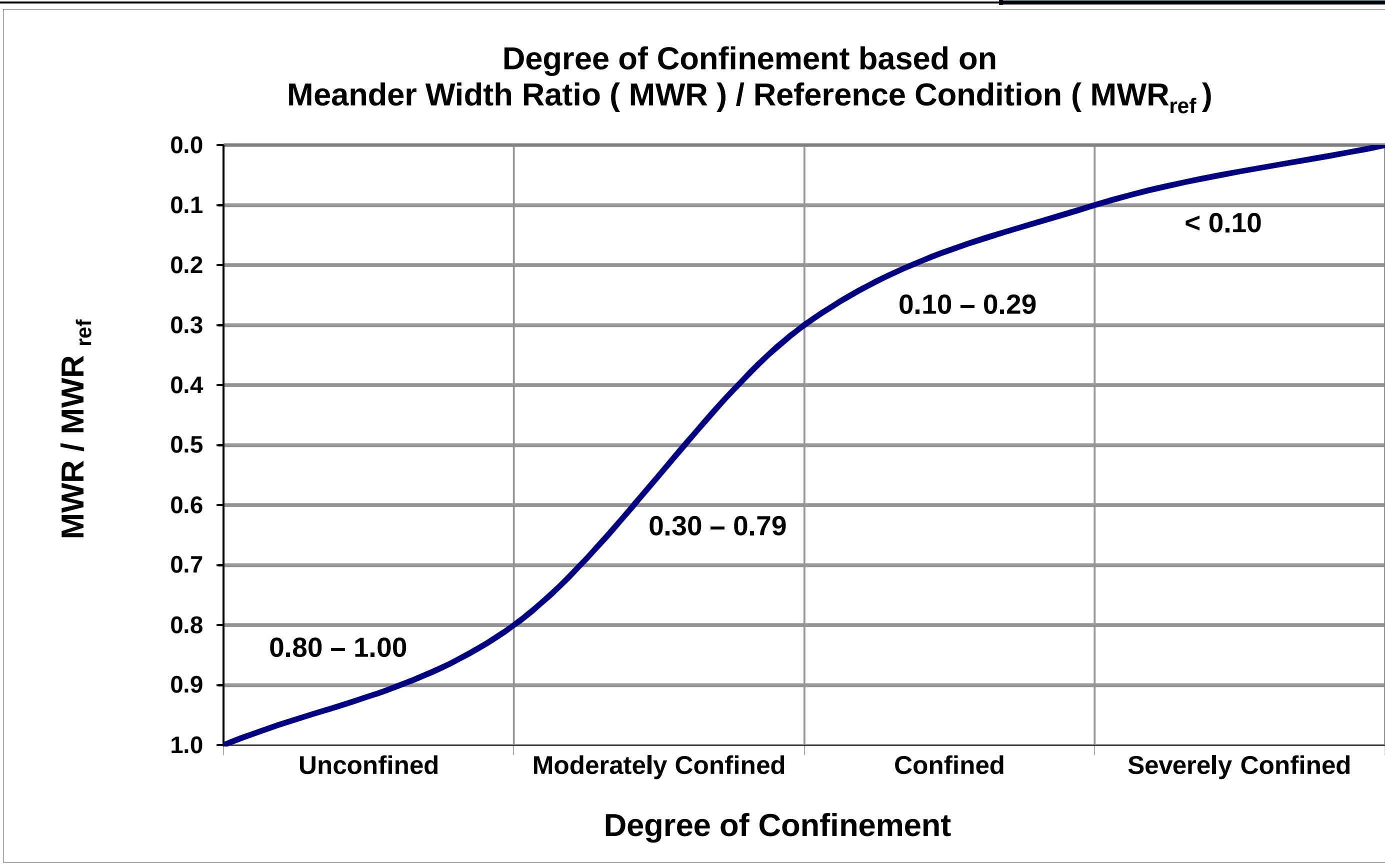
Existing Width/Depth Ratio:	**15.5**	Ratio of existing W/d to reference W/d:	**1**
Reference Width/Depth Ratio:	**15.5**		

Width/Depth Ratio State Stability Rating ☞	**Stable**



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	17.2	Ratio of MWR to MWR_{ref}:	1
Reference Meander Width Ratio (MWR_{ref}):	17.2		
Degree of Confinement Stability Rating ☞		Unconfined	



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Red River **Location:** Red River - 4 - 452.52 **Valley Type:** X **Observers:** KD, JB **Date:** 11/16/2010

Location	Key	Category	Excellent – Description	Excellent – Rating	Good – Description	Good – Rating	Fair – Description	Fair – Rating	Poor – Description	Poor – Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	**8**
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	**9**	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	**4**	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	**9**	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	**2**	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	**4**	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	**12**	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	21	Good total =	8	Fair total =	30	Poor total =	12

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	71
Existing stream type =	C6c-
*Potential stream type =	C6c-
Modified channel stability rating =	Good

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream:	**Red River**	Location:	**Red River - 4 - 452.52**
Station:	**49.06**	Observers:	**KD, JB**
Date:	**11/16/2010**	Stream Type: **C6c-**	Valley Type: **X**

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	16.1 (A)	Bankfull Height (ft) =	13.5 (B)	(A) / (B) =	1.2 (C)	BEHI Score: 3

Root Depth / Study Bank Height (E)

Root Depth (ft) =	1 (D)	Study Bank Height (ft) =	16.1 (A)	(D) / (A) =	0.1 (E)	BEHI Score: 8

Weighted Root Density (G)

Root Density as % =	50% (F)	(F) x (E) =	3% (G)	BEHI Score: 10

Bank Angle (H)

Bank Angle as *Degrees* =	18 (H)	BEHI Score: 2

Surface Protection (I)

Surface Protection as % =	5% (I)	BEHI Score: 10

Bank Material Adjustment:

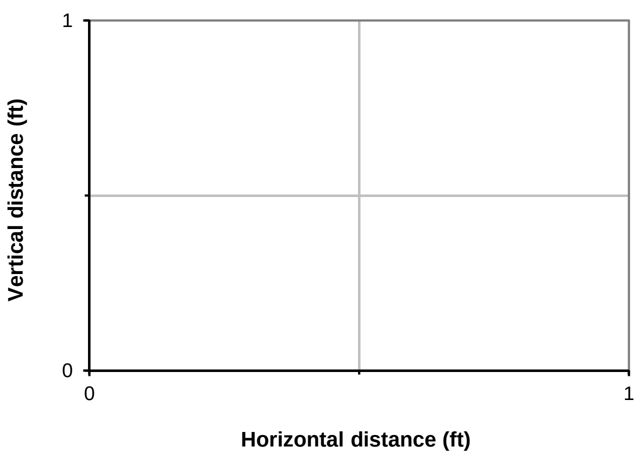
Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

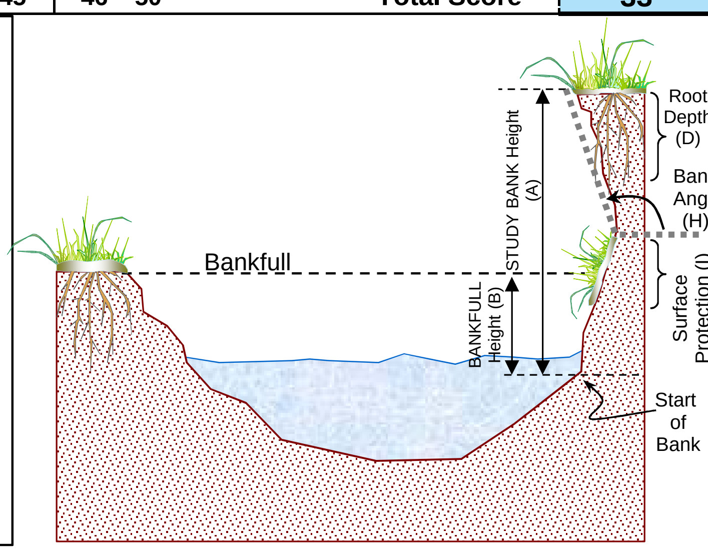
Bank Material Adjustment: 0

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	**High**
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50	**and Total Score**	**33**

Bank Sketch





Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Red River**	Location: **Red River - 4 - 452.52**	
Station: **49.06**	Stream Type: **C6c-**	Valley Type: **X**
Observers: **KD, JB**		Date: **11/16/10**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})...	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S)......................................	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})..	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})............................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient...	Level IV	Validation

Level I	**(1)**	Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High Extensive deposition (continuous, cross-channel).. ....NBS = Extreme Chute cutoffs, down-valley meander migration, converging flow...NBS = Extreme

Level II

(2)	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)

(3)	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)

(4)	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)

Dominant Near-Bank Stress
Very Low

Level III

(5)	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)

(6)	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)

Level IV

(7)	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
	0.03	**Very Low**

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	**Method number**						
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating	**Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Red River**			Location:	**Red River - 4 - 452.52**		
Graph Used:	**Fig 3-9**	Total Bank Length (ft):	**14428.3**			Date:	**11/16/2010**
Observers:	**KD, JB**	Valley Type:	**X**			Stream Type:	**C6c-**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**14428.3**	**16.1**	**38329**	**0.13**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**38329**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**1420**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**1845**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.13**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Red River**		Stream Type: **C6c-**		
Location:	**Red River - 4 - 452.52**		Valley Type: **X**		
Observers:	**KD, JB**		Date: **11/16/2010**		
Enter Required Information for Existing Condition					
0.0028	D_{50}	Riffle bed material D_{50} (mm)			
0.0028	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
9.19E-06	D_{max}	Largest particle from bar sample (ft)	**0.0028**	**(mm)**	304.8 mm/ft
0.00017	S	Existing bankfull water surface slope (ft/ft)			
13.7	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			
Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress					
1	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1: $\tau^* = 0.0834\ (D_{50}/\hat{D}_{50})^{-0.872}$		
1	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2: $\tau^* = 0.0384\ (D_{max}/D_{50})^{-0.887}$		
0.0384	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:		**2**
Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample					
0.003424	d	Required bankfull mean depth (ft) $d = \dfrac{\tau^* \gamma_s D_{max}}{S}$ (use D_{max} in ft)			
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample					
4.25E-08	S	Required bankfull water surface slope (ft/ft) $S = \dfrac{\tau^* \gamma_s D_{max}}{d}$ (use D_{max} in ft)			
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Sediment Competence Using Dimensional Shear Stress					
0.14533	Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope				
9	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**				
0.002	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**				
13.7	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope $d = \dfrac{\tau}{\gamma S}$				
0.00017	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth $S = \dfrac{\tau}{\gamma d}$				

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Sub-samples	Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis																		Observers: **KD, JB**		
	Stream: **Red River**								Location: **Red River - 4 - 452.52**										Date: **11/16/2010**		
	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		SURFACE MATERIALS DATA (Two largest particles)		
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight				
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights				
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	No.	Dia.	WT.
1																			1		
2																			2		
3																					
4																			Bucket + materials weight		
5																					
6																					
7																			Bucket tare weight		
8																					
9																			Materials weight	0	
10																					
11																			Materials less than:	mm	
12																					
13																			*Be sure to add separate material weights to grand total*		
14																					
15																					
Net wt. total		0		0		0		0		0		0		0		0		0	0		
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####	GRAND TOTAL		
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		100%			

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Red River**	Stream Type: **C6c-**
Location: **Red River - 4 - 452.52**	Valley Type: **X**
Observers: **KD, JB**	Date: **11/16/2010**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream:	**Red River**	Stream Type:	**C6c-**
Location:	**Red River - 4 - 452.52**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**11/16/2010**

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 3-8)**	< 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	> 1.6 **(8)**	**2**
2	**Depositional pattern (Worksheet 3-5)**	B1, B2 **(1)**	B4, B8 **(2)**	B3 **(3)**	B5, B6, B7 **(4)**	**1**
3	**Meander pattern (Worksheet 3-4)**	M1, M3, M4 **(1)**		M2, M5, M6, M7, M8 **(3)**		**3**
4	**Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL **(2)**	M/L, M/M, M/H, L/Ex, H/L **(4)**	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL **(6)**	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex **(8)**	**4**
5	**Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.8 – 1.0 **(1)**	0.3 – 0.79 **(2)**	0.1 – 0.29 **(3)**	< 0.1 **(4)**	**1**
					Total points	**11**

Overall lateral stability category (use total points and check stability rating)	**Lateral stability category point range**			
	Stable 7 – 9 ☐	**Moderately unstable 10 – 12** ☑	**Unstable 13 – 21** ☐	**Highly unstable > 21** ☐

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream: **Red River**			Stream Type: **C6c-**		
Location: **Red River - 4 - 452.52**			Valley Type: **X**		
Observers: **KD, JB**			Date: **11/16/2010**		
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 3-14)**	Sufficient depth and/or slope to transport largest size available **(2)**	Trend toward insufficient depth and/or slope-slightly incompetent **(4)**	Cannot move D_{35} of bed material and/or D_{100} of bar material **(6)**	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size **(8)**	**2**
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load **(2)**	Trend toward insufficient sediment capacity **(4)**	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand **(6)**	Reduction over 25% of annual sediment yield for bedload and/or suspended sand **(8)**	**2**
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	>1.6 **(8)**	**2**
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation **(2)**	(E→C) **(4)**	(C→High W/d C), (B→High W/d B), (C→F) **(6)**	(C→D), (F→D) **(8)**	**2**
5 **Depositional patterns (Worksheet 3-5)**	B1 **(1)**	B2, B4 **(2)**	B3, B5 **(3)**	B6, B7, B8 **(4)**	**1**
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 **(1)**	D4, D7 **(2)**	D5, D8 **(3)**	D6, D9, D10 **(4)**	**1**
				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** ☐	

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream: **Red River**			Stream Type:	**C6c-**	
Location: **Red River - 4 - 452.52**			Valley Type:	**X**	
Observers: **KD, JB**			Date:	**11/16/2010**	
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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	**2**
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	**2**
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	**2**
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	**2**
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	**1**
				Total points	**9**
	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** ☐	

Worksheet 3-20. Channel enlargement prediction summary.

Stream: **Red River**			Stream Type: **C6c-**		
Location: **Red River - 4 - 452.52**			Valley Type: **X**		
Observers: **KD, JB**			Date: **11/16/2010**		
Channel enlargement prediction criteria (choose one stability category for each criterion 1–4)	**Channel Enlargement Prediction Categories**				**Selected points (from each row)**
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) **(2)**	(C→High W/d C), (E→C) **(4)**	(G→F), (F→D) **(6)**	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) **(8)**	**2**
2 **Lateral stability (Worksheet 3-17)**	Stable **(2)**	Moderately unstable **(4)**	Unstable **(6)**	Highly unstable **(8)**	**4**
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition **(2)**	Moderate deposition **(4)**	Excess deposition **(6)**	Aggradation **(8)**	**2**
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised **(2)**	Slightly incised **(4)**	Moderately incised **(6)**	Degradation **(8)**	**2**
				Total points	**10**
	Category point range				
Channel enlargement prediction (use total points and check stability rating)	**No increase 8 – 10** ☑	**Slight increase 11 – 16** ☐	**Moderate increase 17 – 24** ☐	**Extensive > 24** ☐	

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream:	**Red River**	Stream Type:	**C6c-**
Location:	**Red River - 4 - 452.52**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**11/16/2010**

	Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	Stability Rating	Points	Selected Points
1	Lateral stability (Worksheet 3-17)	Stable	1	2
		Mod. unstable	2	
		Unstable	3	
		Highly unstable	4	
2	Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition	1	1
		Mod. deposition	2	
		Excess deposition	3	
		Aggradation	4	
3	Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	1
		Slightly incised	2	
		Mod. Incised	3	
		Degradation	4	
4	Channel enlargement prediction (Worksheet 3-20)	No increase	1	1
		Slight increase	2	
		Mod. increase	3	
		Extensive	4	
5	Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	1
		Fair: mod unstable	2	
		Poor: unstable	4	
			Total Points	6

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

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Red River**					Location:	**Red River - 4 - 452.52**		
Observers:	**KD, JB**			Date:	**11/16/2010**	Stream Type:	**C6c-**	Valley Type:	**X**
Channel Dimension	Mean bankfull depth (ft): **10.3**	Mean bankfull width (ft): **159.5**	Cross-section area (ft^2): **1633**	Width of flood-prone area (ft): **709**	Entrenchment ratio: **4.4**				
Channel Pattern	Mean: Range:	MWR: **17.2**	Lm/W_{bkf}: **17.2**	Rc/W_{bkf}: **3.6**	Sinuosity: **2.17**				
River Profile and Bed Features	Check: ☐ Riffle/pool	☐ Step/pool	☑ Plane bed	☐ Convergence/divergence	☑ Dunes/antidunes/smooth bed				
	Max bankfull depth (ft):	Riffle: **15.0**	Pool:	Depth ratio (max/mean):	Riffle: **1.5**	Pool:	Pool to pool spacing:	Ratio:	Slope — Valley: ; Average bankfull: **0.00017**
Level III Stream Stability Indices	Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:					
	Flow regime: **P1, 2, 7, 8, 9**	Stream size and order: **S-9**	Meander pattern(s): **M2**	Depositional pattern(s): **NONE**	Debris/channel blockage(s): **D2**				
	Degree of incision (Bank-Height Ratio): **1.1**	Degree of incision stability rating: **Stable**	Modified Pfankuch stability rating (numeric and adjective rating): **Good**						
	Width/depth ratio (W/d): **15.5**	Reference W/d ratio (W/d_{ref}): **15.5**	Width/depth ratio state $(W/d) / (W/d_{ref})$: **1.0**	W/d ratio state stability rating: **Stable**					
	Meander Width Ratio (MWR): **17.2**	Reference MWR_{ref}: **17.2**	Degree of confinement (MWR / MWR_{ref}): **1.0**	MWR / MWR_{ref} stability rating: **Unconfined**					
Bank Erosion Summary	Length of reach studied (ft): **14428**	Annual streambank erosion rate: **1845** (tons/yr) **0.13** (tons/yr/ft)	Curve used: **Fig 3-9**	Remarks:					
Sediment Capacity (POWERSED)	☑ Sufficient capacity	☐ Insufficient capacity	☐ Excess capacity	Remarks:					
Entrainment/ Competence	Largest particle from bar sample (mm):	$\tau =$	$\tau^* =$	Existing $depth_{bkf}$:	Required $depth_{bkf}$:	Existing $slope_{bkf}$:	Required $slope_{bkf}$:		
Successional Stage Shift	**C** ⟶ **E** ⟶ ⟶ ⟶ ⟶	Existing stream state (type): **C6c-**	Potential stream state (type): **C6c-**						
Lateral Stability	☐ Stable	☑ Mod. unstable	☐ Unstable	☐ Highly unstable	Remarks/causes: **None**				
Vertical Stability (Aggradation)	☑ No deposition	☐ Mod. deposition	☐ Ex. deposition	☐ Aggradation	Remarks/causes: **None**				
Vertical Stability (Degradation)	☑ Not incised	☐ Slightly incised	☐ Mod. incised	☐ Degradation	Remarks/causes: **None**				
Channel Enlargement	☑ No increase	☐ Slight increase	☐ Mod. increase	☐ Extensive	Remarks/causes: **None**				
Sediment Supply (Channel Source)	☐ Low	☑ Moderate	☐ High	☐ Very high	Remarks/causes: **None**				

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Red River**			Location: **Red River - 5 - 463.56**	
Observers: **KD, JB**	Reference reach		Disturbed (impacted reach) **X**	Date: **11/19/2010**
Existing species composition: **Trees, cockleburs, grass**			Potential species composition: **Trees, cockleburs, grass**	

Riparian cover categories		Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**80% with leaves, 5% without leaves**	**1%**	**trees**	**100%**
					100%
2. Understory	Shrub layer		**3%**	**cockleburs**	**100%**
					100%
3. Ground level	Herbaceous		**5%**	**grass**	**100%**
					100%
	Leaf or needle litter		**0%**		
	Bare ground		**91%**		
			Column total = 100%		

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

Remarks:
Condition, vigor and/or usage of existing reach:
None

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Red River**			Location: **Red River - 5 - 463.56**					
Observers: **KD, JB**						Date: **11/19/2010**		
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P7**	**P9**				

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order

Stream:	**Red River**
Location:	**Red River - 5 - 463.56**
Observers:	**KD, JB**
Date:	**11/19/2010**
Stream Size Category and Order ☞	**S-8**

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).

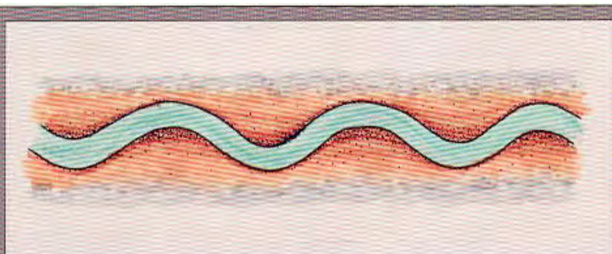
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Red River**		Reach:	**Red River - 5 - 463.56**	
Observers:	**KD, JB**		Date:	**11/19/2010**	

List ALL CATEGORIES that APPLY ☞	M2				

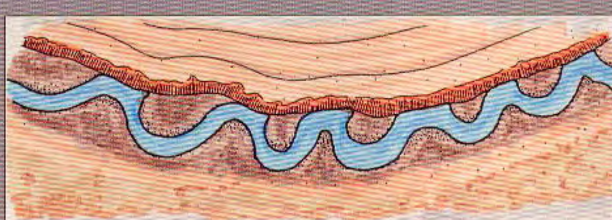
Various Meander Pattern variables modified from Galay et al. (1973)



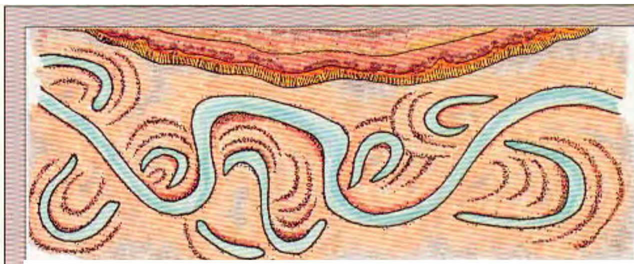
M1 REGULAR MEANDERS

M2 TORTUOUS MEANDERS

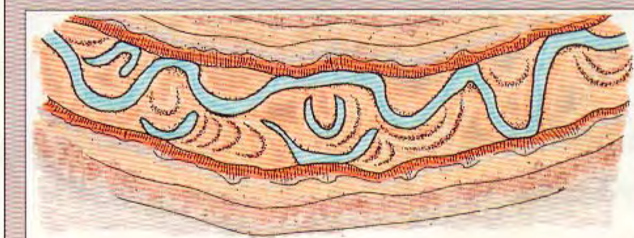
M3 IRREGULAR MEANDERS



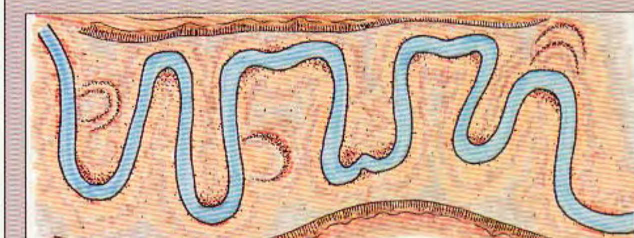
M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS



M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

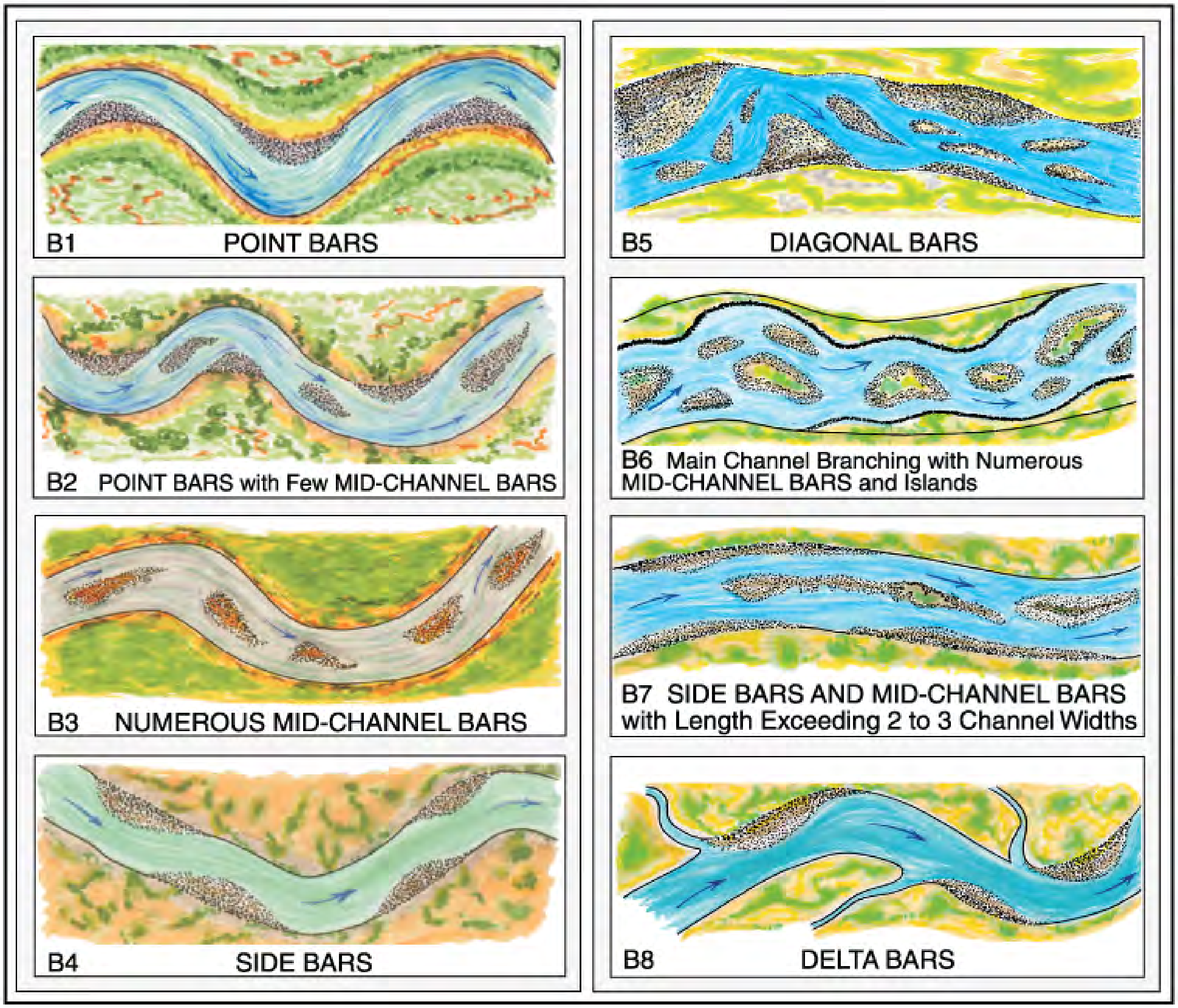
Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns

Stream:	**Red River**	Reach:	**Red River - 5 - 463.56**
Observers:	**KD, JB**	Date:	**11/19/2010**

List ALL CATEGORIES that APPLY ☞	**NONE**				

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



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages				
Stream:	Red River		Location: **Red River - 5 - 463.56**	
Observers:	**KD, JB**		Date: **11/19/2010**	
Description/extent			**Materials that 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.	☐

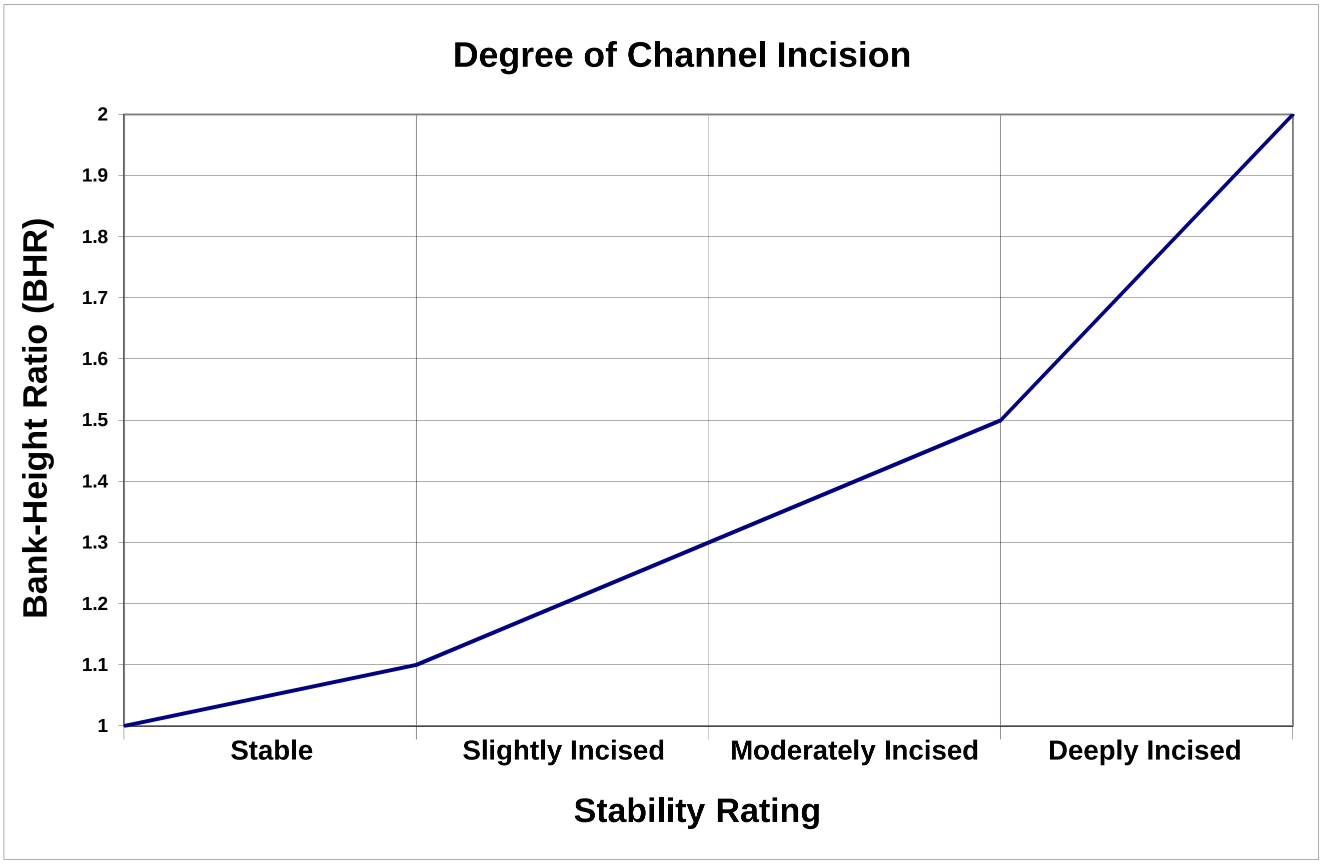
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision

Low Bank Height:	**21.7**
Max Bankfull Depth:	**17.59**

Bank-Height Ratio:	**1.2**

Degree of Channel Incision Stability Rating ☞	**Slightly Incised**

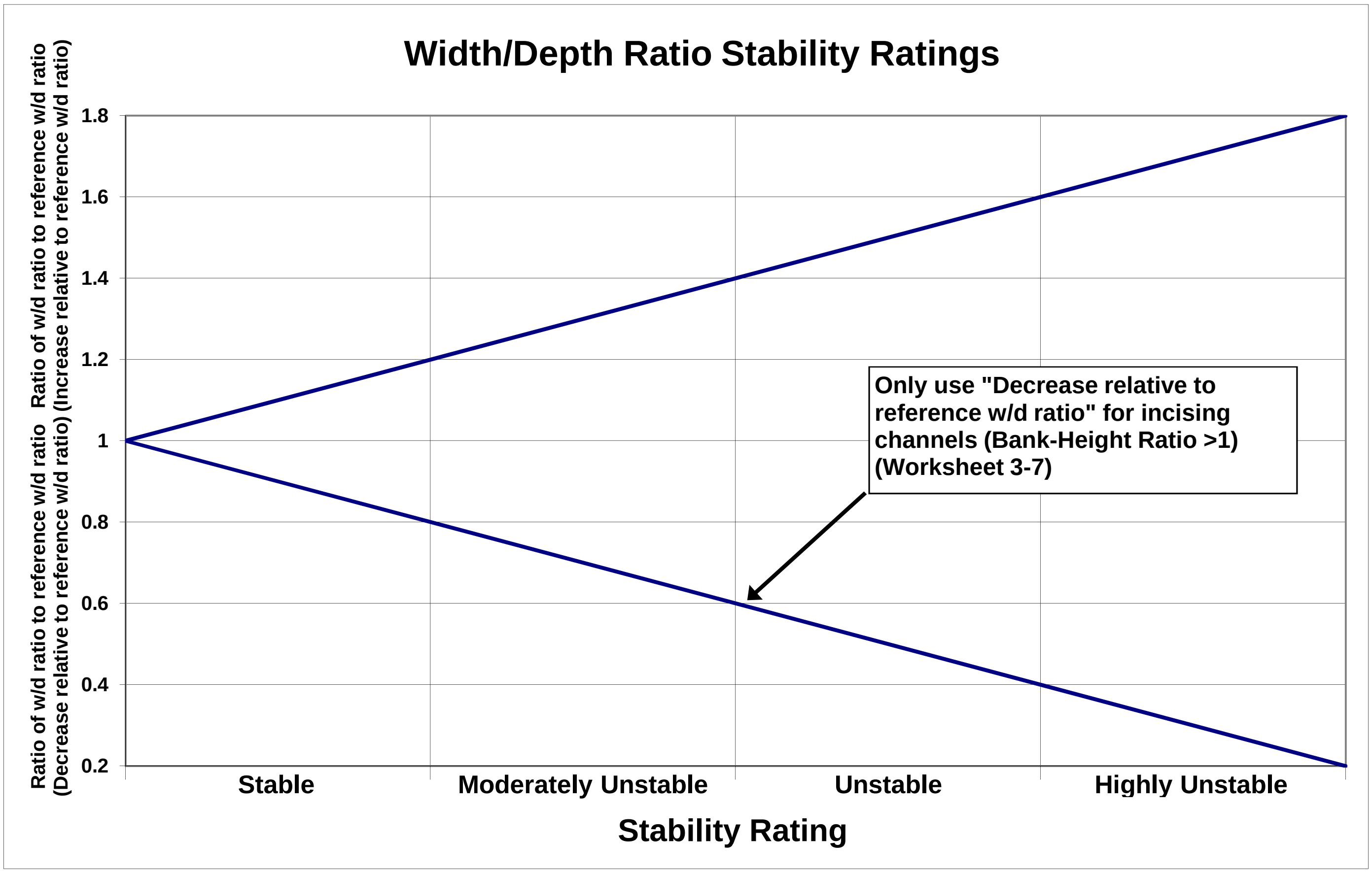


Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State

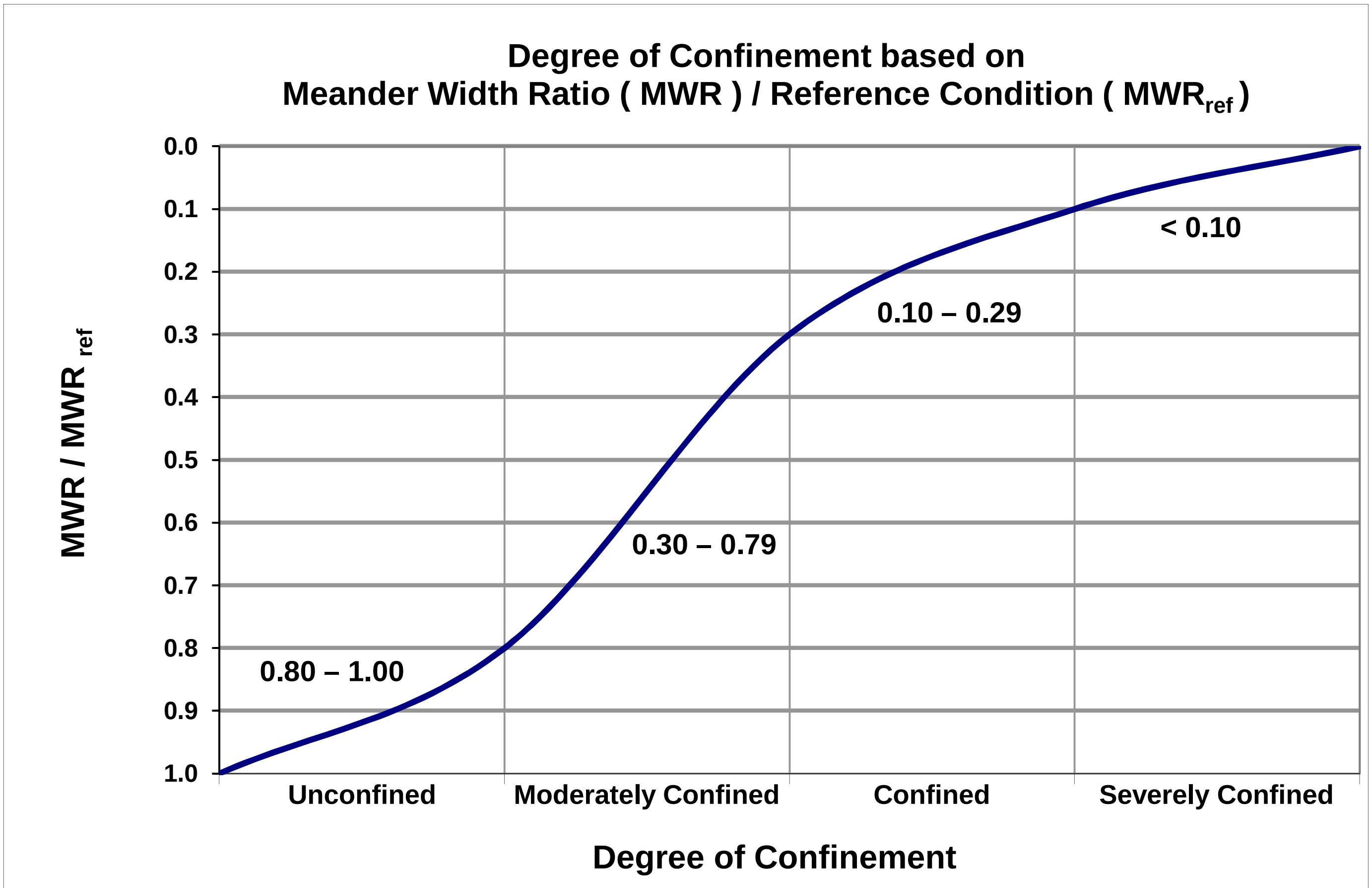
Existing Width/Depth Ratio:	**12.9**	Ratio of existing W/d to reference W/d:	**1.103**
Reference Width/Depth Ratio:	**11.7**		

Width/Depth Ratio State Stability Rating ☞	**Stable**



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	17.1	Ratio of MWR to MWR_{ref}:	0.972
Reference Meander Width Ratio (MWR_{ref}):	17.6		
Degree of Confinement Stability Rating ☞		**Unconfined**	



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Red River **Location:** Red River - 5 - 463.56 **Valley Type:** X **Observers:** KD, JB **Date:** 11/19/2010

Location	Key	Category	Excellent – Description	Excellent – Rating	Good – Description	Good – Rating	Fair – Description	Fair – Rating	Poor – Description	Poor – Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	**4**	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	**9**	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	**2**	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	**6**	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	**2**	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	**6**	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	**16**
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	23	Good total =	10	Fair total =	15	Poor total =	20

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	68
Existing stream type =	C6c-
*Potential stream type =	C6c-
Modified channel stability rating =	Good

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream:	**Red River**	Location:	**Red River - 5 - 463.56**
Station:		Observers:	**KD, JB**
Date:	**11/19/2010**	Stream Type: **C6c-**	Valley Type: **X**

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	25.7 **(A)**	**Bankfull Height** (ft) =	15.7 **(B)**	(A) / (B) = 1.6 **(C)**	**6**

Root Depth / Study Bank Height (E)

Root Depth (ft) =	1 **(D)**	**Study Bank Height** (ft) =	25.7 **(A)**	(D) / (A) = 0.0 **(E)**	**10**

Weighted Root Density (G)

Root Density as **%** =	40% **(F)**	(F) x (E) = 2% **(G)**	**10**

Bank Angle (H)

Bank Angle as *Degrees* =	20 **(H)**	**2**

Surface Protection (I)

Surface Protection as **%** =	3% **(I)**	**10**

Bank Material Adjustment:

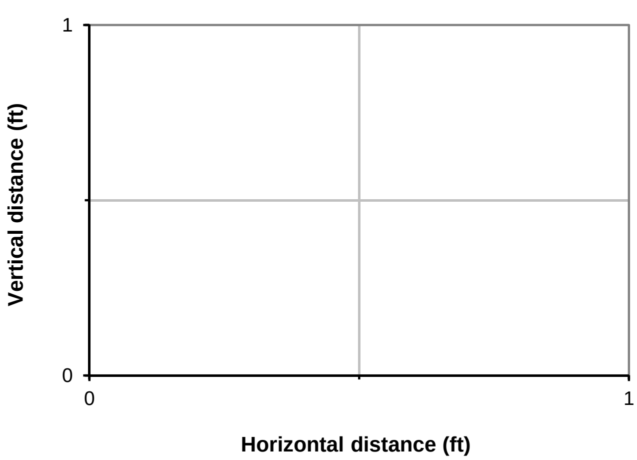
Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

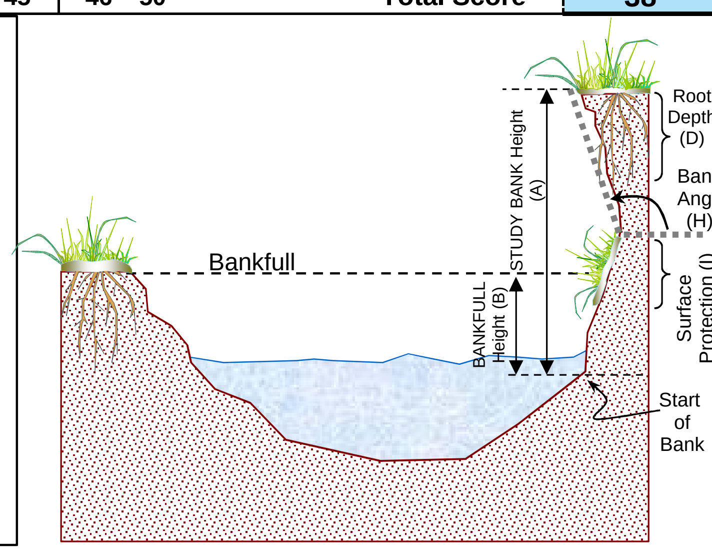
Bank Material Adjustment: **0**

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	**High**
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50	**and Total Score**	**38**

Bank Sketch





Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Red River** Location: **Red River - 5 - 463.56**

Station: **0** Stream Type: **C6c-** Valley Type: **X**

Observers: **KD, JB** Date: **11/19/10**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})..	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S).......................................	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})..	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})...........................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient..	Level IV	Validation

Level I (1)

- Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
- Extensive deposition (continuous, cross-channel).. ....NBS = Extreme
- Chute cutoffs, down-valley meander migration, converging flow.......................................NBS = Extreme

Level II

	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)
(2)				

	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)
(3)				

	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)
(4)				

Dominant Near-Bank Stress
Very Low

Level III

	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)
(5)				

	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)
(6)								

Level IV

	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
(7)	**0.02**	**Very Low**

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating	**Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Red River**			Location: **Red River - 5 - 463.56**			
Graph Used:	**Fig 3-9**	Total Bank Length (ft): **4916.7**				Date: **11/19/2010**	
Observers:	**KD, JB**		Valley Type: **X**			Stream Type: **C6c-**	
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**4916.7**	**25.7**	**20849**	**0.20**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**20849**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**772**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**1004**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.20**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Red River**	Stream Type:	**C6c-**
Location:	**Red River - 5 - 463.56**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**11/19/2010**

Enter Required Information for Existing Condition

	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	**#DIV/0!**

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	d	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	S	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Sediment Competence Using Dimensional Shear Stress

0	Bankfull shear stress $\tau = \gamma d S$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) $d = \dfrac{\tau}{\gamma S}$ τ = predicted shear stress, γ = 62.4, S = existing slope
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) $S = \dfrac{\tau}{\gamma d}$ τ = predicted shear stress, γ = 62.4, d = existing depth

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis | Observers: **KD, JB**

Stream: **Red River** | Location: **Red River - 5 - 463.56** | Date: **11/19/2010**

Sub-samples	Catch Pan or BUCKET / Tare weight / Sample weights Total	Net	Sieve SIZE mm / Tare weight / Sample weights Total	Net	Sieve SIZE mm / Tare weight / Sample weights Total	Net	Sieve SIZE mm / Tare weight / Sample weights Total	Net	Sieve SIZE mm / Tare weight / Sample weights Total	Net	Sieve SIZE mm / Tare weight / Sample weights Total	Net	Sieve SIZE mm / Tare weight / Sample weights Total	Net	Sieve SIZE mm / Tare weight / Sample weights Total	Net	Sieve SIZE mm / Tare weight / Sample weights Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		0		0		0		0		0		0		0		0		0
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		100%

SURFACE MATERIALS DATA (Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	0
Materials less than:	mm

Be sure to add separate material weights to grand total

GRAND TOTAL: 0

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Red River**	Stream Type: **C6c-**
Location: **Red River - 5 - 463.56**	Valley Type: **X**
Observers: **KD, JB**	Date: **11/19/2010**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream: **Red River**			Stream Type:	**C6c-**	
Location: **Red River - 5 - 463.56**			Valley Type:	**X**	
Observers: **KD, JB**			Date:	**11/19/2010**	
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 3-8)**	< 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	> 1.6 **(8)**	**2**
2 **Depositional pattern (Worksheet 3-5)**	B1, B2 **(1)**	B4, B8 **(2)**	B3 **(3)**	B5, B6, B7 **(4)**	**1**
3 **Meander pattern (Worksheet 3-4)**	M1, M3, M4 **(1)**		M2, M5, M6, M7, M8 **(3)**		**3**
4 **Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL **(2)**	M/L, M/M, M/H, L/Ex, H/L **(4)**	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL **(6)**	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex **(8)**	**4**
5 **Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.8 – 1.0 **(1)**	0.3 – 0.79 **(2)**	0.1 – 0.29 **(3)**	< 0.1 **(4)**	**1**
				Total points	**11**
	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** ☐	

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Red River**	Stream Type:	**C6c-**
Location:	**Red River - 5 - 463.56**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**11/19/2010**

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 3-14)**	Sufficient depth and/or slope to transport largest size available (2)	Trend toward insufficient depth and/or slope-slightly incompetent (4)	Cannot move D_{35} of bed material and/or D_{100} of bar material (6)	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size (8)	2
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load (2)	Trend toward insufficient sediment capacity (4)	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand (6)	Reduction over 25% of annual sediment yield for bedload and/or suspended sand (8)	2
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 (2)	1.2 – 1.4 (4)	1.4 – 1.6 (6)	>1.6 (8)	2
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation (2)	(E→C) (4)	(C→High W/d C), (B→High W/d B), (C→F) (6)	(C→D), (F→D) (8)	2
5 **Depositional patterns (Worksheet 3-5)**	B1 (1)	B2, B4 (2)	B3, B5 (3)	B6, B7, B8 (4)	1
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 (1)	D4, D7 (2)	D5, D8 (3)	D6, D9, D10 (4)	1
				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** ☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream: **Red River**				Stream Type: **C6c-**	
Location: **Red River - 5 - 463.56**				Valley Type: **X**	
Observers: **KD, JB**				Date: **11/19/2010**	
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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	2
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	2
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	4
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	4
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	1
				Total points	**13**
	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** ☐	

Worksheet 3-20. Channel enlargement prediction summary.

Stream:	**Red River**	Stream Type:	**C6c-**
Location:	**Red River - 5 - 463.56**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**11/19/2010**

Channel enlargement prediction criteria (choose one stability category for each criterion 1–4)	**Channel Enlargement Prediction Categories**				**Selected points** (from each row)
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) **(2)**	(C→High W/d C), (E→C) **(4)**	(G→F), (F→D) **(6)**	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) **(8)**	**2**
2 **Lateral stability (Worksheet 3-17)**	Stable **(2)**	Moderately unstable **(4)**	Unstable **(6)**	Highly unstable **(8)**	**4**
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition **(2)**	Moderate deposition **(4)**	Excess deposition **(6)**	Aggradation **(8)**	**2**
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised **(2)**	Slightly incised **(4)**	Moderately incised **(6)**	Degradation **(8)**	**4**
				Total points	**12**

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

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream:	**Red River**	Stream Type:	**C6c-**
Location:	**Red River - 5 - 463.56**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**11/19/2010**

	Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	Stability Rating	Points	Selected Points
1	Lateral stability (Worksheet 3-17)	Stable	1	2
		Mod. unstable	2	
		Unstable	3	
		Highly unstable	4	
2	Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition	1	1
		Mod. deposition	2	
		Excess deposition	3	
		Aggradation	4	
3	Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	2
		Slightly incised	2	
		Mod. Incised	3	
		Degradation	4	
4	Channel enlargement prediction (Worksheet 3-20)	No increase	1	2
		Slight increase	2	
		Mod. increase	3	
		Extensive	4	
5	Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	1
		Fair: mod unstable	2	
		Poor: unstable	4	
			Total Points	8

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

Worksheet 3-22. Summary of stability condition categories.

Stream: **Red River** Location: **Red River - 5 - 463.56**

Observers: **KD, JB** Date: **11/19/2010** Stream Type: **C6c-** Valley Type: **X**

Channel Dimension	Mean bankfull depth (ft):	11.1	Mean bankfull width (ft):	143.1	Cross-section area (ft^2):	1581	Width of flood-prone area (ft):	949	Entrenchment ratio:	6.6
Channel Pattern	Mean: Range:	MWR:	17.2	Lm/W_{bkf}:	17.1	Rc/W_{bkf}:	3.1	Sinuosity:	2.42	

River Profile and Bed Features

Check: ☐ Riffle/pool ☐ Step/pool ☑ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed

Max bankfull depth (ft):	Riffle	Pool	Depth ratio (max/mean):	Riffle	Pool	Pool to pool spacing:	Ratio	Slope: Valley:	Slope: Average bankfull:
	17.6			1.6					4.9E-05

Level III Stream Stability Indices

Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:

Flow regime:	P1, 2, 7, 9	Stream size and order:	S-8	Meander pattern(s):	M2	Depositional pattern(s):	NONE	Debris/channel blockage(s):	D2

Degree of incision (Bank-Height Ratio):	1.2	Degree of incision stability rating:	**Slightly Incised**	Modified Pfankuch stability rating (numeric and adjective rating):	**Good**
Width/depth ratio (W/d):	12.9	Reference W/d ratio (W/d_{ref}):	11.7	Width/depth ratio state $(W/d) / (W/d_{ref})$: 1.1	W/d ratio state stability rating: **Stable**
Meander Width Ratio (MWR):	17.1	Reference MWR_{ref}:	17.6	Degree of confinement (MWR / MWR_{ref}): 1.0	MWR / MWR_{ref} stability rating: **Unconfined**

Bank Erosion Summary

Length of reach studied (ft):	Annual streambank erosion rate:		Curve used:	Remarks:
4917	1004 (tons/yr)	0.20 (tons/yr/ft)	Fig 3-9	

Sediment Capacity (POWERSED)

☑ Sufficient capacity ☐ Insufficient capacity ☐ Excess capacity — Remarks:

Entrainment/ Competence

Largest particle from bar sample (mm):	τ =	τ* =	Existing $depth_{bkf}$:	Required $depth_{bkf}$:	Existing $slope_{bkf}$:	Required $slope_{bkf}$:

Successional Stage Shift

→ → → → → Existing stream state (type): **C6c-** Potential stream state (type): **C6c-**

Lateral Stability	☐ Stable	☑ Mod. unstable	☐ Unstable	☐ Highly unstable	Remarks/causes: **None**
Vertical Stability (Aggradation)	☑ No deposition	☐ Mod. deposition	☐ Ex. deposition	☐ Aggradation	Remarks/causes: **None**
Vertical Stability (Degradation)	☐ Not incised	☑ Slightly incised	☐ Mod. incised	☐ Degradation	Remarks/causes: **None**
Channel Enlargement	☐ No increase	☑ Slight increase	☐ Mod. increase	☐ Extensive	Remarks/causes: **None**
Sediment Supply (Channel Source)	☐ Low	☑ Moderate	☐ High	☐ Very high	Remarks/causes: **None**

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Red River**

Location: **Red River - 6 - 470.23**

Observers: **KD, JB**

Reference reach: [ ]

Disturbed (impacted reach): [X]

Date: **11/18/2010**

Existing species composition: **Trees, small cocklebur bushes**

Potential species composition: **Trees, small cocklebur bushes**

	Riparian cover categories	Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**20% without leaves, 85% with leaves**	**2%**	**trees**	**100%**
					100%
2. Understory	Shrub layer		**1%**	**cockleburs**	**100%**
					100%
3. Ground level	Herbaceous		**1%**	**grass**	**100%**
					100%
	Leaf or needle litter		**0%**		
	Bare ground		**96%**		
			Column total = 100%		

*Based on crown closure.

**Based on basal area to surface area.

Remarks:
Condition, vigor and/or usage of existing reach:
None

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Red River**			Location: **Red River - 6 - 470.23**					
Observers: **KD, JB**						Date: **11/18/2010**		
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P7**	**P9**				

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order

Stream:	**Red River**
Location:	**Red River - 6 - 470.23**
Observers:	**KD, JB**
Date:	**11/18/2010**

Stream Size Category and Order ☞ **S-8**

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).

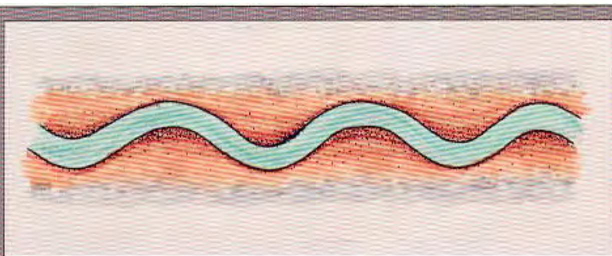
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	Red River	Reach:	Red River - 6 - 470.23
Observers:	KD, JB	Date:	11/18/2010

List ALL CATEGORIES that APPLY ☞	M2				

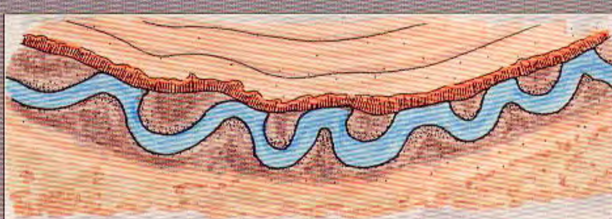
Various Meander Pattern variables modified from Galay et al. (1973)



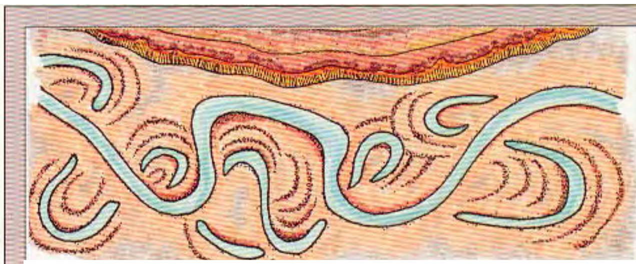
M1 REGULAR MEANDERS

M2 TORTUOUS MEANDERS

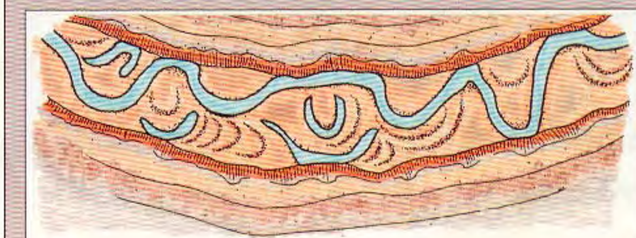
M3 IRREGULAR MEANDERS



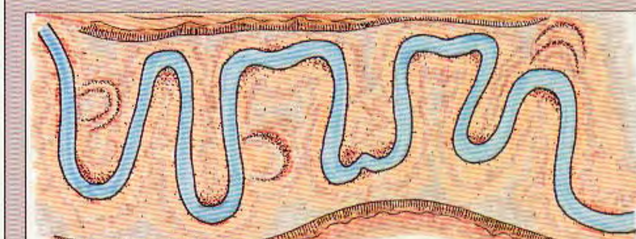
M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS



M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

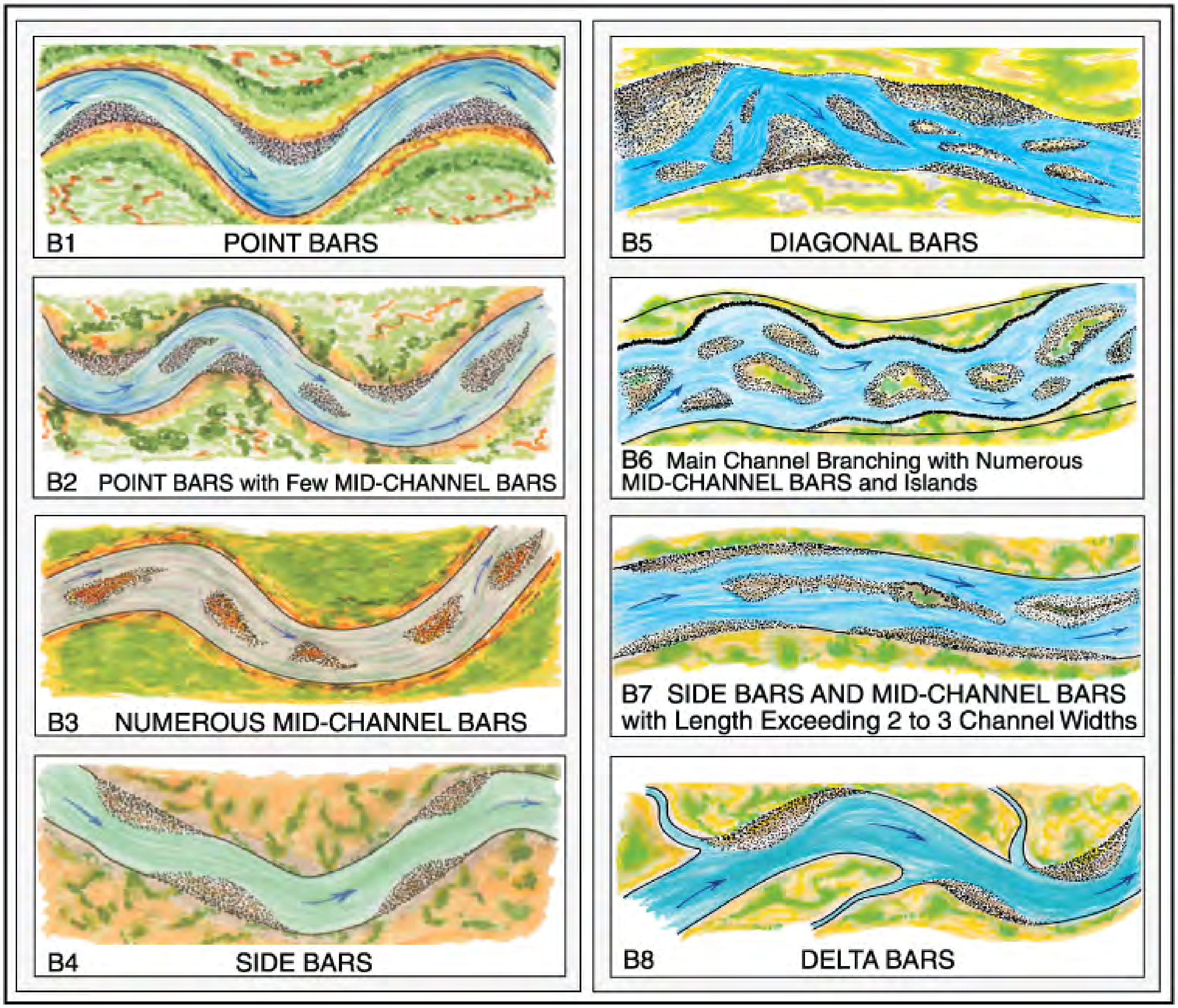
Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns

Stream:	**Red River**	Reach:	**Red River - 6 - 470.23**
Observers:	**KD, JB**	Date:	**11/18/2010**

List ALL CATEGORIES that APPLY ☞	NONE				

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



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

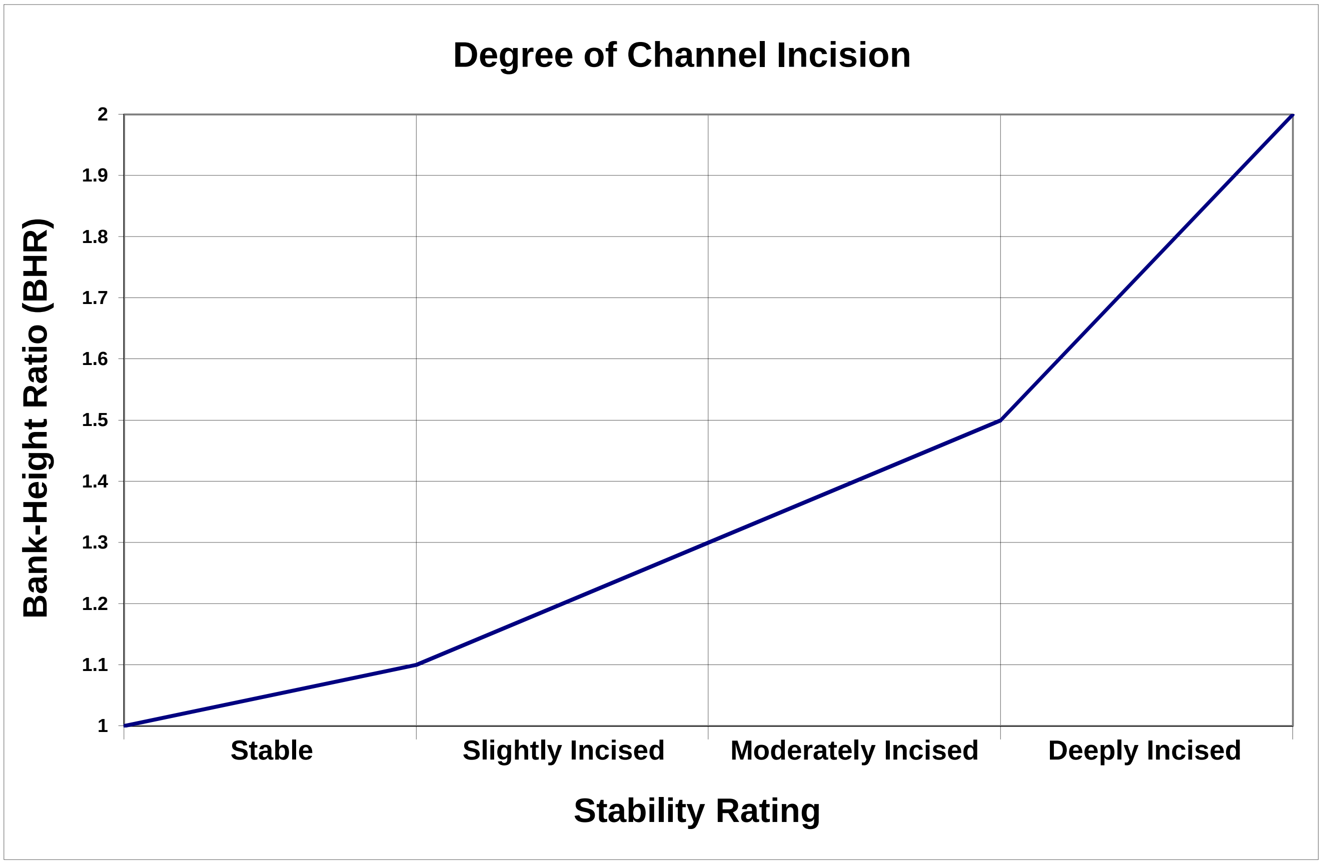
Channel Blockages			
Stream: Red River		Location: Red River - 6 - 470.23	
Observers: KD, JB		Date: 11/18/2010	
Description/extent		**Materials that upon placement into the active channel or flood-prone area may cause adjustments in channel dimensions or conditions due to influences on the existing flow 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.	☐

Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision

Low Bank Height:	**27.3**	Bank-Height Ratio:	**1.7**
Max Bankfull Depth:	**16.2**		

Degree of Channel Incision Stability Rating ☞	**Deeply Incised**

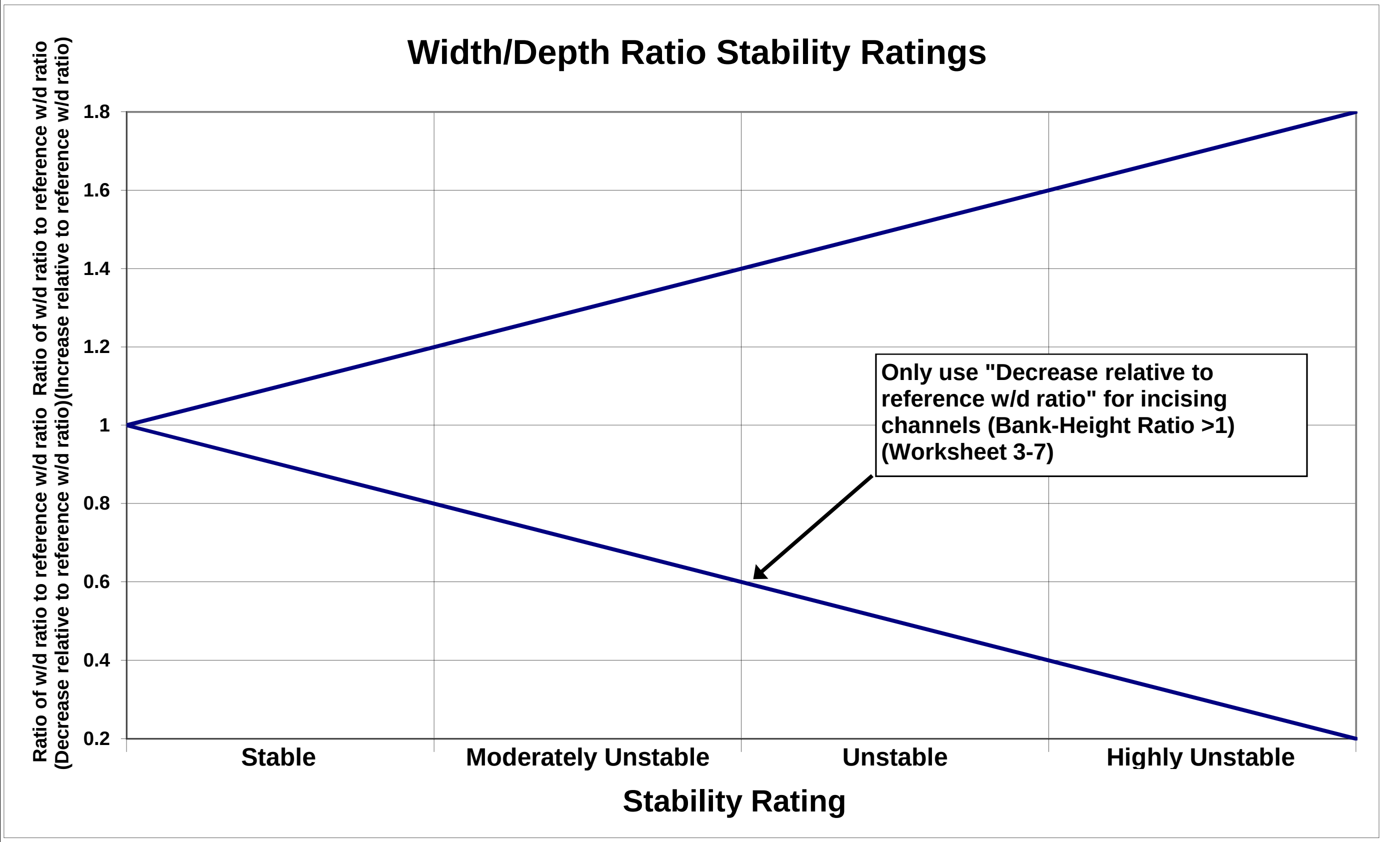


Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State

Existing Width/Depth Ratio:	**12.7**	Ratio of existing W/d to reference W/d:	**0.99**
Reference Width/Depth Ratio:	**12.8**		

Width/Depth Ratio State Stability Rating ☞ **Stable**

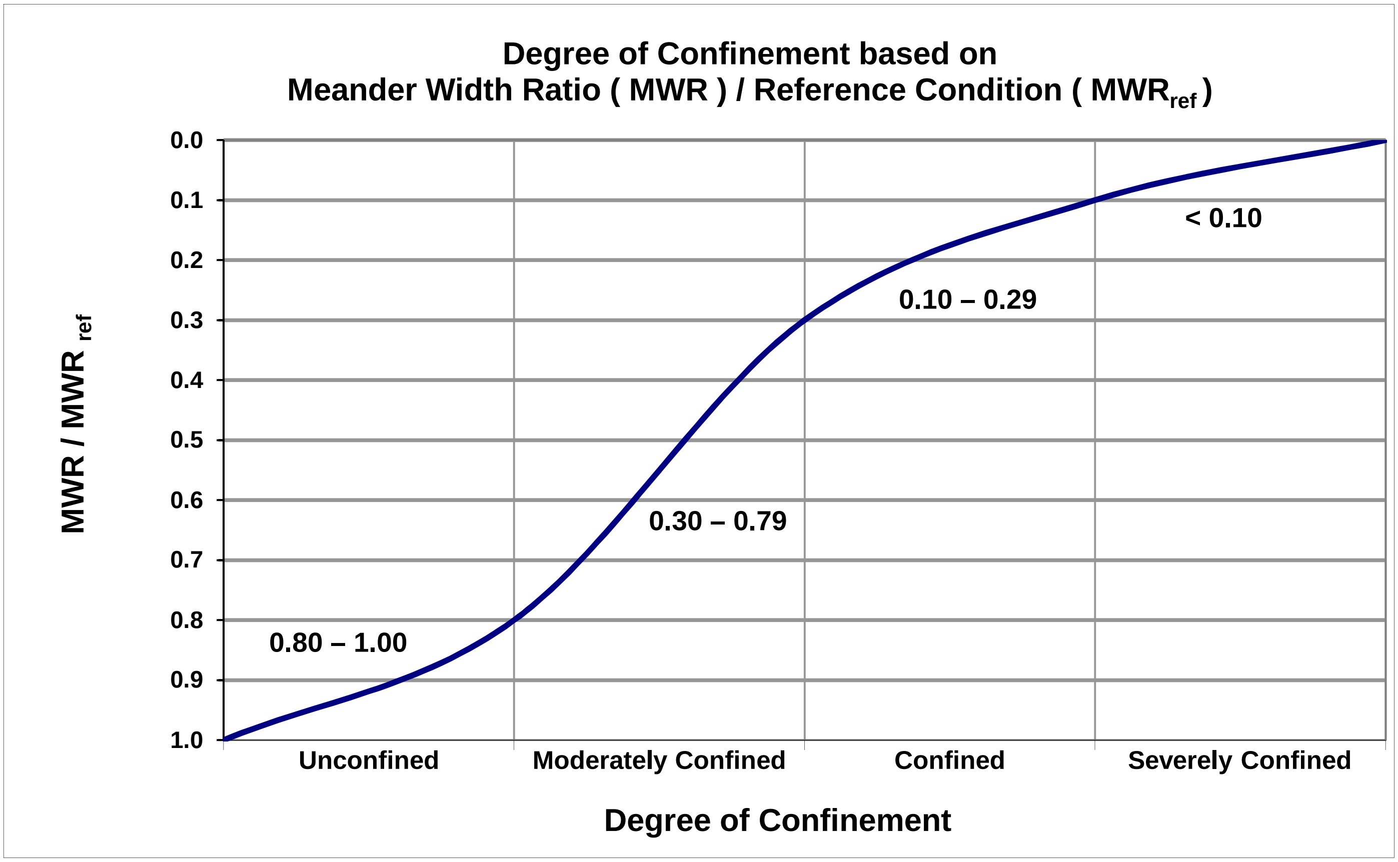


Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement

Existing Meander Width Ratio (MWR):	11.1	Ratio of MWR to MWR_{ref}:	1.043
Reference Meander Width Ratio (MWR_{ref}):	10.6		

Degree of Confinement Stability Rating ☞ **Unconfined**



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Red River **Location:** Red River - 6 - 470.23 **Valley Type:** X **Observers:** KD, JB **Date:** 11/18/2010

Location	Key	Category	Excellent Description	Rating	Good Description	Rating	Fair Description	Rating	Poor Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	**2**	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	**9**	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	**6**	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	**12**
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	**2**	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	**6**	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	**12**	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	**23**	Good total =	**0**	Fair total =	**33**	Poor total =	**16**

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	**72**
Existing stream type =	**C6c-**
*Potential stream type =	**C6c-**
Modified channel stability rating =	**Good**

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream: **Red River** Location: **Red River - 6 - 470.23**

Station: Observers: **KD, JB**

Date: **11/18/2010** Stream Type: **C6c-** Valley Type: **X**

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	29.4 (A)	**Bankfull Height** (ft) =	14.7 (B)	(A) / (B) =	2.0 (C)	8

Root Depth / Study Bank Height (E)

Root Depth (ft) =	2 (D)	**Study Bank Height** (ft) =	29.4 (A)	(D) / (A) =	0.1 (E)	8

Weighted Root Density (G)

Root Density as **%** =	5% (F)	(F) x (E) =	0% (G)	10

Bank Angle (H)

Bank Angle as *Degrees* =	18 (H)	2

Surface Protection (I)

Surface Protection as **%** =	1% (I)	10

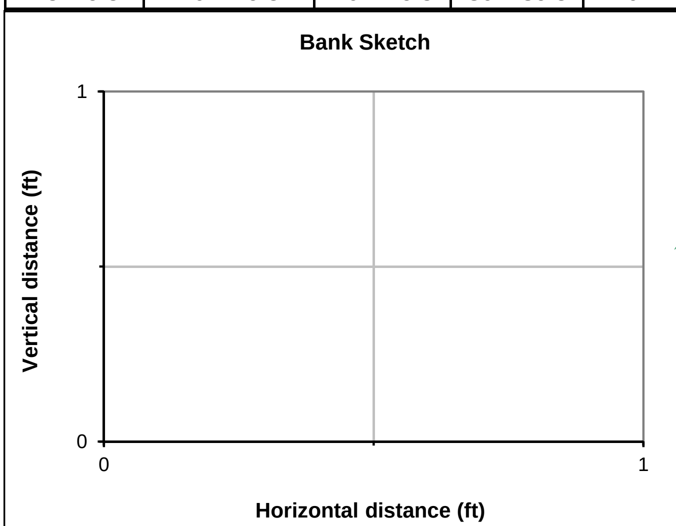
Bank Material Adjustment:

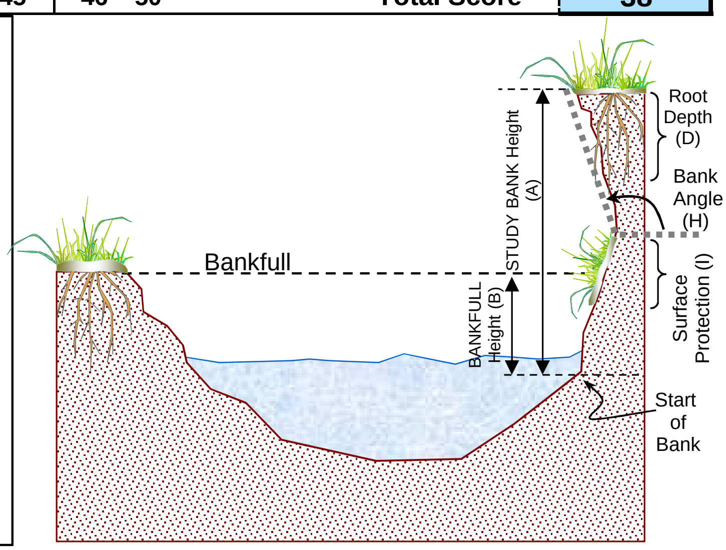
Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

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**	**High**
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50	and **Total Score**	**38**





Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Red River** Location: **Red River - 6 - 470.23**

Station: **0** Stream Type: **C6c-** Valley Type: **X**

Observers: **KD, JB** Date: **11/18/10**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})..	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S)..	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})..	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})........................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient..	Level IV	Validation

Level I

(1)
Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
Extensive deposition (continuous, cross-channel).. ....NBS = Extreme
Chute cutoffs, down-valley meander migration, converging flow..NBS = Extreme

Level II

	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)
(2)				

	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)
(3)				

	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)
(4)				

Dominant Near-Bank Stress
Very Low

Level III

	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)
(5)				

	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)
(6)								

Level IV

	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
(7)	**0.03**	**Very Low**

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating **Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Red River**			Location:	**Red River - 6 - 470.23**		
Graph Used:	**Fig 3-9**	Total Bank Length (ft):	**8419.4**			Date:	**11/18/2010**
Observers:	**KD, JB**	Valley Type:	**X**			Stream Type:	**C6c-**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**8419.4**	**29.4**	**40843**	**0.23**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**40843**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**1513**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**1966**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.23**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Red River**			Stream Type:	**C6c-**
Location:	**Red River - 6 - 470.23**			Valley Type:	**X**
Observers:	**KD, JB**			Date:	**11/18/2010**

Enter Required Information for Existing Condition

	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	**#DIV/0!**

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	**d**	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	**S**	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Sediment Competence Using Dimensional Shear Stress

0	Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope	
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**	
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**	
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope	$d = \dfrac{\tau}{\gamma S}$
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth	$S = \dfrac{\tau}{\gamma d}$

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis

Observers: **KD, JB**

Stream: **Red River** | Location: **Red River - 6 - 470.23** | Date: **11/18/2010**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		0		0		0		0		0		0		0		0		0
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		100%

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	0
Materials less than:	mm

Be sure to add separate material weights to grand total

GRAND TOTAL: 0

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Red River**	Stream Type: **C6c-**
Location: **Red River - 6 - 470.23**	Valley Type: **X**
Observers: **KD, JB**	Date: **11/18/2010**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream: **Red River**			Stream Type:	**C6c-**	
Location: **Red River - 6 - 470.23**			Valley Type:	**X**	
Observers: **KD, JB**			Date:	**11/18/2010**	
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 3-8)**	< 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	> 1.6 **(8)**	**2**
2 **Depositional pattern (Worksheet 3-5)**	B1, B2 **(1)**	B4, B8 **(2)**	B3 **(3)**	B5, B6, B7 **(4)**	**1**
3 **Meander pattern (Worksheet 3-4)**	M1, M3, M4 **(1)**		M2, M5, M6, M7, M8 **(3)**		**3**
4 **Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL **(2)**	M/L, M/M, M/H, L/Ex, H/L **(4)**	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL **(6)**	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex **(8)**	**4**
5 **Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.8 – 1.0 **(1)**	0.3 – 0.79 **(2)**	0.1 – 0.29 **(3)**	< 0.1 **(4)**	**1**
				Total points	**11**
	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** ☐	

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Red River**	Stream Type:	**C6c-**
Location:	**Red River - 6 - 470.23**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**11/18/2010**

	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 3-14)**	Sufficient depth and/or slope to transport largest size available **(2)**	Trend toward insufficient depth and/or slope-slightly incompetent **(4)**	Cannot move D_{35} of bed material and/or D_{100} of bar material **(6)**	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size **(8)**	**2**
2	**Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load **(2)**	Trend toward insufficient sediment capacity **(4)**	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand **(6)**	Reduction over 25% of annual sediment yield for bedload and/or suspended sand **(8)**	**2**
3	**W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	>1.6 **(8)**	**2**
4	**Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation **(2)**	(E→C) **(4)**	(C→High W/d C), (B→High W/d B), (C→F) **(6)**	(C→D), (F→D) **(8)**	**2**
5	**Depositional patterns (Worksheet 3-5)**	B1 **(1)**	B2, B4 **(2)**	B3, B5 **(3)**	B6, B7, B8 **(4)**	**1**
6	**Debris / blockages (Worksheet 3-6)**	D1, D2, D3 **(1)**	D4, D7 **(2)**	D5, D8 **(3)**	D6, D9, D10 **(4)**	**1**
					Total points	**10**

Vertical stability for excess deposition / aggradation (use total points and check stability rating)	**Vertical stability category point range for excess deposition / aggradation**			
	No deposition 10 – 14 ☑	**Moderate deposition 15 – 20** ☐	**Excess deposition 21 – 30** ☐	**Aggradation > 30** ☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream: **Red River**			Stream Type: **C6c-**		
Location: **Red River - 6 - 470.23**			Valley Type: **X**		
Observers: **KD, JB**			Date: **11/18/2010**		
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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	**2**
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	**2**
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	**8**
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	**4**
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	**1**
				Total points	**17**
	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** ☐	

Worksheet 3-20. Channel enlargement prediction summary.

Stream:	**Red River**			Stream Type:	**C6c-**
Location:	**Red River - 6 - 470.23**			Valley Type:	**X**
Observers:	**KD, JB**			Date:	**11/18/2010**

Channel enlargement prediction criteria (choose one stability category for each criterion 1–4)	**Channel Enlargement Prediction Categories**				**Selected points** (from each row)
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) **(2)**	(C→High W/d C), (E→C) **(4)**	(G→F), (F→D) **(6)**	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) **(8)**	**2**
2 **Lateral stability (Worksheet 3-17)**	Stable **(2)**	Moderately unstable **(4)**	Unstable **(6)**	Highly unstable **(8)**	**4**
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition **(2)**	Moderate deposition **(4)**	Excess deposition **(6)**	Aggradation **(8)**	**2**
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised **(2)**	Slightly incised **(4)**	Moderately incised **(6)**	Degradation **(8)**	**4**
				Total points	**12**
	Category point range				
Channel enlargement prediction (use total points and check stability rating)	**No increase 8 – 10** ☐	**Slight increase 11 – 16** ☑	**Moderate increase 17 – 24** ☐	**Extensive > 24** ☐	

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream:	**Red River**		Stream Type:	**C6c-**	
Location:	**Red River - 6 - 470.23**		Valley Type:	**X**	
Observers:	**KD, JB**		Date:	**11/18/2010**	

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	Stability Rating	Points	Selected Points
1 Lateral stability (Worksheet 3-17)	Stable	1	2
	Mod. unstable	2	
	Unstable	3	
	Highly unstable	4	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition	1	1
	Mod. deposition	2	
	Excess deposition	3	
	Aggradation	4	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	2
	Slightly incised	2	
	Mod. Incised	3	
	Degradation	4	
4 Channel enlargement prediction (Worksheet 3-20)	No increase	1	2
	Slight increase	2	
	Mod. increase	3	
	Extensive	4	
5 Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	1
	Fair: mod unstable	2	
	Poor: unstable	4	
		Total Points	8

	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 ☐

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Red River**		Location: **Red River - 6 - 470.23**		
Observers:	**KD, JB**	Date: **11/18/2010**	Stream Type: **C6c-**	Valley Type: **X**	
Channel Dimension	Mean bankfull depth (ft): **9.28**	Mean bankfull width (ft): **118**	Cross-section area (ft^2): **1084**	Width of flood-prone area (ft): **404.6667**	Entrenchment ratio: **3.4**
Channel Pattern	Mean: Range: MWR: **11.1**	Lm/W_{bkf}: **11.1**	Rc/W_{bkf}: **3.0**	Sinuosity: **2.25**	
River Profile and Bed Features	Check: ☐ Riffle/pool ☐ Step/pool ☑ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed				
	Max bankfull depth (ft): Riffle **16.2**; Pool	Depth ratio (max/mean): Riffle **1.7**; Pool	Pool to pool spacing: Ratio	Slope: Valley:	Average bankfull: **0.00014**
Level III Stream Stability Indices	Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:	
	Flow regime: **P1, 2, 7, 9**	Stream size and order: **S-8**	Meander pattern(s): **M2**	Depositional pattern(s): **NONE**	Debris/channel blockage(s): **D3**
	Degree of incision (Bank-Height Ratio): **1.7**	Degree of incision stability rating: **Deeply Incised**	Modified Pfankuch stability rating (numeric and adjective rating): **Good**		
	Width/depth ratio (W/d): **12.7**	Reference W/d ratio (W/d_{ref}): **12.8**	Width/depth ratio state $(W/d) / (W/d_{ref})$: **1.0**	W/d ratio state stability rating: **Stable**	
	Meander Width Ratio (MWR): **11.1**	Reference MWR_{ref}: **10.6**	Degree of confinement (MWR / MWR_{ref}): **1.0**	MWR / MWR_{ref} stability rating: **Unconfined**	
Bank Erosion Summary	Length of reach studied (ft): **8419**	Annual streambank erosion rate: **1966** (tons/yr) **0.23** (tons/yr/ft)	Curve used: **Fig 3-9**	Remarks:	
Sediment Capacity (POWERSED)	☑ Sufficient capacity ☐ Insufficient capacity ☐ Excess capacity			Remarks:	
Entrainment/ Competence	Largest particle from bar sample (mm):	$\tau =$	$\tau^* =$	Existing $depth_{bkf}$: Required $depth_{bkf}$:	Existing $slope_{bkf}$: Required $slope_{bkf}$:
Successional Stage Shift	→ → → → →		Existing stream state (type): **C6c-**	Potential stream state (type): **C6c-**	
Lateral Stability	☐ Stable ☑ Mod. unstable ☐ Unstable ☐ Highly unstable			Remarks/causes: None	
Vertical Stability (Aggradation)	☑ No deposition ☐ Mod. deposition ☐ Ex. deposition ☐ Aggradation			Remarks/causes: **None**	
Vertical Stability (Degradation)	☐ Not incised ☑ Slightly incised ☐ Mod. incised ☐ Degradation			Remarks/causes: **None**	
Channel Enlargement	☐ No increase ☑ Slight increase ☐ Mod. increase ☐ Extensive			Remarks/causes: **None**	
Sediment Supply (Channel Source)	☐ Low ☑ Moderate ☐ High ☐ Very high			Remarks/causes: **None**	

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Red River**

Location: **Red River-7-492.47**

Observers: **KD, JB**

Reference reach: [ ]

Disturbed (impacted reach): **X**

Date: **9/30/2011**

Existing species composition: **Trees**

Potential species composition:

	Riparian cover categories	Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**80%**	**3%**	**Trees**	**100%**
					100%
2. Understory	Shrub layer		**40%**	**Weeds, shrubs**	**100%**
					100%
3. Ground level	Herbaceous		**20%**	**Grass, weeds**	**100%**
					100%
	Leaf or needle litter		**5%**		
	Bare ground		**32%**		
			Column total = 100%		

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

Remarks:
Condition, vigor and/or usage of existing reach:

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Red River**			Location: **Red River-7-492.47**					
Observers: **KD, JB**							Date: **9/30/2011**	
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P7**	**P9**				

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

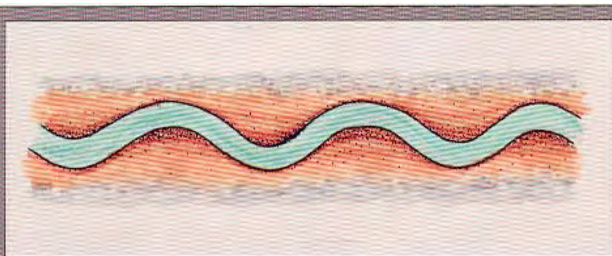
Stream Size and Order			
Stream:	**Red River**		
Location:	**Red River-7-492.47**		
Observers:	**KD, JB**		
Date:	**9/30/2011**		
Stream Size Category and Order ☞			**S-8**
Category	**STREAM SIZE: Bankfull width**		**Check (✓) appropriate category**
	meters	**feet**	
S-1	0.305	<1	☐
S-2	0.3 – 1.5	1 – 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).			

Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

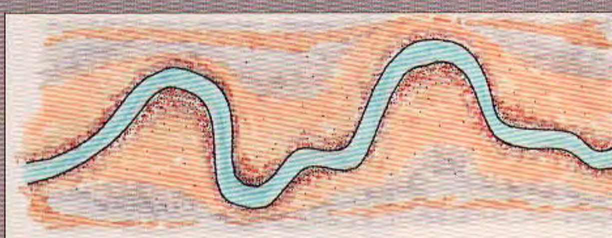
Stream:	**Red River**		Reach:	**Red River-7-492.47**	
Observers:	**KD, JB**		Date:	**9/30/2011**	
List ALL CATEGORIES that APPLY ☞	**M2**				

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

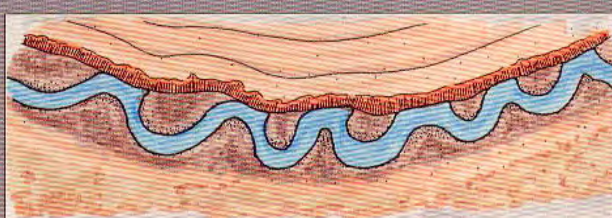


M1 REGULAR MEANDERS

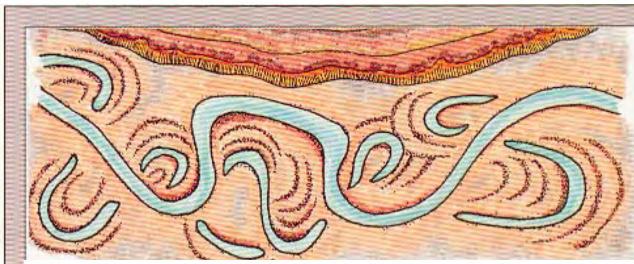
M2 TORTUOUS MEANDERS



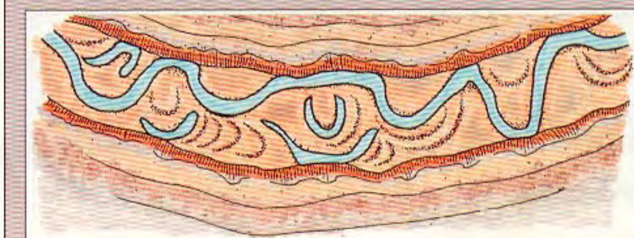
M3 IRREGULAR MEANDERS



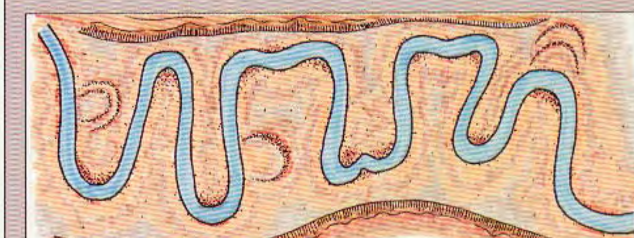
M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS



M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

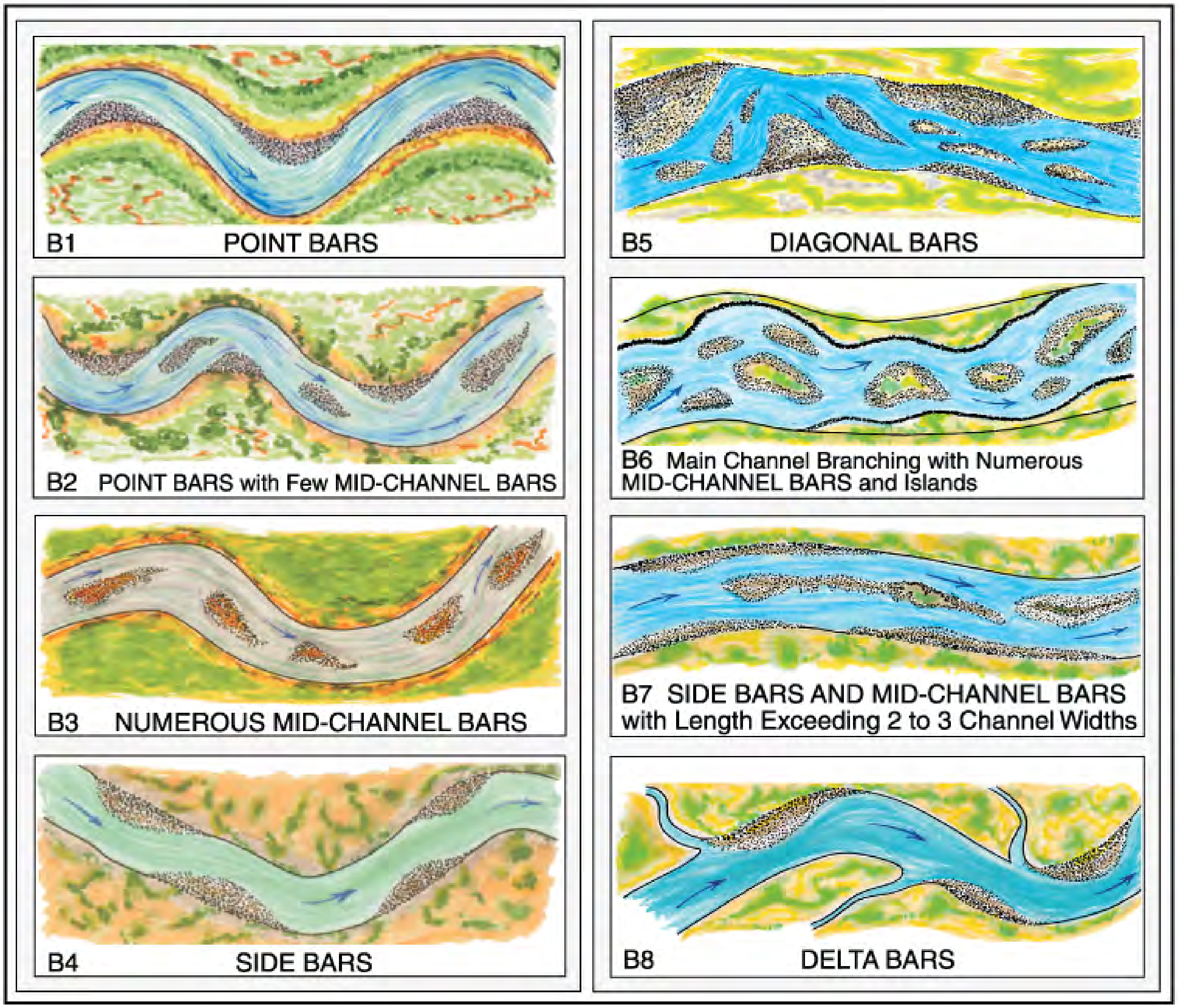
Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns

Stream:	**Red River**	Reach:	**Red River-7-492.47**
Observers:	**KD, JB**	Date:	**9/30/2011**

List ALL CATEGORIES that APPLY ☞	**None**				

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



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Red River**		Location: **Red River-7-492.47**	
Observers: **KD, JB**		Date: **9/30/2011**	
Description/extent		**Materials that 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.	☐

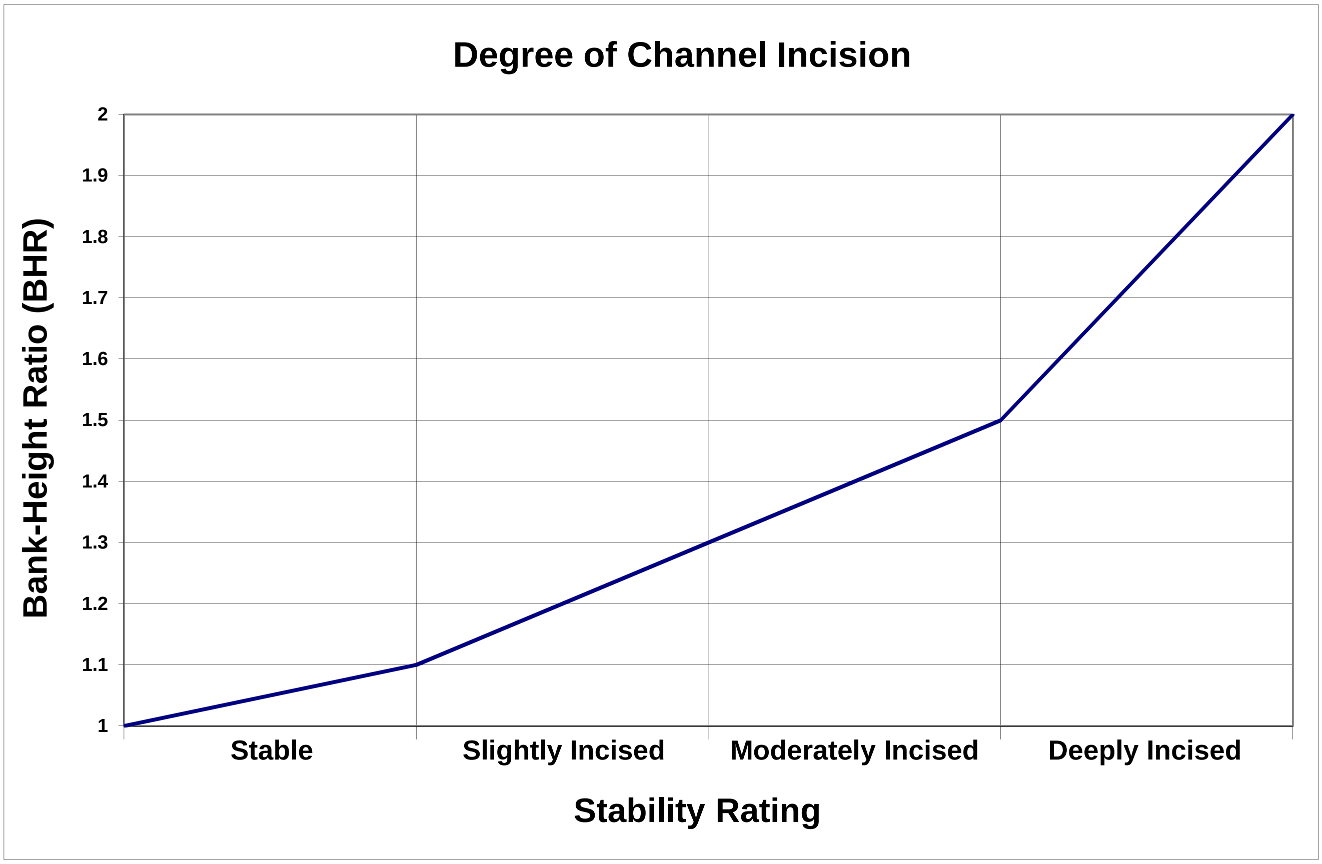
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision

Low Bank Height:	24
Max Bankfull Depth:	13.33

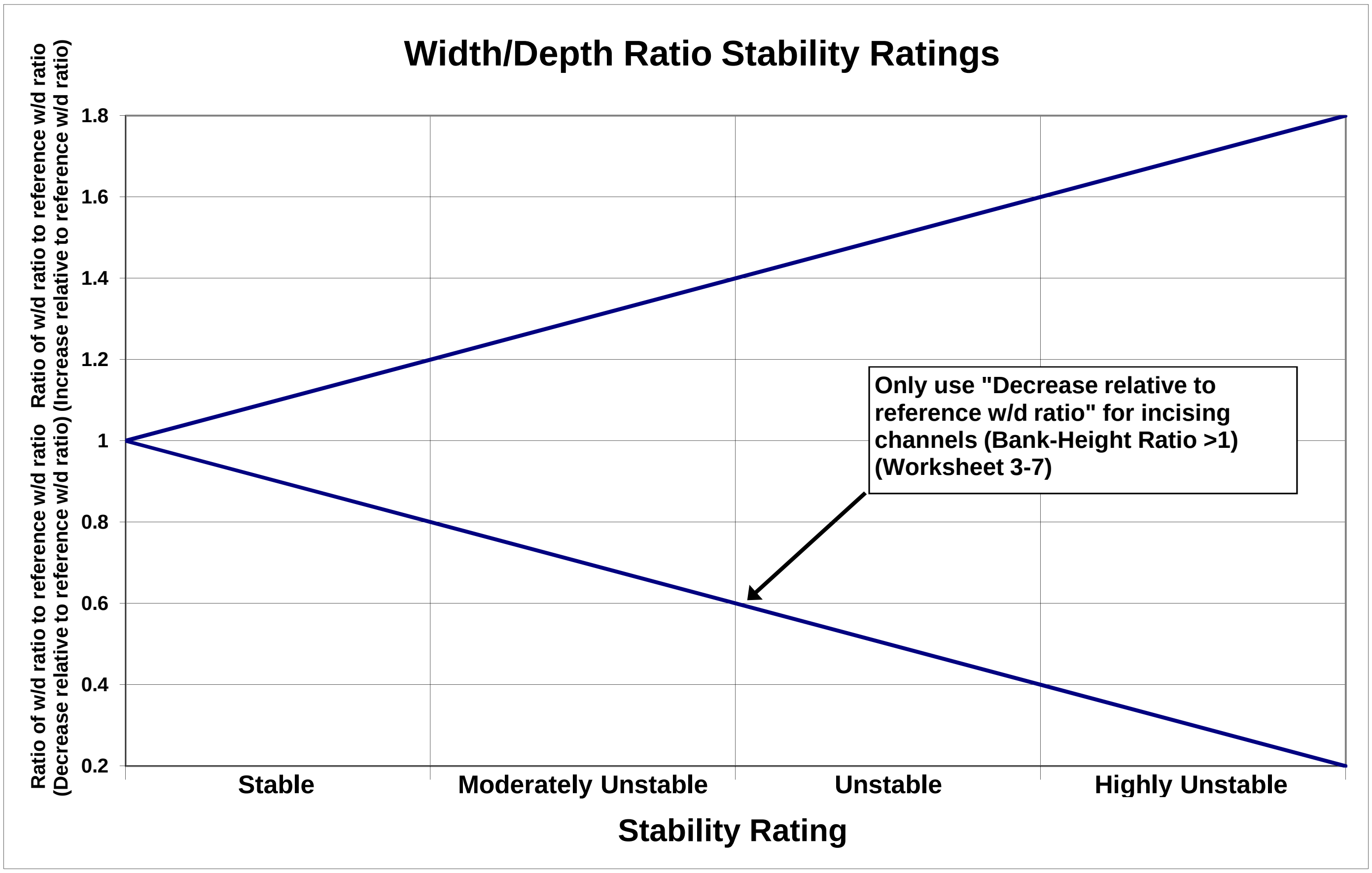
Bank-Height Ratio:	1.8

Degree of Channel Incision Stability Rating ☞	**Deeply Incised**



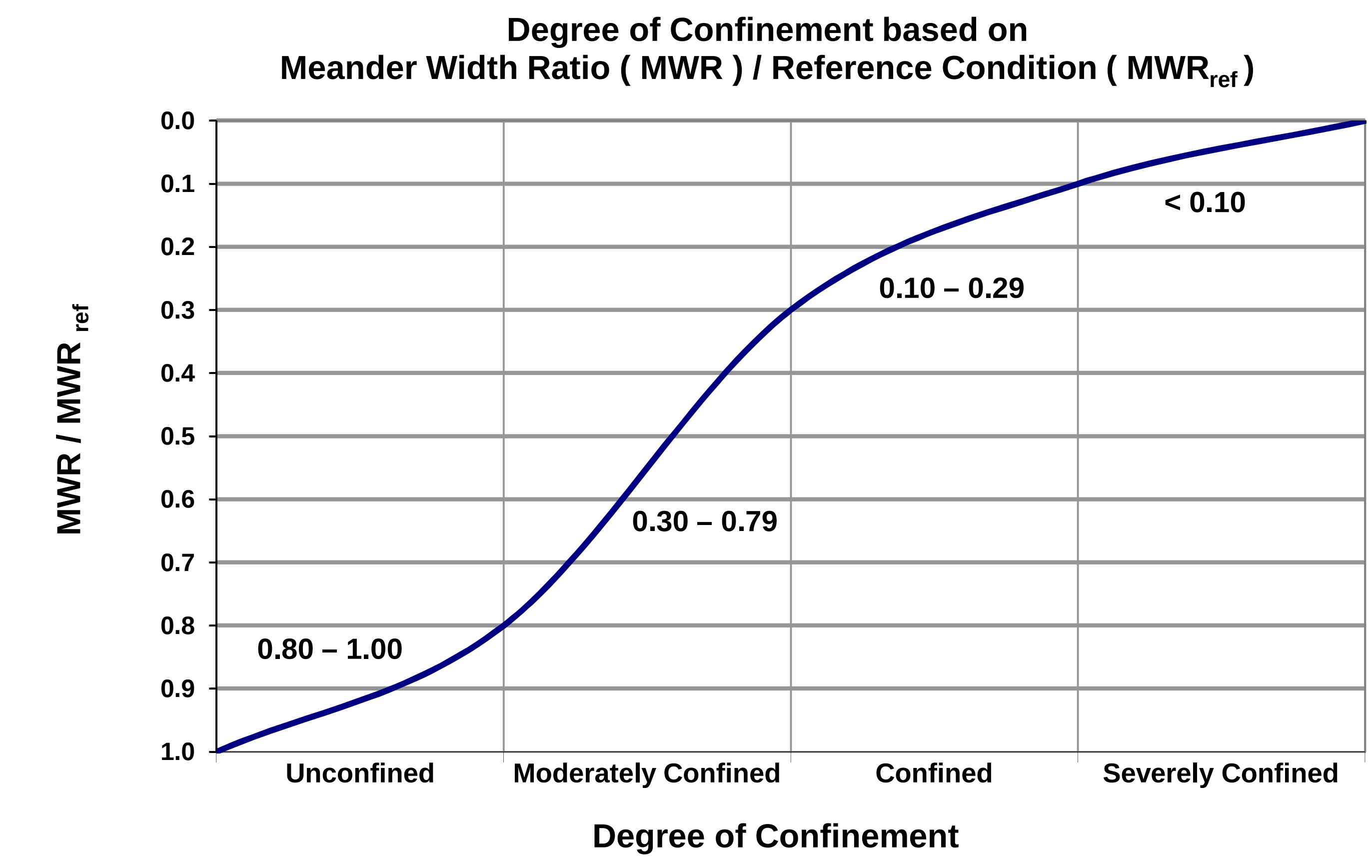
Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State			
Existing Width/Depth Ratio:	**13.6**	Ratio of existing W/d to reference W/d:	**1**
Reference Width/Depth Ratio:	**13.6**		
Width/Depth Ratio State Stability Rating ☞		**Stable**	



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	16.6	Ratio of MWR to MWR_{ref}:	1
Reference Meander Width Ratio (MWR_{ref}):	16.6		
Degree of Confinement Stability Rating ☞		Unconfined	



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Red River **Location:** Red River-7-492.47 **Valley Type:** X **Observers:** KD, JB **Date:** 9/30/2011

Location	Key	Category	Excellent Description	Excellent Rating	Good Description	Good Rating	Fair Description	Fair Rating	Poor Description	Poor Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	**4**	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	**12**
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	**6**	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	**12**
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	**8**
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	**6**	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	**16**
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	2	Moderately packed with some overlapping.	**4**	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	4	Distribution shift light. Stable material 50–80%.	**8**	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	6	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	**12**	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	7	Good total =	28	Fair total =	12	Poor total =	52

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total = 99

Existing stream type = C6c-

***Potential stream type =** C6c-

Modified channel stability rating = **Fair**

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream: **Red River** — Location: **Red River-7-492.47**

Station: — Observers: **KD, JB**

Date: **9/30/2011** — Stream Type: **C6c-** — Valley Type: **X**

Variable	Inputs	Calculation	Value	BEHI Score (Fig. 3-7)
Study Bank Height / Bankfull Height (C)	Study Bank Height (ft) = 29.8 (A); Bankfull Height (ft) = 10.6 (B)	(A) / (B) =	2.8 (C)	9
Root Depth / Study Bank Height (E)	Root Depth (ft) = 3 (D); Study Bank Height (ft) = 29.8 (A)	(D) / (A) =	0.1 (E)	8
Weighted Root Density (G)	Root Density as % = 10% (F)	(F) x (E) =	1% (G)	10
Bank Angle (H)	Bank Angle as *Degrees* =		20 (H)	2
Surface Protection (I)	Surface Protection as % =		5% (I)	10

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)

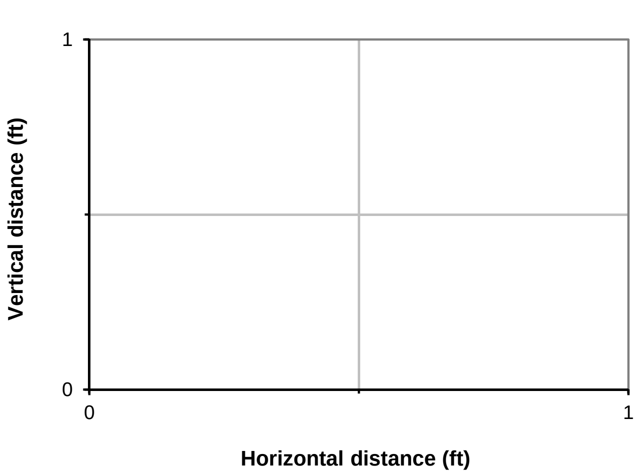
Bank Material Adjustment: 0

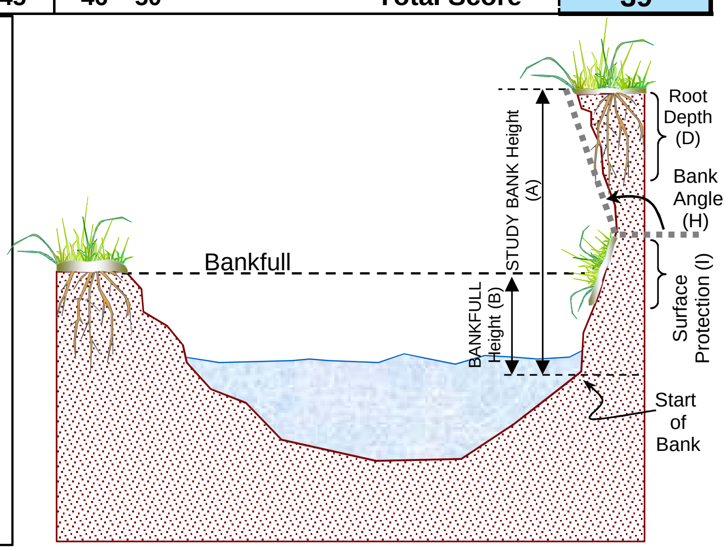
Stratification Adjustment
Add 5–10 points, depending on position of unstable layers in relation to bankfull stage: 0

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**: **High** **39**

Bank Sketch





Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Red River**	Location: **Red River-7-492.47**	
Station: **0**	Stream Type: **C6c-**	Valley Type: **X**
Observers: **KD, JB**		Date: **9/30/11**

Methods for Estimating Near-Bank Stress (NBS)

(1)	Channel pattern, transverse bar or split channel/central bar creating NBS……….	Level I	Reconaissance
(2)	Ratio of radius of curvature to bankfull width (R_c / W_{bkf})…………………...…………………	Level II	General prediction
(3)	Ratio of pool slope to average water surface slope (S_p / S)……………...……..........…….	Level II	General prediction
(4)	Ratio of pool slope to riffle slope (S_p / S_{rif})…………………..………………..………….……	Level II	General prediction
(5)	Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})…………………..	Level III	Detailed prediction
(6)	Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})……..……............….	Level III	Detailed prediction
(7)	Velocity profiles / Isovels / Velocity gradient……………………………….....……....….	Level IV	Validation

Level I

(1)
Transverse and/or central bars-short and/or discontinuous………… …………….....…NBS = High / Very High
Extensive deposition (continuous, cross-channel)…………….………………..……. …………...NBS = Extreme
Chute cutoffs, down-valley meander migration, converging flow……………………….……………NBS = Extreme

Level II

(2)	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)

(3)	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)

(4)	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)

Dominant Near-Bank Stress
Very Low

Level III

(5)	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)

(6)	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)

Level IV

(7)	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
	0.01	**Very Low**

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating	**Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	Red River			Location:	Red River-7-492.47		
Graph Used:	Fig 3-9	Total Bank Length (ft):	12938.9			Date:	9/30/2011
Observers:	KD, JB	Valley Type:	X			Stream Type:	C6c-
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	High	Very Low	0.165	12938.9	29.8	63621	0.24
2.						0	#DIV/0!
3.						0	#DIV/0!
4.						0	#DIV/0!
5.						0	#DIV/0!
6.						0	#DIV/0!
7.						0	#DIV/0!
8.						0	#DIV/0!
9.						0	#DIV/0!
10.						0	#DIV/0!
11.						0	#DIV/0!
12.						0	#DIV/0!
13.						0	#DIV/0!
14.						0	#DIV/0!
15.						0	#DIV/0!
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	63621	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	2356	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	3063	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	0.24	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Red River**		Stream Type:	**C6c-**
Location:	**Red River-7-492.47**		Valley Type:	**X**
Observers:	**KD, JB**		Date:	**9/30/2011**

Enter Required Information for Existing Condition

	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
0	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	**#DIV/0!**

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	**d**	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	**S**	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Sediment Competence Using Dimensional Shear Stress

0	Bankfull shear stress $\tau = \gamma ds$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope	
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**	
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**	
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope	$d = \dfrac{\tau}{\gamma S}$
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth	$S = \dfrac{\tau}{\gamma d}$

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis	Observers: **KD, JB**	
Stream: **Red River**	Location: **Red River-7-492.47**	Date: **9/30/2011**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		0		0		0		0		0		0		0		0		0
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		100%

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	0
Materials less than:	mm

Be sure to add separate material weights to grand total

GRAND TOTAL: 0

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream:	**Red River**	Stream Type:	**C6c-**
Location:	**Red River-7-492.47**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**9/30/2011**

Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream:	**Red River**		Stream Type:	**C6c-**	
Location:	**Red River-7-492.47**		Valley Type:	**X**	
Observers:	**KD, JB**		Date:	**9/30/2011**	

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 3-8)**	< 1.2 (2)	1.2 – 1.4 (4)	1.4 – 1.6 (6)	> 1.6 (8)	**2**
2 **Depositional pattern (Worksheet 3-5)**	B1, B2 (1)	B4, B8 (2)	B3 (3)	B5, B6, B7 (4)	**1**
3 **Meander pattern (Worksheet 3-4)**	M1, M3, M4 (1)		M2, M5, M6, M7, M8 (3)		**3**
4 **Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL (2)	M/L, M/M, M/H, L/Ex, H/L (4)	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL (6)	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex (8)	**4**
5 **Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.8 – 1.0 (1)	0.3 – 0.79 (2)	0.1 – 0.29 (3)	< 0.1 (4)	**1**
				Total points	**11**

	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** ☐

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Red River**	Stream Type:	**C6c-**
Location:	**Red River-7-492.47**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**9/30/2011**

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 3-14)**	Sufficient depth and/or slope to transport largest size available **(2)**	Trend toward insufficient depth and/or slope-slightly incompetent **(4)**	Cannot move D_{35} of bed material and/or D_{100} of bar material **(6)**	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size **(8)**	2
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load **(2)**	Trend toward insufficient sediment capacity **(4)**	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand **(6)**	Reduction over 25% of annual sediment yield for bedload and/or suspended sand **(8)**	2
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	>1.6 **(8)**	2
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation **(2)**	(E→C) **(4)**	(C→High W/d C), (B→High W/d B), (C→F) **(6)**	(C→D), (F→D) **(8)**	2
5 **Depositional patterns (Worksheet 3-5)**	B1 **(1)**	B2, B4 **(2)**	B3, B5 **(3)**	B6, B7, B8 **(4)**	1
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 **(1)**	D4, D7 **(2)**	D5, D8 **(3)**	D6, D9, D10 **(4)**	2
				Total points	**11**

	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** ☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream:	**Red River**			Stream Type:	**C6c-**
Location:	**Red River-7-492.47**			Valley Type:	**X**
Observers:	**KD, JB**			Date:	**9/30/2011**

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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	**2**
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	**2**
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	**8**
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	**4**
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	**1**
				Total points	**17**

	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** ☐

Worksheet 3-20. Channel enlargement prediction summary.

Stream:	**Red River**			Stream Type:	**C6c-**
Location:	**Red River-7-492.47**			Valley Type:	**X**
Observers:	**KD, JB**			Date:	**9/30/2011**

Channel enlargement prediction criteria (choose one stability category for each criterion 1–4)	**Channel Enlargement Prediction Categories**				**Selected points** (from each row)
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) **(2)**	(C→High W/d C), (E→C) **(4)**	(G→F), (F→D) **(6)**	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) **(8)**	**2**
2 **Lateral stability (Worksheet 3-17)**	Stable **(2)**	Moderately unstable **(4)**	Unstable **(6)**	Highly unstable **(8)**	**4**
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition **(2)**	Moderate deposition **(4)**	Excess deposition **(6)**	Aggradation **(8)**	**2**
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised **(2)**	Slightly incised **(4)**	Moderately incised **(6)**	Degradation **(8)**	**4**
				Total points	**12**
	Category point range				
Channel enlargement prediction (use total points and check stability rating)	**No increase 8 – 10** ☐	**Slight increase 11 – 16** ☑	**Moderate increase 17 – 24** ☐	**Extensive > 24** ☐	

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream: **Red River**		Stream Type:	**C6c-**
Location: **Red River-7-492.47**		Valley Type:	**X**
Observers: **KD, JB**		Date:	**9/30/2011**

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	Stability Rating	Points	Selected Points
1 Lateral stability (Worksheet 3-17)	Stable	1	2
	Mod. unstable	2	
	Unstable	3	
	Highly unstable	4	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition	1	1
	Mod. deposition	2	
	Excess deposition	3	
	Aggradation	4	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	2
	Slightly incised	2	
	Mod. Incised	3	
	Degradation	4	
4 Channel enlargement prediction (Worksheet 3-20)	No increase	1	2
	Slight increase	2	
	Mod. increase	3	
	Extensive	4	
5 Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	2
	Fair: mod unstable	2	
	Poor: unstable	4	
		Total Points	**9**

	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 ☐

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Red River**	Location:	**Red River-7-492.47**
Observers:	**KD, JB**	Date: **9/30/2011**	Stream Type: **C6c-** Valley Type: **X**

Channel Dimension	Mean bankfull depth (ft): **8.89**	Mean bankfull width (ft): **120.8**	Cross-section area (ft^2): **1074**	Width of flood-prone area (ft): **404**	Entrenchment ratio: **3.3**
Channel Pattern	Mean: Range:	MWR: **16.6**	Lm/W_{bkf}: **16.6**	Rc/W_{bkf}: **4.1**	Sinuosity: **2.56**
River Profile and Bed Features	Check: ☐ Riffle/pool ☐ Step/pool ☐ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed				
	Max bankfull depth (ft): Riffle **13.3**; Pool	Depth ratio (max/mean): Riffle **1.5**; Pool	Pool to pool spacing: Ratio	Slope — Valley:	Average bankfull: **7.5E-05**
Level III Stream Stability Indices	Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:	
	Flow regime: **P1, 2, 7, 9**	Stream size and order: **S-8**	Meander pattern(s): **M2**	Depositional pattern(s): **NONE**	Debris/channel blockage(s): **D1-4**
	Degree of incision (Bank-Height Ratio): **1.8**	Degree of incision stability rating: **Deeply Incised**	Modified Pfankuch stability rating (numeric and adjective rating): **Fair**		
	Width/depth ratio (W/d): **13.6**	Reference W/d ratio (W/d_{ref}): **13.6**	Width/depth ratio state $(W/d) / (W/d_{ref})$: **1.0**	W/d ratio state stability rating: **Stable**	
	Meander Width Ratio (MWR): **16.6**	Reference MWR_{ref}: **16.6**	Degree of confinement (MWR / MWR_{ref}): **1.0**	MWR / MWR_{ref} stability rating: **Unconfined**	
Bank Erosion Summary	Length of reach studied (ft): **####**	Annual streambank erosion rate: **3063** (tons/yr) **0.24** (tons/yr/ft)	Curve used: **Fig 3-9**	Remarks:	
Sediment Capacity (POWERSED)	☑ Sufficient capacity ☐ Insufficient capacity ☐ Excess capacity		Remarks:		
Entrainment/ Competence	Largest particle from bar sample (mm):	τ =	τ* =	Existing $depth_{bkf}$: Required $depth_{bkf}$:	Existing $slope_{bkf}$: Required $slope_{bkf}$:
Successional Stage Shift	→ → → → →		Existing stream state (type): **C6c-**	Potential stream state (type): **C6c-**	
Lateral Stability	☐ Stable ☑ Mod. unstable ☐ Unstable ☐ Highly unstable		Remarks/causes:		
Vertical Stability (Aggradation)	☑ No deposition ☐ Mod. deposition ☐ Ex. deposition ☐ Aggradation		Remarks/causes:		
Vertical Stability (Degradation)	☐ Not incised ☑ Slightly incised ☐ Mod. incised ☐ Degradation		Remarks/causes:		
Channel Enlargement	☐ No increase ☑ Slight increase ☐ Mod. increase ☐ Extensive		Remarks/causes:		
Sediment Supply (Channel Source)	☐ Low ☑ Moderate ☐ High ☐ Very high		Remarks/causes:		

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Red River**			Location: **Red River-8-521.18**	
Observers: **KD, JB**	Reference reach [ ]	Disturbed (impacted reach) [X]	Date: **10/5/2011**	
Existing species composition:			Potential species composition:	

	Riparian cover categories	Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**60%**	**2%**	**Trees**	**100%**
					100%
2. Understory	Shrub layer		**35%**	**Shrubs**	**100%**
					100%
3. Ground level	Herbaceous		**15%**	**Grass, weeds**	**100%**
					100%
	Leaf or needle litter		**5%**		
	Bare ground		**43%**		
			Column total = 100%		

Remarks:
Condition, vigor and/or usage of existing reach:

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

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Red River**			Location: **Red River-8-521.18**					
Observers: **KD, JB**						Date: **10/5/2011**		
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P7**	**P9**				

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order

Stream:	**Red River**
Location:	**Red River-8-521.18**
Observers:	**KD, JB**
Date:	**10/5/2011**
Stream Size Category and Order ☞	**S-8**

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

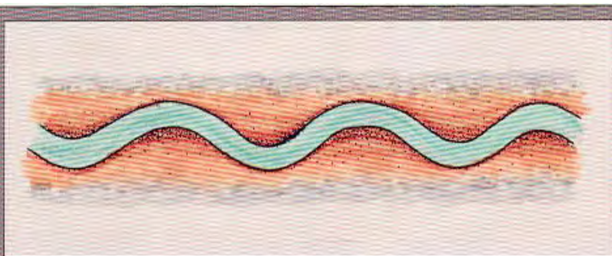
Add categories in parenthesis for specific stream order of reach. For example a third order stream with a bankfull width of 6.1 meters (20 feet) would be indexed as: S-4(3).

Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

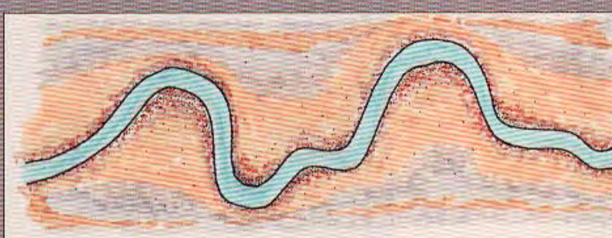
Stream:	**Red River**		Reach:	**Red River-8-521.18**	
Observers:	**KD, JB**		Date:	**10/5/2011**	
List ALL CATEGORIES that APPLY ☞	**M2**				

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

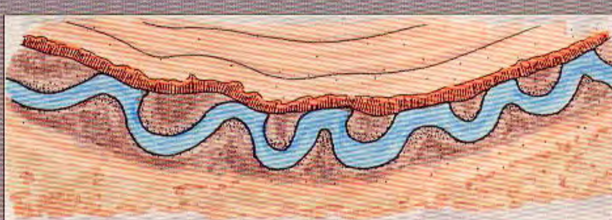


M1 REGULAR MEANDERS

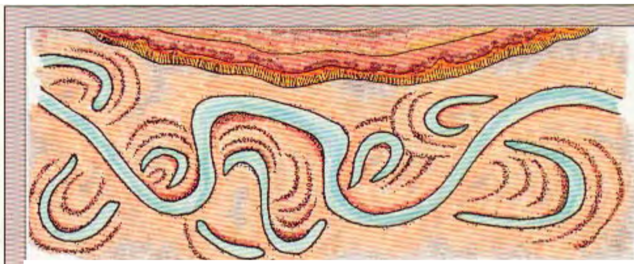
M2 TORTUOUS MEANDERS



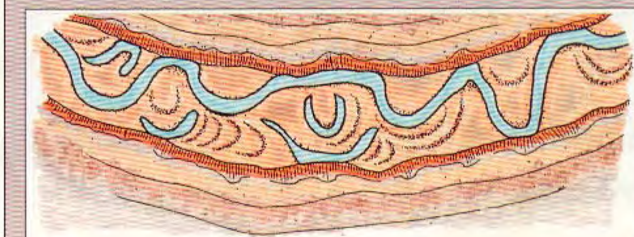
M3 IRREGULAR MEANDERS



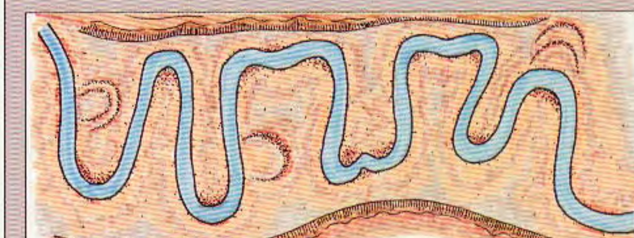
M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS



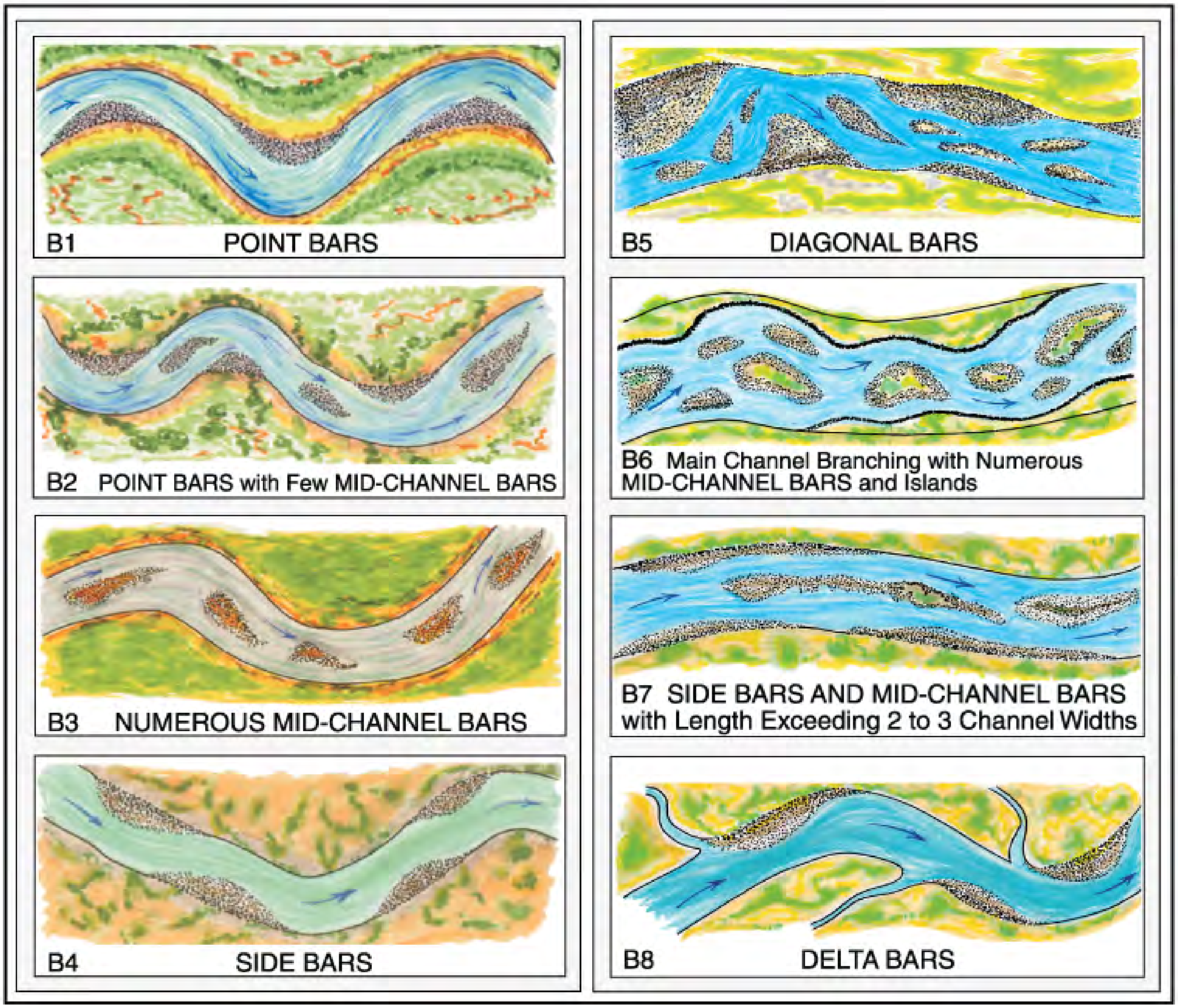
M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns						
Stream:	**Red River**		Reach:	**Red River-8-521.18**		
Observers:	**KD, JB**		Date:	**10/5/2011**		
List ALL CATEGORIES that APPLY ☞	**None**					

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



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Red River**		Location: **Red River-8-521.18**	
Observers: **KD, JB**		Date: **10/5/2011**	
Description/extent		**Materials that 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.	☐

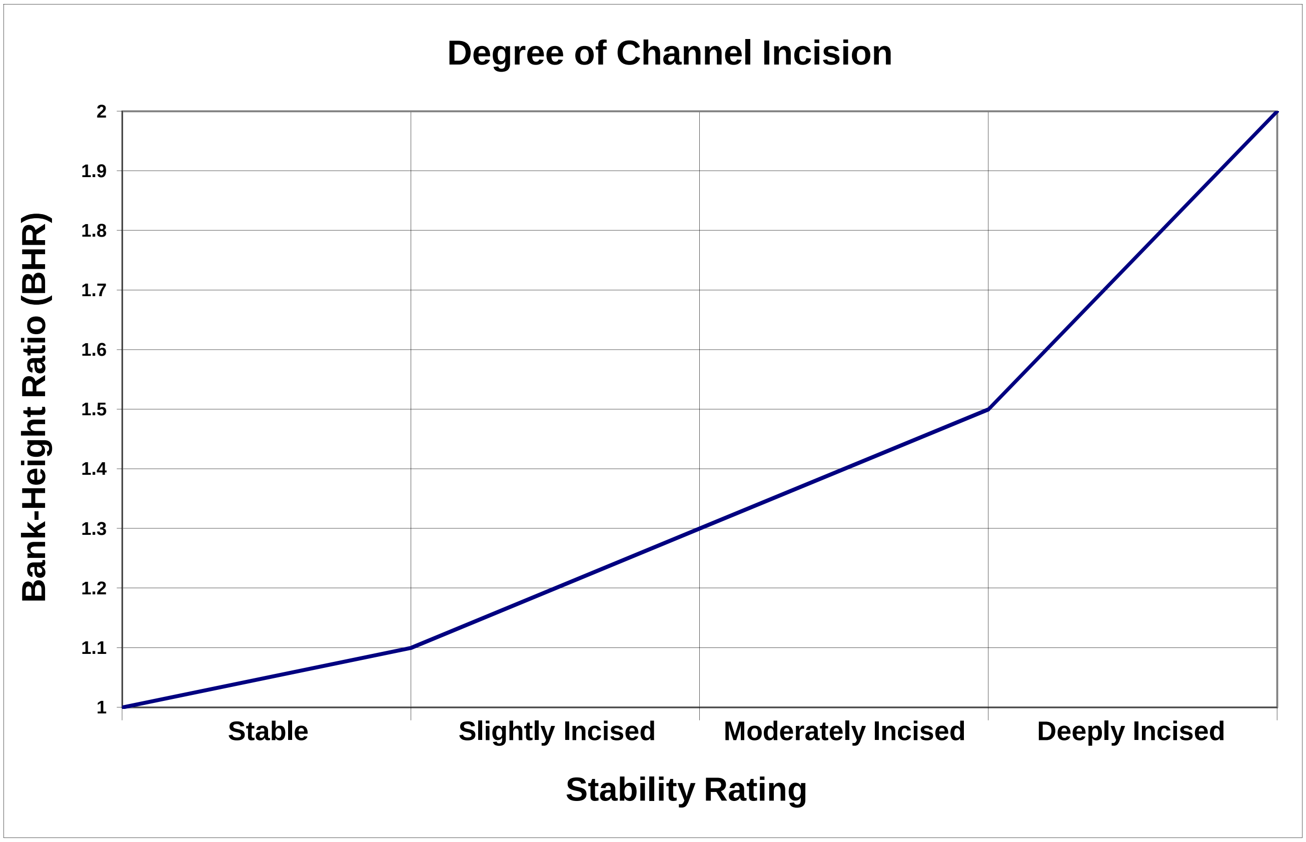
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision

Low Bank Height:	**20.1**
Max Bankfull Depth:	**6.6367**

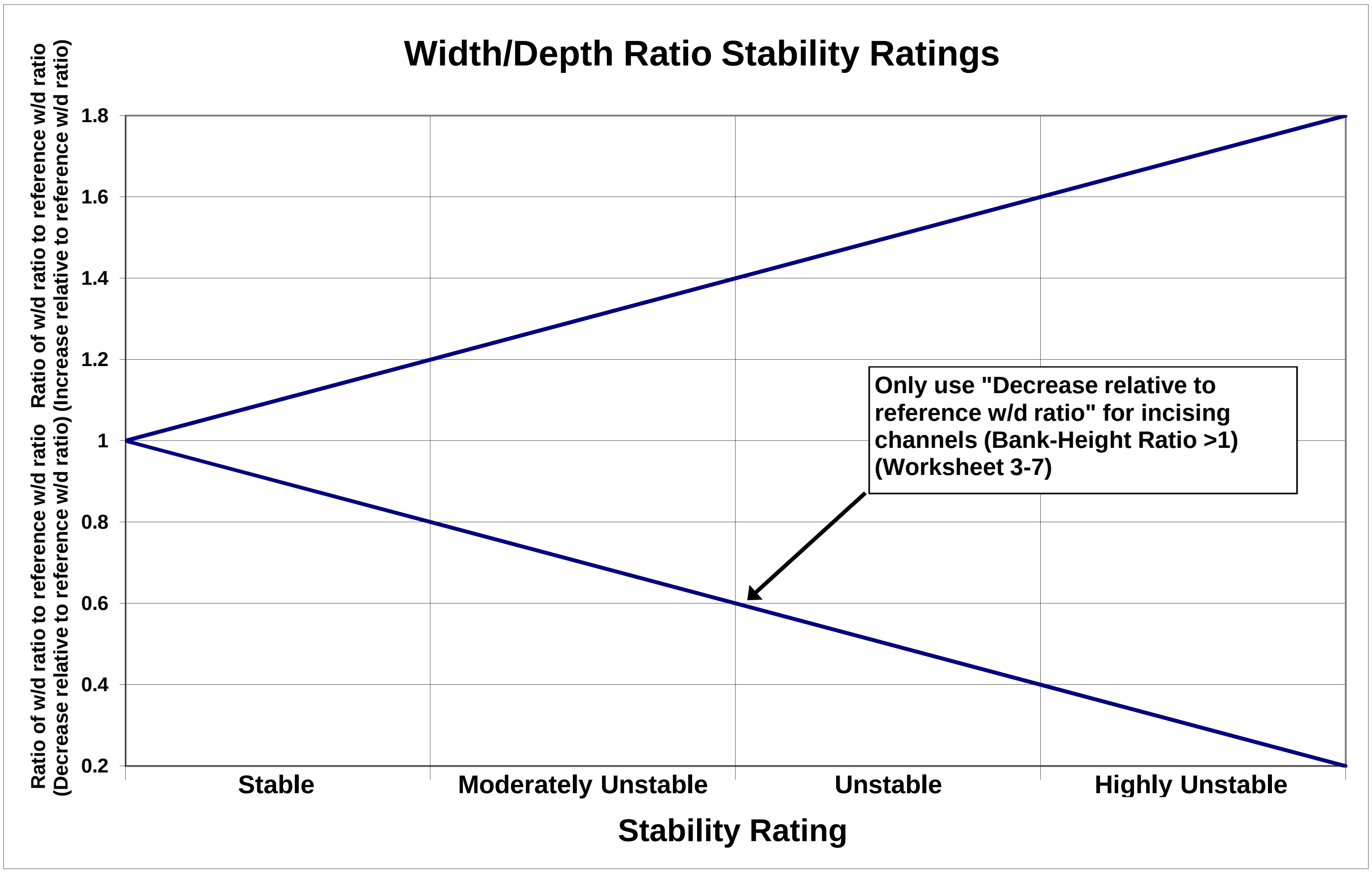
Bank-Height Ratio:	**3.0**

Degree of Channel Incision Stability Rating ☞	**Deeply Incised**



Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State			
Existing Width/Depth Ratio:	20.8	Ratio of existing W/d to reference W/d:	1
Reference Width/Depth Ratio:	20.8		
Width/Depth Ratio State Stability Rating ☞		Stable	

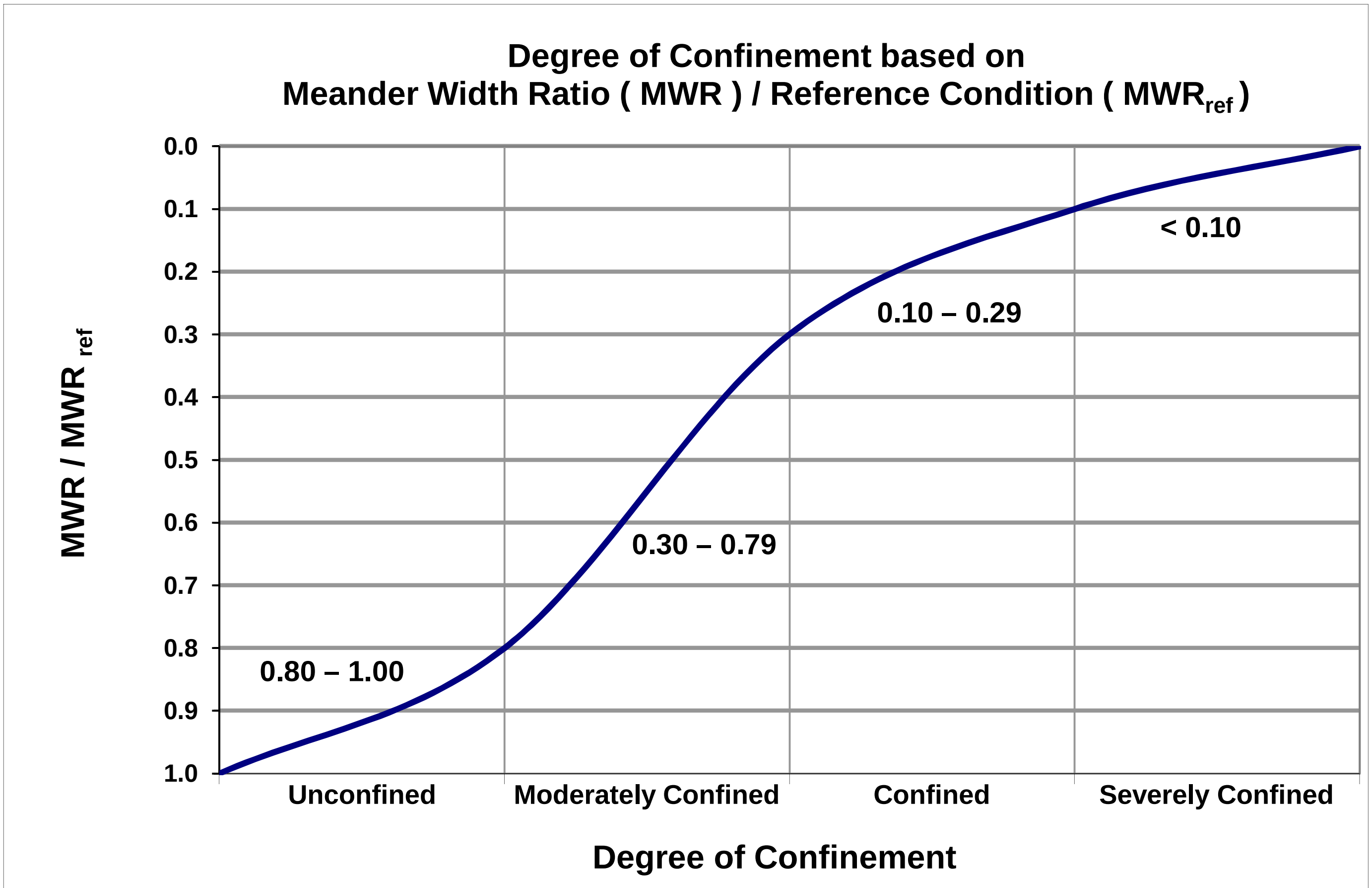


Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement

Existing Meander Width Ratio (MWR):	**9.4**	Ratio of MWR to MWR_{ref}:	**1**
Reference Meander Width Ratio (MWR_{ref}):	**9.4**		

Degree of Confinement Stability Rating ☞	**Unconfined**



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Red River **Location:** Red River-8-521.18 **Valley Type:** X **Observers:** KD, JB **Date:** 10/5/2011

Location	Key	Category	Excellent Description	Excellent Rating	Good Description	Good Rating	Fair Description	Fair Rating	Poor Description	Poor Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	**2**	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	**12**
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	**6**	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	**12**
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	**8**
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	**6**	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	**16**
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	**21**	Good total =	**0**	Fair total =	**12**	Poor total =	**52**

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	**85**
Existing stream type =	**C6c-**
*Potential stream type =	**C6c-**
Modified channel stability rating =	**Good**

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream:	**Red River**	Location:	**Red River-8-521.18**
Station:		Observers:	**KD, JB**
Date:	**10/5/2011**	Stream Type: **C6c-**	Valley Type: **X**

Variable	Input 1	Value	Input 2	Value	Calculation	Result	BEHI Score (Fig. 3-7)
Study Bank Height / Bankfull Height (C)	**Study Bank Height** (ft) =	20.2 (A)	**Bankfull Height** (ft) =	9.2 (B)	(A) / (B) =	2.2 (C)	8
Root Depth / Study Bank Height (E)	**Root Depth** (ft) =	2 (D)	**Study Bank Height** (ft) =	20.2 (A)	(D) / (A) =	0.1 (E)	8
Weighted Root Density (G)			**Root Density** as % =	3% (F)	(F) x (E) =	0% (G)	10
Bank Angle (H)					**Bank Angle** as *Degrees* =	20 (H)	2
Surface Protection (I)					**Surface Protection** as % =	5% (I)	10

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

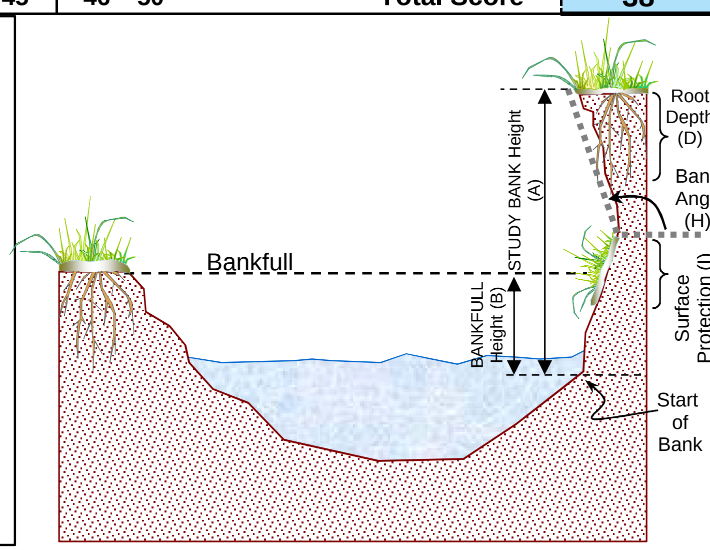
Stratification Adjustment

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**: **High** / **38**

Bank Sketch



Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Red River**	Location: **Red River-8-521.18**	
Station: **0**	Stream Type: **C6c-**	Valley Type: **X**
Observers: **KD, JB**		Date: **10/5/11**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})..	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S)..	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})..	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})............................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient..	Level IV	Validation

Level I

(1)
- Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
- Extensive deposition (continuous, cross-channel)....................................... ....NBS = Extreme
- Chute cutoffs, down-valley meander migration, converging flow.......................................NBS = Extreme

Level II

	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)
(2)				

	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)
(3)				

	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)
(4)				

Dominant Near-Bank Stress
Very Low

Level III

	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)
(5)				

	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)
(6)								

Level IV

	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
(7)	**0.01**	**Very Low**

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating	**Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Red River**			Location:	**Red River-8-521.18**		
Graph Used:	**Fig 3-9**	Total Bank Length (ft):	**13236.8**			Date:	**10/5/2011**
Observers:	**KD, JB**		Valley Type:	**X**		Stream Type:	**C6c-**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**13236.8**	**20.2**	**44118**	**0.16**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**44118**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**1634**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**2124**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.16**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Red River**		Stream Type:	**C6c-**	
Location:	**Red River-8-521.18**		Valley Type:	**X**	
Observers:	**KD, JB**		Date:	**10/5/2011**	
Enter Required Information for Existing Condition					
	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
0	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			
Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress					
#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1: $\tau^* = 0.0834\ (D_{50}/\hat{D}_{50})^{-0.872}$		
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2: $\tau^* = 0.0384\ (D_{max}/D_{50})^{-0.887}$		
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:		**#DIV/0!**
Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample					
#DIV/0!	d	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)	
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample					
#DIV/0!	S	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)	
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Sediment Competence Using Dimensional Shear Stress					
0	Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope				
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**				
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**				
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope			$d = \dfrac{\tau}{\gamma S}$	
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth			$S = \dfrac{\tau}{\gamma d}$	

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis	Observers: **KD, JB**
Stream: **Red River** · Location: **Red River-8-521.18**	Date: **10/5/2011**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		0		0		0		0		0		0		0		0		0
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		100%

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	0
Materials less than:	mm

Be sure to add separate material weights to grand total

GRAND TOTAL: 0

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Red River**	Stream Type: **C6c-**
Location: **Red River-8-521.18**	Valley Type: **X**
Observers: **KD, JB**	Date: **10/5/2011**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream:	**Red River**		Stream Type:	**C6c-**	
Location:	**Red River-8-521.18**		Valley Type:	**X**	
Observers:	**KD, JB**		Date:	**10/5/2011**	

Lateral stability criteria (choose one stability category for each criterion 1–5)	**Lateral Stability Categories** Stable	Moderately unstable	Unstable	Highly unstable	**Selected points** (from each row)
1 **W/d ratio state (Worksheet 3-8)**	< 1.2 (2)	1.2 – 1.4 (4)	1.4 – 1.6 (6)	> 1.6 (8)	2
2 **Depositional pattern (Worksheet 3-5)**	B1, B2 (1)	B4, B8 (2)	B3 (3)	B5, B6, B7 (4)	1
3 **Meander pattern (Worksheet 3-4)**	M1, M3, M4 (1)		M2, M5, M6, M7, M8 (3)		3
4 **Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL (2)	M/L, M/M, M/H, L/Ex, H/L (4)	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL (6)	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex (8)	4
5 **Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.8 – 1.0 (1)	0.3 – 0.79 (2)	0.1 – 0.29 (3)	< 0.1 (4)	1
				Total points	**11**

Overall lateral stability category (use total points and check stability rating)	**Lateral stability category point range** Stable 7 – 9 ☐	Moderately unstable 10 – 12 ☑	Unstable 13 – 21 ☐	Highly unstable > 21 ☐

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Red River**	Stream Type:	**C6c-**
Location:	**Red River-8-521.18**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**10/5/2011**

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 3-14)**	Sufficient depth and/or slope to transport largest size available **(2)**	Trend toward insufficient depth and/or slope-slightly incompetent **(4)**	Cannot move D_{35} of bed material and/or D_{100} of bar material **(6)**	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size **(8)**	**2**
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load **(2)**	Trend toward insufficient sediment capacity **(4)**	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand **(6)**	Reduction over 25% of annual sediment yield for bedload and/or suspended sand **(8)**	**2**
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	>1.6 **(8)**	**2**
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation **(2)**	(E→C) **(4)**	(C→High W/d C), (B→High W/d B), (C→F) **(6)**	(C→D), (F→D) **(8)**	**2**
5 **Depositional patterns (Worksheet 3-5)**	B1 **(1)**	B2, B4 **(2)**	B3, B5 **(3)**	B6, B7, B8 **(4)**	**1**
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 **(1)**	D4, D7 **(2)**	D5, D8 **(3)**	D6, D9, D10 **(4)**	**1**
				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** ☐	

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream:	**Red River**	Stream Type:	**C6c-**
Location:	**Red River-8-521.18**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**10/5/2011**

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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	2
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	2
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	8
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	4
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	1
				Total points	**17**

	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** ☐

Worksheet 3-20. Channel enlargement prediction summary.

Stream:	Red River			Stream Type:	C6c-
Location:	Red River-8-521.18			Valley Type:	X
Observers:	KD, JB			Date:	10/5/2011

Channel enlargement prediction criteria (choose one stability category for each criterion 1–4)	**Channel Enlargement Prediction Categories**				**Selected points** (from each row)
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C)	(C→High W/d C), (E→C)	(G→F), (F→D)	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F)	**2**
	(2)	**(4)**	**(6)**	**(8)**	
2 **Lateral stability (Worksheet 3-17)**	Stable	Moderately unstable	Unstable	Highly unstable	**4**
	(2)	**(4)**	**(6)**	**(8)**	
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition	Moderate deposition	Excess deposition	Aggradation	**2**
	(2)	**(4)**	**(6)**	**(8)**	
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised	Slightly incised	Moderately incised	Degradation	**4**
	(2)	**(4)**	**(6)**	**(8)**	
				Total points	**12**
	Category point range				
Channel enlargement prediction (use total points and check stability rating)	**No increase 8 – 10** ☐	**Slight increase 11 – 16** ☑	**Moderate increase 17 – 24** ☐	**Extensive > 24** ☐	

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream: **Red River**		Stream Type:	**C6c-**
Location: **Red River-8-521.18**		Valley Type:	**X**
Observers: **KD, JB**		Date:	**10/5/2011**

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	Stability Rating	Points	Selected Points
1 Lateral stability (Worksheet 3-17)	Stable	1	2
	Mod. unstable	2	
	Unstable	3	
	Highly unstable	4	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition	1	1
	Mod. deposition	2	
	Excess deposition	3	
	Aggradation	4	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	2
	Slightly incised	2	
	Mod. Incised	3	
	Degradation	4	
4 Channel enlargement prediction (Worksheet 3-20)	No increase	1	2
	Slight increase	2	
	Mod. increase	3	
	Extensive	4	
5 Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	1
	Fair: mod unstable	2	
	Poor: unstable	4	
		Total Points	8

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

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Red River**	Location:	**Red River-8-521.18**
Observers:	**KD, JB**	Date: **10/5/2011**	Stream Type: **C6c-** Valley Type: **X**

Channel Dimension	Mean bankfull depth (ft):	6.64	Mean bankfull width (ft):	138	Cross-section area (ft^2):	914.5	Width of flood-prone area (ft):	788	Entrenchment ratio:	5.7
Channel Pattern	Mean: Range:	MWR:	9.4	Lm/W_{bkf}:	9.4	Rc/W_{bkf}:	3.7	Sinuosity:	2.6	

River Profile and Bed Features

Check: ☐ Riffle/pool ☐ Step/pool ☐ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed

Max bankfull depth (ft): Riffle	Max bankfull depth (ft): Pool	Depth ratio (max/mean): Riffle	Depth ratio (max/mean): Pool	Pool to pool spacing: Ratio	Slope: Valley	Slope: Average bankfull
6.6		1.0				0.00016

Level III Stream Stability Indices

Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:

Flow regime:	P1, 2, 7, 9	Stream size and order:	S-8	Meander pattern(s):	M2	Depositional pattern(s):	NONE
Debris/channel blockage(s):	D1-3						
Degree of incision (Bank-Height Ratio):	3.0	Degree of incision stability rating:	Deeply Incised	Modified Pfankuch stability rating (numeric and adjective rating):	Good		
Width/depth ratio (W/d):	20.8	Reference W/d ratio (W/d_{ref}):	20.8	Width/depth ratio state $(W/d) / (W/d_{ref})$:	1.0	W/d ratio state stability rating:	Stable
Meander Width Ratio (MWR):	9.4	Reference MWR_{ref}:	9.4	Degree of confinement (MWR / MWR_{ref}):	1.0	MWR / MWR_{ref} stability rating:	Unconfined

Bank Erosion Summary	Length of reach studied (ft):	####	Annual streambank erosion rate: 2124 (tons/yr)	0.16 (tons/yr/ft)	Curve used: Fig 3-9	Remarks:	
Sediment Capacity (POWERSED)	☑ Sufficient capacity	☐ Insufficient capacity	☐ Excess capacity	Remarks:			
Entrainment/ Competence	Largest particle from bar sample (mm):	$\tau =$	$\tau^* =$	Existing $depth_{bkf}$:	Required $depth_{bkf}$:	Existing $slope_{bkf}$:	Required $slope_{bkf}$:
Successional Stage Shift	→ → → → →	Existing stream state (type):	C6c-	Potential stream state (type):	C6c-		
Lateral Stability	☐ Stable	☑ Mod. unstable	☐ Unstable	☐ Highly unstable	Remarks/causes:		
Vertical Stability (Aggradation)	☑ No deposition	☐ Mod. deposition	☐ Ex. deposition	☐ Aggradation	Remarks/causes:		
Vertical Stability (Degradation)	☐ Not incised	☑ Slightly incised	☐ Mod. incised	☐ Degradation	Remarks/causes:		
Channel Enlargement	☐ No increase	☑ Slight increase	☐ Mod. increase	☐ Extensive	Remarks/causes:		
Sediment Supply (Channel Source)	☐ Low	☑ Moderate	☐ High	☐ Very high	Remarks/causes:		

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Rush River**			Location: **Rush River - 1 - 0.08**	
Observers: **KP, AL**	Reference reach:	Disturbed (impacted reach): **X**	Date: **11/17/2010**	
Existing species composition:			Potential species composition:	

Riparian cover categories		Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**0%**	**0%**		
					100%
2. Understory	Shrub layer				
					100%
3. Ground level	Herbaceous				
					100%
	Leaf or needle litter				
	Bare ground				
			Column total = 100%		

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

Remarks:
Condition, vigor and/or usage of existing reach:
None

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Rush River**			Location: **Rush River - 1 - 0.08**					
Observers: **KP, AL**						Date: **11/17/2010**		
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P9**					

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order			
Stream:	**Rush River**		
Location:	**Rush River - 1 - 0.08**		
Observers:	**KP, AL**		
Date:	**11/17/2010**		
Stream Size Category and Order ☞			**S-5**
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).			

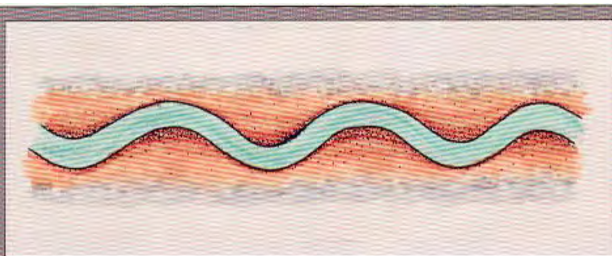
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Rush River**	Reach:	**Rush River - 1 - 0.08**
Observers:	**KP, AL**	Date:	**11/17/2010**

List ALL CATEGORIES that APPLY ☞	**M1**				

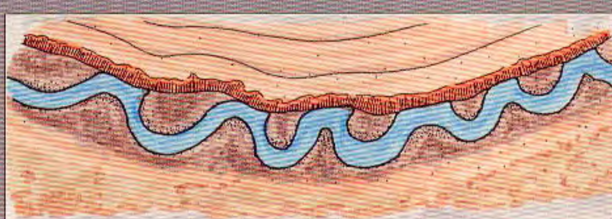
Various Meander Pattern variables modified from Galay et al. (1973)



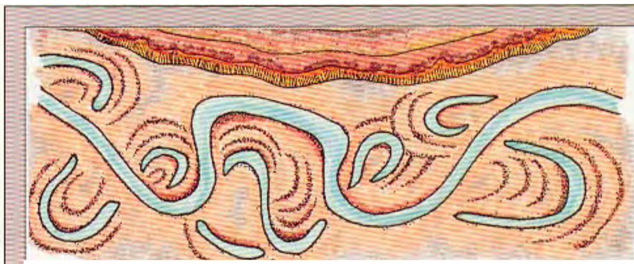
M1 REGULAR MEANDERS

M2 TORTUOUS MEANDERS

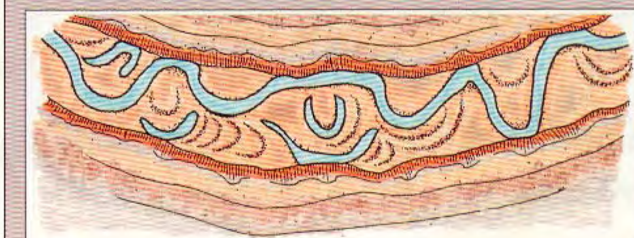
M3 IRREGULAR MEANDERS



M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS

M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

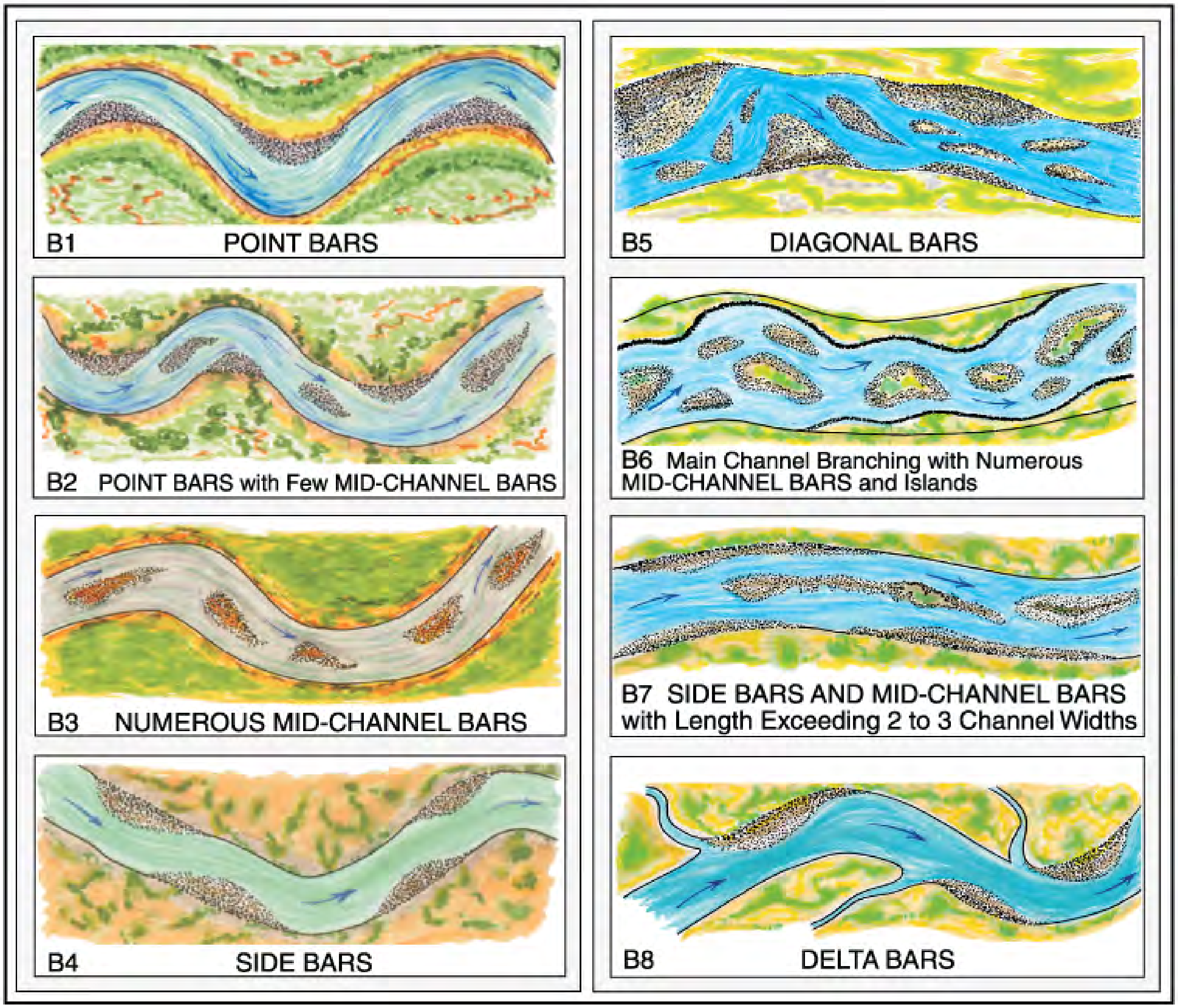
Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns

Stream:	**Rush River**	Reach:	**Rush River - 1 - 0.08**
Observers:	**KP, AL**	Date:	**11/17/2010**

List ALL CATEGORIES that APPLY ☞	**NONE**				

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



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Rush River**		Location: **Rush River - 1 - 0.08**	
Observers: **KP, AL**		Date: **11/17/2010**	
Description/extent		**Materials that 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.	☐

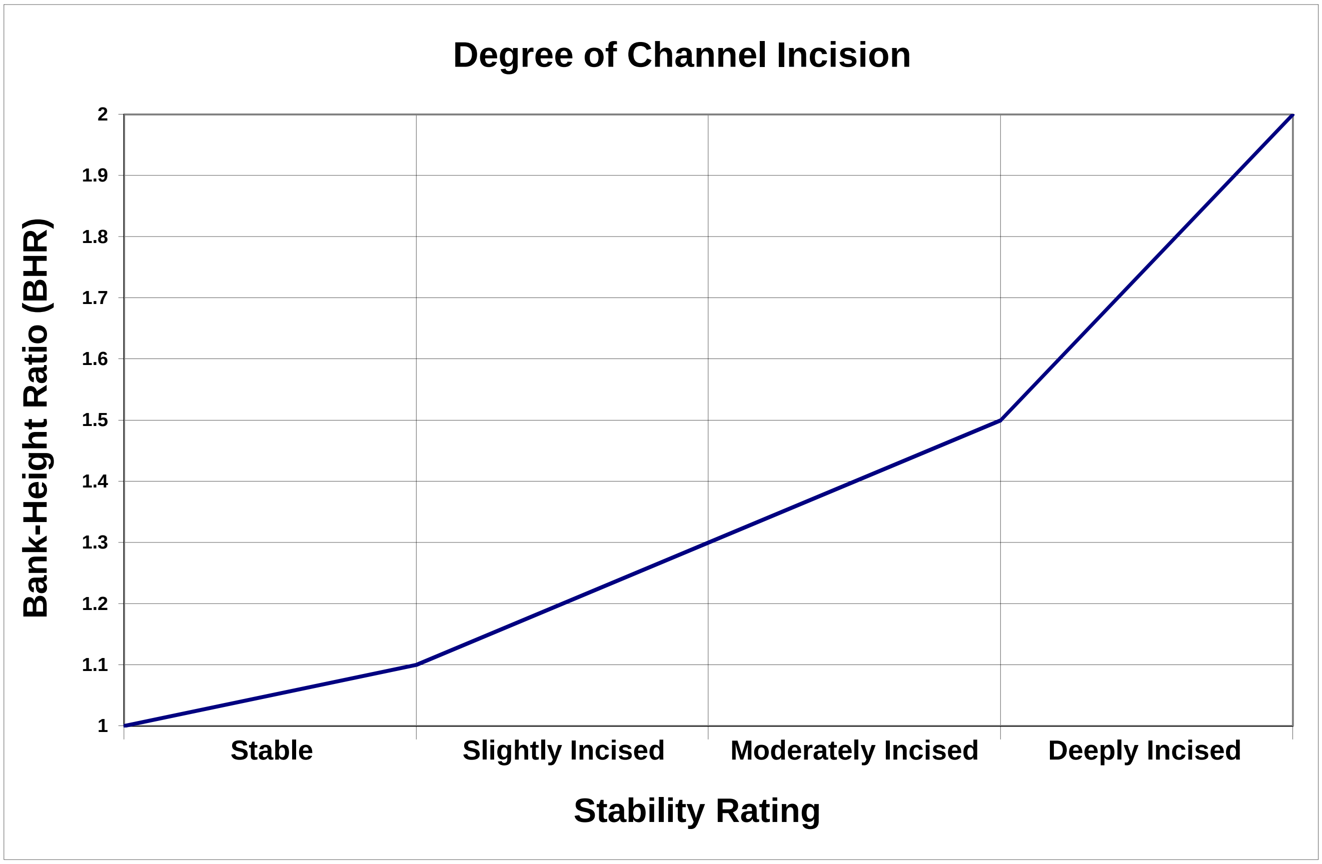
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision

Low Bank Height:	**15.1**
Max Bankfull Depth:	**5.18**

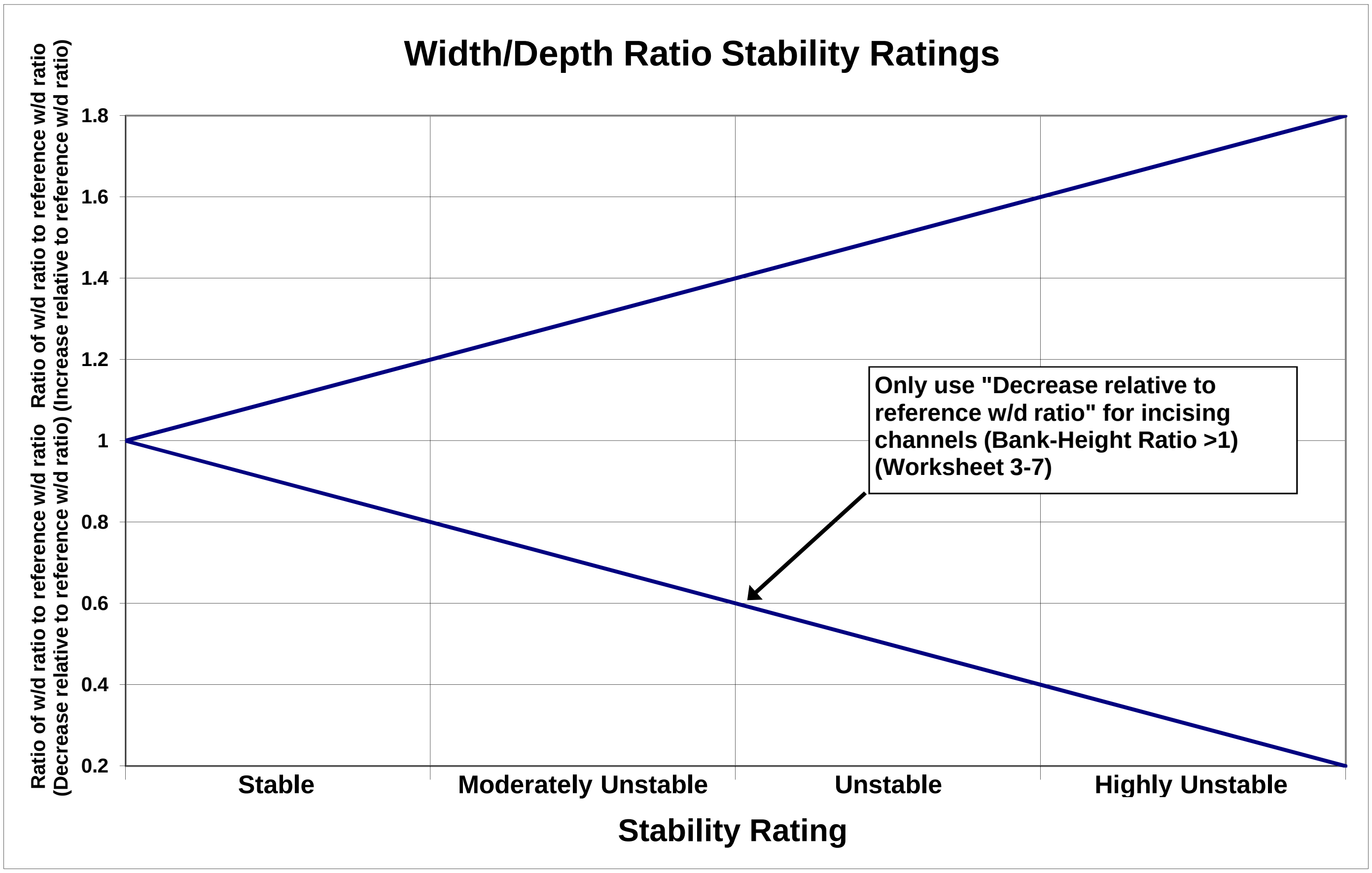
Bank-Height Ratio:	**2.9**

Degree of Channel Incision Stability Rating ☞ **Deeply Incised**



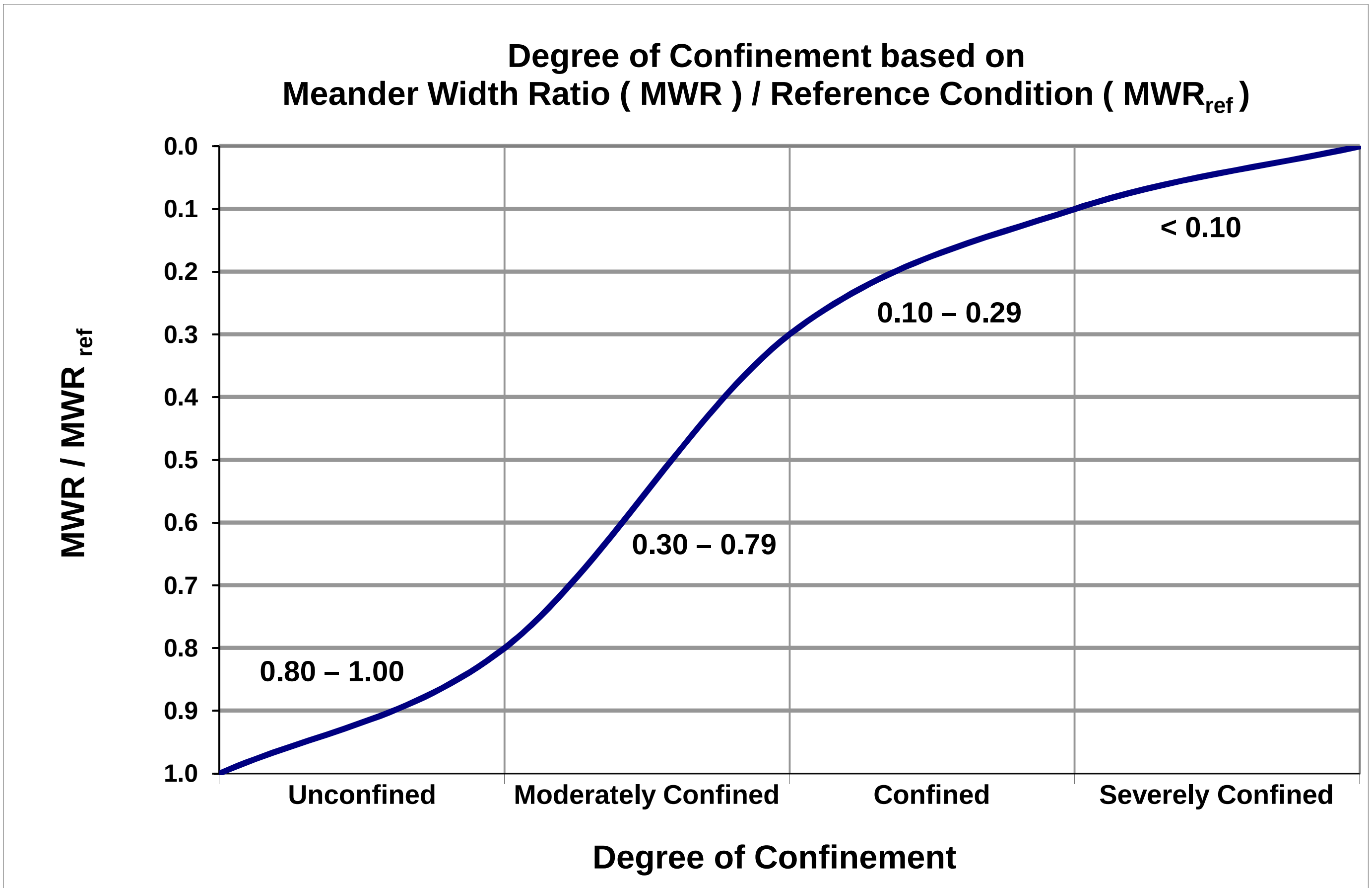
Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State			
Existing Width/Depth Ratio:	11.5	Ratio of existing W/d to reference W/d:	1.051
Reference Width/Depth Ratio:	11.0		
Width/Depth Ratio State Stability Rating ☞		Stable	



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	0.0	Ratio of MWR to MWR_{ref}:	1
Reference Meander Width Ratio (MWR_{ref}):	0.0		
Degree of Confinement Stability Rating ☞	Unconfined		



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Rush River **Location:** Rush River - 1 - 0.08 **Valley Type:** X **Observers:** KP, AL **Date:** 11/17/2010

Location	Key	Category	Excellent – Description	Excellent – Rating	Good – Description	Good – Rating	Fair – Description	Fair – Rating	Poor – Description	Poor – Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	**2**	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	**12**
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	**2**	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	**6**	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	**2**	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	**2**	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	**6**	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	**27**	Good total =	**12**	Fair total =	**0**	Poor total =	**16**

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	**55**
Existing stream type =	**E6**
*Potential stream type =	**E6**
Modified channel stability rating =	**Good**

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream: **Rush River**		Location: **Rush River - 1 - 0.08**	
Station:		Observers: **KP, AL**	
Date: **11/17/2010**	Stream Type: **E6**	Valley Type: **X**	

Study Bank Height / Bankfull Height (C) — **BEHI Score (Fig. 3-7)**

Study Bank Height (ft) =	15.6 (A)	Bankfull Height (ft) =	2.6 (B)	(A) / (B) =	6.0 (C)	10

Root Depth / Study Bank Height (E)

Root Depth (ft) =	1 (D)	Study Bank Height (ft) =	15.6 (A)	(D) / (A) =	0.1 (E)	8

Weighted Root Density (G)

Root Density as % =	25% (F)	(F) x (E) =	2% (G)	10

Bank Angle (H)

Bank Angle as *Degrees* =	11 (H)	2

Surface Protection (I)

Surface Protection as % =	20% (I)	7

Bank Material Adjustment:

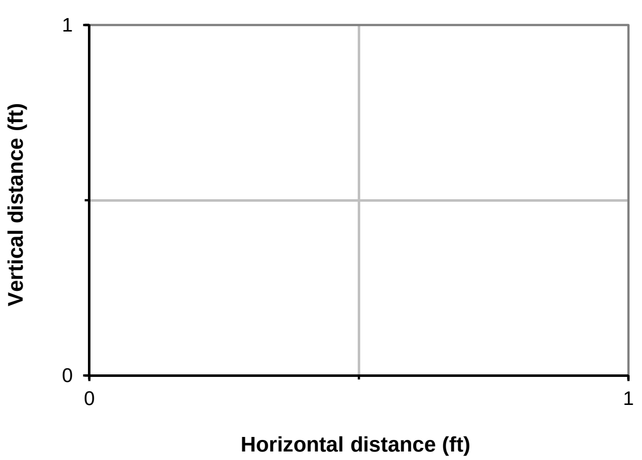
Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

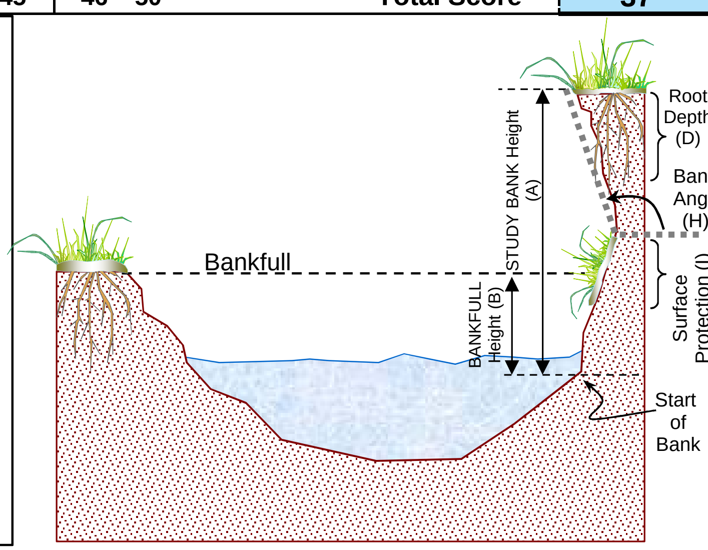
Bank Material Adjustment: 0

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**	**High**
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50	and **Total Score**	**37**

Bank Sketch





Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Rush River**	Location: **Rush River - 1 - 0.08**	
Station: **0**	Stream Type: **E6**	Valley Type: **X**
Observers: **KP, AL**		Date: **11/17/10**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})...	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S).......................................	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})..	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})...........................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient..	Level IV	Validation

Level I

(1)
- Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
- Extensive deposition (continuous, cross-channel).. ....NBS = Extreme
- Chute cutoffs, down-valley meander migration, converging flow..NBS = Extreme

Level II

	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)
(2)				

	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)
(3)				

	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)
(4)				

Dominant Near-Bank Stress
Very Low

Level III

	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)
(5)				

	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)
(6)								

Level IV

	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
(7)		**Very Low**

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating	**Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Rush River**			Location:	**Rush River - 1 - 0.08**		
Graph Used:	**Fig 3-9**	Total Bank Length (ft):	**4896.1**			Date:	**11/17/2010**
Observers:	**KP, AL**	Valley Type:	**X**			Stream Type:	**E6**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**4896.1**	**15.6**	**12603**	**0.12**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**12603**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**467**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**607**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.12**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Rush River**			Stream Type:	**E6**
Location:	**Rush River - 1 - 0.08**			Valley Type:	**X**
Observers:	**KP, AL**			Date:	**11/17/2010**

Enter Required Information for Existing Condition

	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	**#DIV/0!**

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	**d**	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	**S**	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Sediment Competence Using Dimensional Shear Stress

0	Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) $\quad d = \dfrac{\tau}{\gamma S}$ τ = predicted shear stress, γ = 62.4, S = existing slope
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) $\quad S = \dfrac{\tau}{\gamma d}$ τ = predicted shear stress, γ = 62.4, d = existing depth

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis

Observers: **KP, AL**

Stream: **Rush River** | Location: **Rush River - 1 - 0.08** | Date: **11/17/2010**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		0		0		0		0		0		0		0		0		0
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		100%

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	0
Materials less than:	mm

Be sure to add separate material weights to grand total

GRAND TOTAL: 0

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Rush River**	Stream Type: **E6**
Location: **Rush River - 1 - 0.08**	Valley Type: **X**
Observers: **KP, AL**	Date: **11/17/2010**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream: **Rush River**				Stream Type:	**E6**
Location: **Rush River - 1 - 0.08**				Valley Type:	**X**
Observers: **KP, AL**				Date:	**11/17/2010**
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 3-8)**	< 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	> 1.6 **(8)**	**2**
2 **Depositional pattern (Worksheet 3-5)**	B1, B2 **(1)**	B4, B8 **(2)**	B3 **(3)**	B5, B6, B7 **(4)**	**1**
3 **Meander pattern (Worksheet 3-4)**	M1, M3, M4 **(1)**		M2, M5, M6, M7, M8 **(3)**		**1**
4 **Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL **(2)**	M/L, M/M, M/H, L/Ex, H/L **(4)**	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL **(6)**	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex **(8)**	**4**
5 **Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.8 – 1.0 **(1)**	0.3 – 0.79 **(2)**	0.1 – 0.29 **(3)**	< 0.1 **(4)**	**1**
				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** ☐	

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Rush River**	Stream Type:	**E6**
Location:	**Rush River - 1 - 0.08**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**11/17/2010**

	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 3-14)**	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	**2**
		(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 sand	Reduction over 25% of annual sediment yield for bedload and/or suspended sand	**2**
		(2)	**(4)**	**(6)**	**(8)**	
3	**W/d ratio state (Worksheet 3-8)**	1.0 – 1.2	1.2 – 1.4	1.4 – 1.6	>1.6	**2**
		(2)	**(4)**	**(6)**	**(8)**	
4	**Stream succession states (Worksheet 3-16)**	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)	**2**
		(2)	**(4)**	**(6)**	**(8)**	
5	**Depositional patterns (Worksheet 3-5)**	B1	B2, B4	B3, B5	B6, B7, B8	**1**
		(1)	**(2)**	**(3)**	**(4)**	
6	**Debris / blockages (Worksheet 3-6)**	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** ☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream:	**Rush River**	Stream Type:	**E6**
Location:	**Rush River - 1 - 0.08**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**11/17/2010**

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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	**2**
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	**2**
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	**8**
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	**4**
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	**1**
				Total points	**17**

	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** ☐

Worksheet 3-20. Channel enlargement prediction summary.

Stream: **Rush River**				Stream Type: **E6**	
Location: **Rush River - 1 - 0.08**				Valley Type: **X**	
Observers: **KP, AL**				Date: **11/17/2010**	
Channel enlargement prediction criteria **(choose one stability category for each criterion 1–4)**	**Channel Enlargement Prediction Categories**				**Selected points (from each row)**
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) **(2)**	(C→High W/d C), (E→C) **(4)**	(G→F), (F→D) **(6)**	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) **(8)**	**2**
2 **Lateral stability (Worksheet 3-17)**	Stable **(2)**	Moderately unstable **(4)**	Unstable **(6)**	Highly unstable **(8)**	**2**
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition **(2)**	Moderate deposition **(4)**	Excess deposition **(6)**	Aggradation **(8)**	**2**
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised **(2)**	Slightly incised **(4)**	Moderately incised **(6)**	Degradation **(8)**	**4**
				Total points	**10**
	Category point range				
Channel enlargement prediction (use total points and check stability rating)	**No increase** **8 – 10** ☑	**Slight increase** **11 – 16** ☐	**Moderate increase** **17 – 24** ☐	**Extensive** **> 24** ☐	

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream: **Rush River**		Stream Type:	**E6**
Location: **Rush River - 1 - 0.08**		Valley Type:	**X**
Observers: **KP, AL**		Date:	**11/17/2010**

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	**Stability Rating**	**Points**	**Selected Points**
1 **Lateral stability (Worksheet 3-17)**	**Stable**	**1**	**1**
	Mod. unstable	**2**	
	Unstable	**3**	
	Highly unstable	**4**	
2 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	**No deposition**	**1**	**1**
	Mod. deposition	**2**	
	Excess deposition	**3**	
	Aggradation	**4**	
3 **Vertical stability channel incision/ degradation (Worksheet 3-19)**	**Not incised**	**1**	**2**
	Slightly incised	**2**	
	Mod. Incised	**3**	
	Degradation	**4**	
4 **Channel enlargement prediction (Worksheet 3-20)**	**No increase**	**1**	**1**
	Slight increase	**2**	
	Mod. increase	**3**	
	Extensive	**4**	
5 **Pfankuch channel stability (Worksheet 3-10)**	**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** ☐

Worksheet 3-22. Summary of stability condition categories.

Stream: **Rush River**		Location: **Rush River - 1 - 0.08**	
Observers: **KP, AL**	Date: **11/17/2010**	Stream Type: **E6**	Valley Type: **X**

Channel Dimension	Mean bankfull depth (ft): 3.25	Mean bankfull width (ft): 37.4	Cross-section area (ft^2): 111.1	Width of flood-prone area (ft): 91.66667	Entrenchment ratio: 2.5
Channel Pattern	Mean: Range: MWR: 0.0	Lm/W_{bkf}: 0.0	Rc/W_{bkf}: 0.0		Sinuosity: 0

River Profile and Bed Features

Check: ☐ Riffle/pool ☐ Step/pool ☑ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed

Max bankfull depth (ft): Riffle	Pool	Depth ratio (max/mean): Riffle	Pool	Pool to pool spacing: Ratio	Slope: Valley	Average bankfull
5.2		1.6				0.00043

Level III Stream Stability Indices

Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:

Flow regime: P1, 2, 9	Stream size and order: S-5	Meander pattern(s): M1	Depositional pattern(s): NONE	Debris/channel blockage(s): D1
Degree of incision (Bank-Height Ratio): 2.9	Degree of incision stability rating: **Deeply Incised**	Modified Pfankuch stability rating (numeric and adjective rating): Good		
Width/depth ratio (W/d): 11.5	Reference W/d ratio (W/d_{ref}): 11.0	Width/depth ratio state (W/d) / (W/d_{ref}): 1.1	W/d ratio state stability rating: Stable	
Meander Width Ratio (MWR): 0.0	Reference MWR_{ref}: 0.0	Degree of confinement (MWR / MWR_{ref}): 1.0	MWR / MWR_{ref} stability rating: Unconfined	

Bank Erosion Summary	Length of reach studied (ft): 4896	Annual streambank erosion rate: 607 (tons/yr) 0.12 (tons/yr/ft)	Curve used: Fig 3-9	Remarks:
Sediment Capacity (POWERSED)	☑ Sufficient capacity ☐ Insufficient capacity ☐ Excess capacity			Remarks:
Entrainment/ Competence	Largest particle from bar sample (mm):	$\tau =$	$\tau^* =$	Existing $depth_{bkf}$: Required $depth_{bkf}$: Existing $slope_{bkf}$: Required $slope_{bkf}$:
Successional Stage Shift	→ → → → →	Existing stream state (type): E6	Potential stream state (type): E6	
Lateral Stability	☑ Stable ☐ Mod. unstable ☐ Unstable ☐ Highly unstable		Remarks/causes: None	
Vertical Stability (Aggradation)	☑ No deposition ☐ Mod. deposition ☐ Ex. deposition ☐ Aggradation		Remarks/causes: None	
Vertical Stability (Degradation)	☐ Not incised ☑ Slightly incised ☐ Mod. incised ☐ Degradation		Remarks/causes: None	
Channel Enlargement	☑ No increase ☐ Slight increase ☐ Mod. increase ☐ Extensive		Remarks/causes: None	
Sediment Supply (Channel Source)	☐ Low ☑ Moderate ☐ High ☐ Very high		Remarks/causes: None	

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Rush River**		Location: **Rush River-2-6.15**		
Observers: **KP, AL**	Reference reach [ ]	Disturbed (impacted reach) **X**	Date: **9/27/2011**	
Existing species composition:		Potential species composition:		

Riparian cover categories		Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**0%**	**0%**		
					100%
2. Understory	Shrub layer		**0%**		
					100%
3. Ground level	Herbaceous		**94%**		
					100%
	Leaf or needle litter		**1%**		
	Bare ground		**5%**		
			Column total = 100%		

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

Remarks:
Condition, vigor and/or usage of existing reach:

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Rush River**			Location: **Rush River-2-6.15**					
Observers: **KP, AL**						Date: **9/27/2011**		
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P9**					

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order			
Stream:	**Rush River**		
Location:	**Rush River-2-6.15**		
Observers:	**KP, AL**		
Date:	**9/27/2011**		
Stream Size Category and Order ☞			**S-4**
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).			

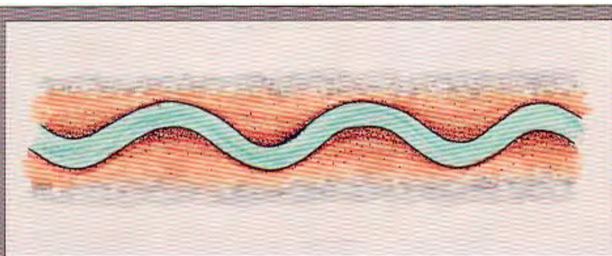
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream: **Rush River**	Reach: **Rush River-2-6.15**
Observers: **KP, AL**	Date: **9/27/2011**

List ALL CATEGORIES that APPLY ☞	M1				

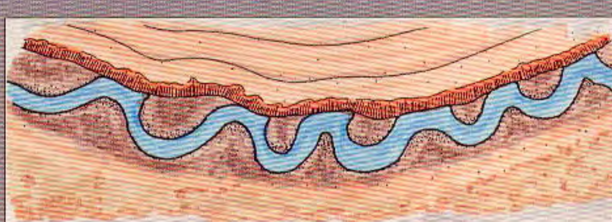
Various Meander Pattern variables modified from Galay et al. (1973)



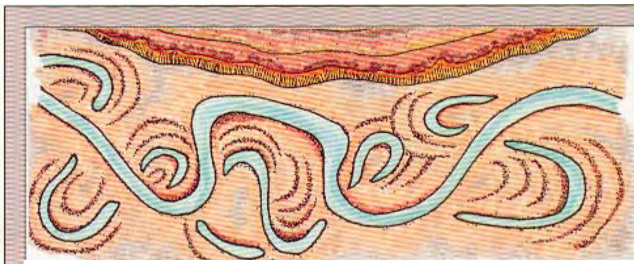
M1 REGULAR MEANDERS

M2 TORTUOUS MEANDERS

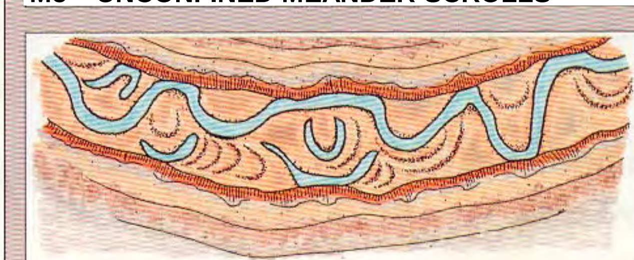
M3 IRREGULAR MEANDERS



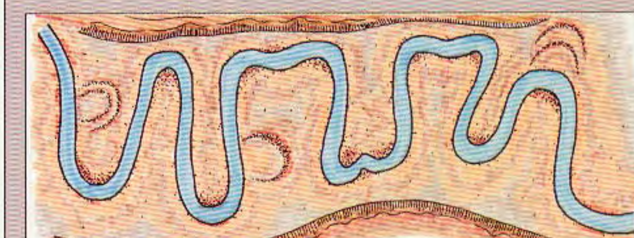
M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS



M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

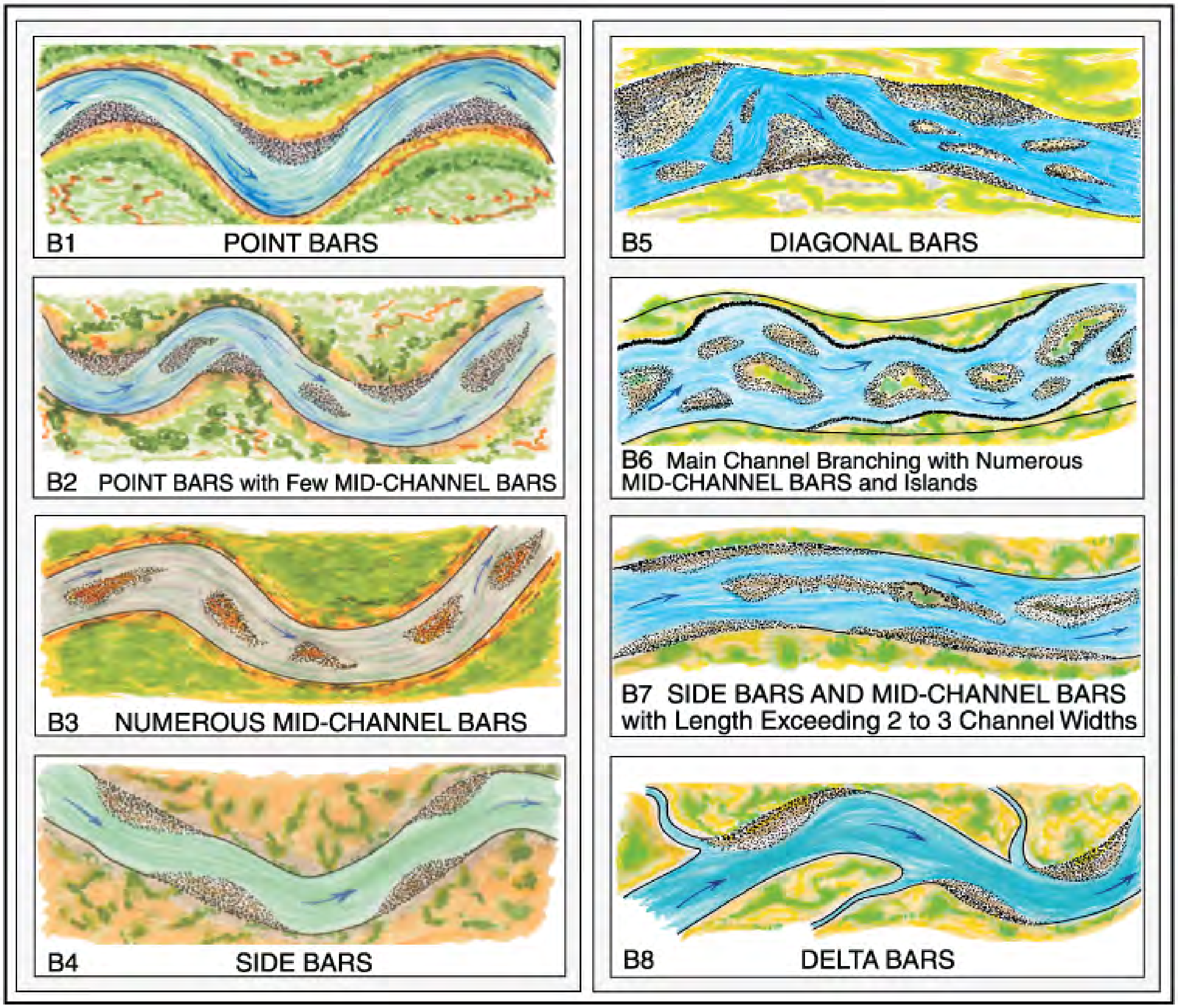
Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns

Stream:	**Rush River**	Reach:	**Rush River-2-6.15**
Observers:	**KP, AL**	Date:	**9/27/2011**

List ALL CATEGORIES that APPLY ☞	**N/A**				

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



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Rush River**		Location: **Rush River-2-6.15**	
Observers: **KP, AL**		Date: **9/27/2011**	
Description/extent		**Materials that 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.	☐

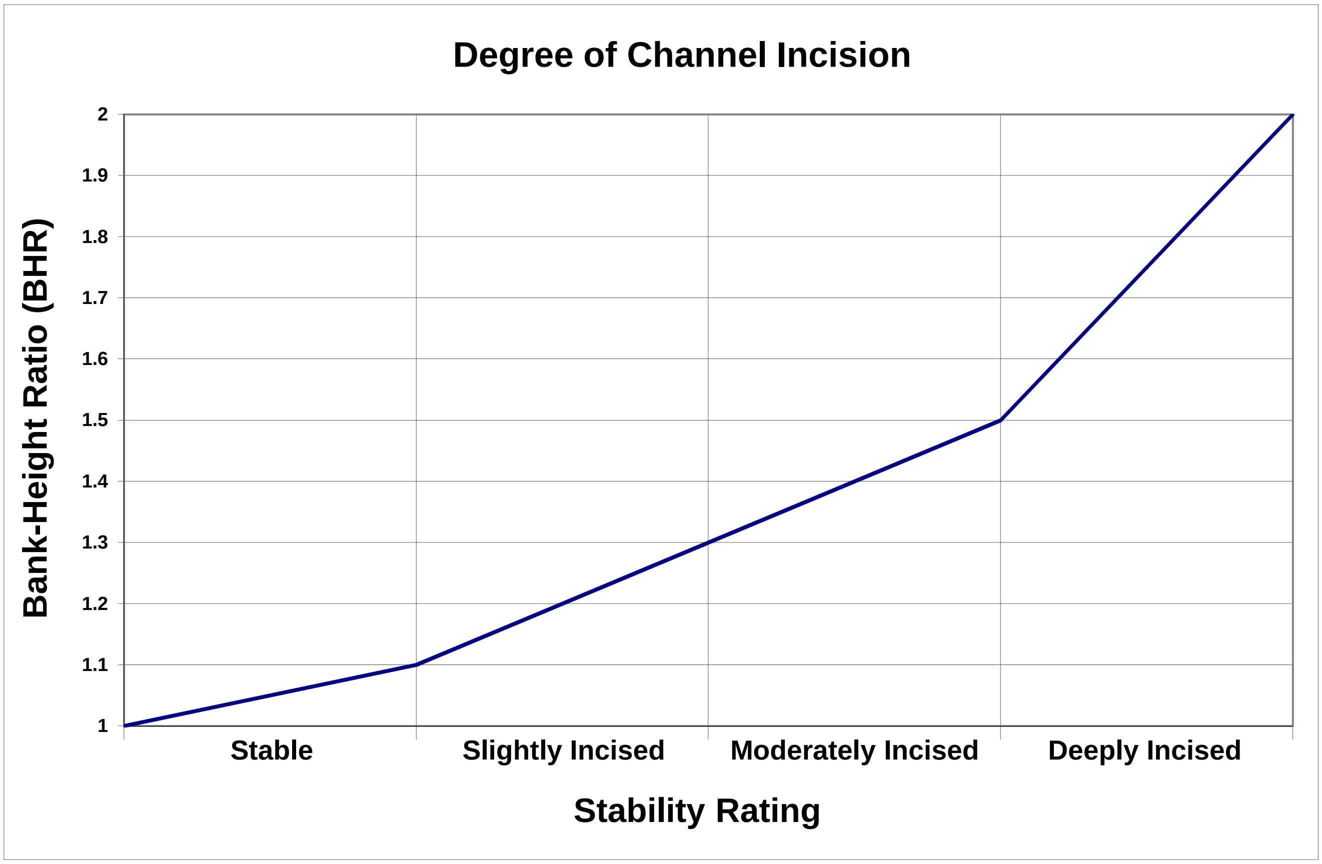
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision

Low Bank Height:	**5.1**
Max Bankfull Depth:	**5.015**

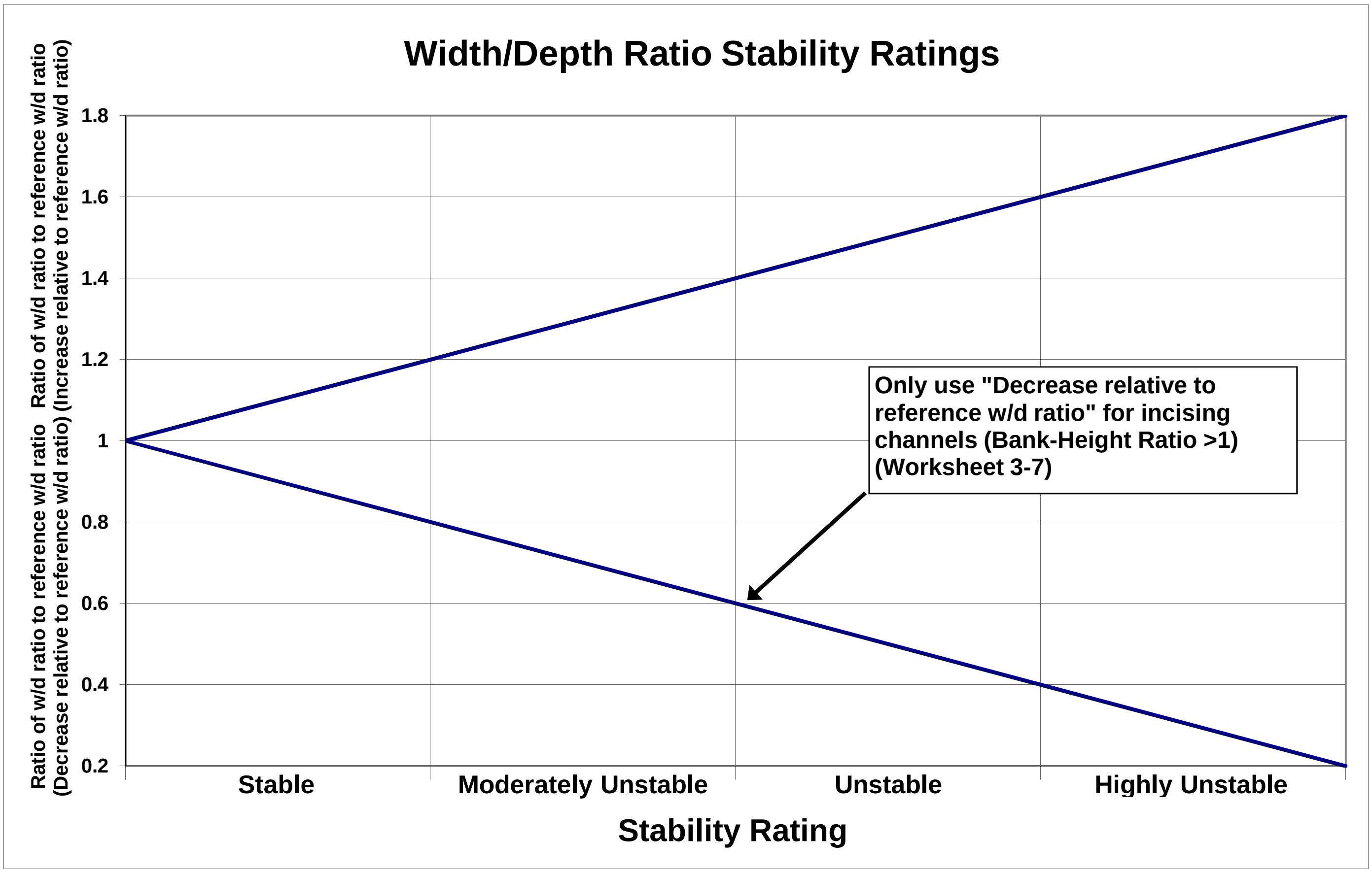
Bank-Height Ratio:	**1.0**

Degree of Channel Incision Stability Rating ☞	**Stable**



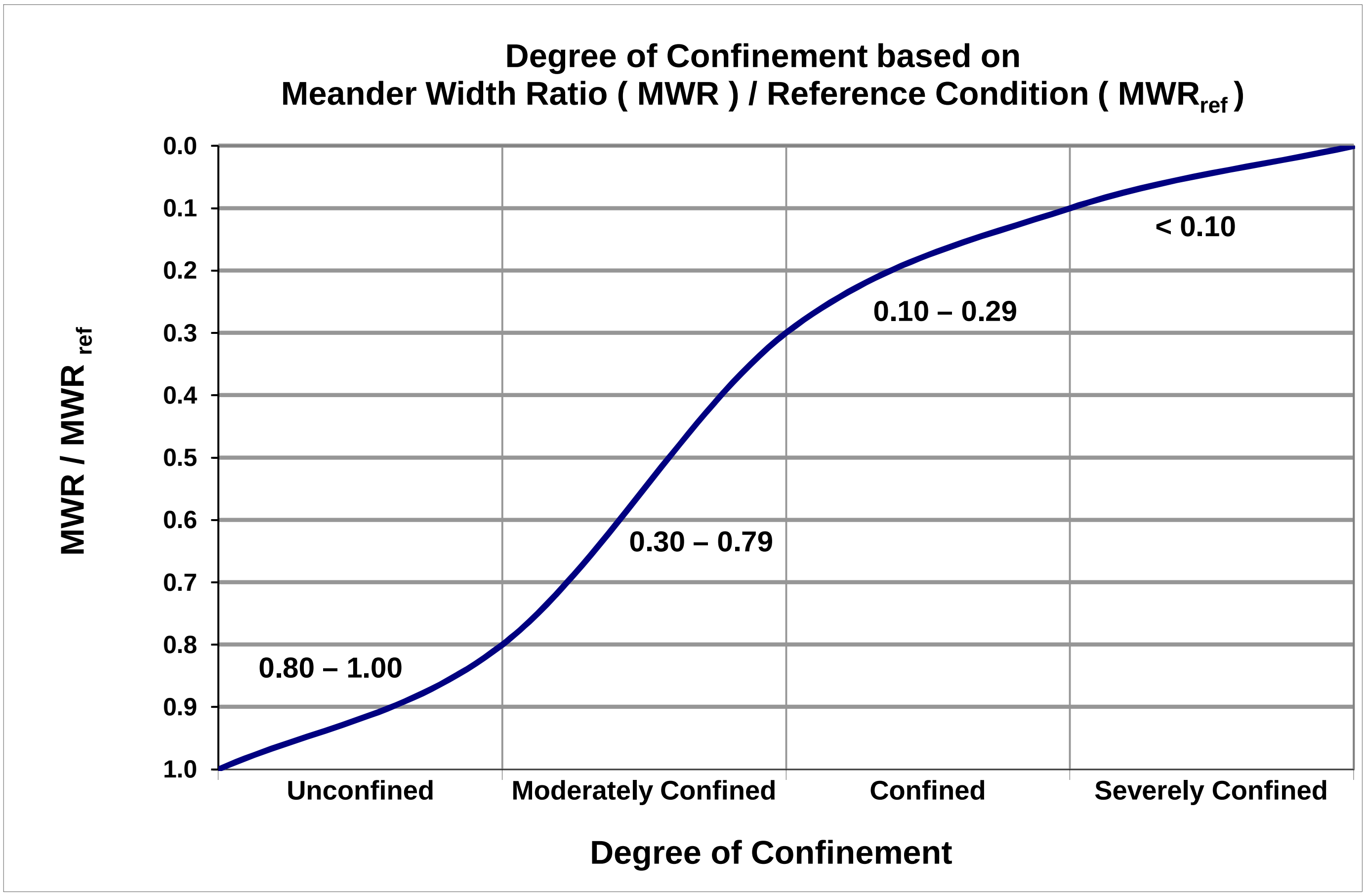
Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State			
Existing Width/Depth Ratio:	8.7	Ratio of existing W/d to reference W/d:	1
Reference Width/Depth Ratio:	8.7		
Width/Depth Ratio State Stability Rating ☞		Stable	



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	**86.9**	Ratio of MWR to MWR_{ref}:	**1**
Reference Meander Width Ratio (MWR_{ref}):	**86.9**		
Degree of Confinement Stability Rating ☞		**Unconfined**	



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Rush River | **Location:** Rush River-2-6.15 | **Valley Type:** X | **Observers:** KP, AL | **Date:** 9/27/2011

Location	Key	Category	Excellent Description	Excellent Rating	Good Description	Good Rating	Fair Description	Fair Rating	Poor Description	Poor Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	**6**	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	**9**	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	**2**	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	**12**
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	1	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	**2**	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	**2**	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	**2**	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	**16**
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	24	Good total =	2	Fair total =	15	Poor total =	32

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	73
Existing stream type =	E6
*Potential stream type =	E6
Modified channel stability rating =	Fair

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream:	**Rush River**	Location:	**Rush River-2-6.15**
Station:		Observers:	**KP, AL**
Date:	**9/27/2011**	Stream Type: **E6**	Valley Type: **X**

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	5.2 (A)	**Bankfull Height** (ft) =	5 (B)	(A) / (B) =	1.0 (C)	1

Root Depth / Study Bank Height (E)

Root Depth (ft) =	0.5 (D)	**Study Bank Height** (ft) =	5.2 (A)	(D) / (A) =	0.1 (E)	8

Weighted Root Density (G)

Root Density as **%** =	50% (F)	(F) x (E) =	5% (G)	9

Bank Angle (H)

Bank Angle as *Degrees* =	21 (H)	2

Surface Protection (I)

Surface Protection as **%** =	10% (I)	9

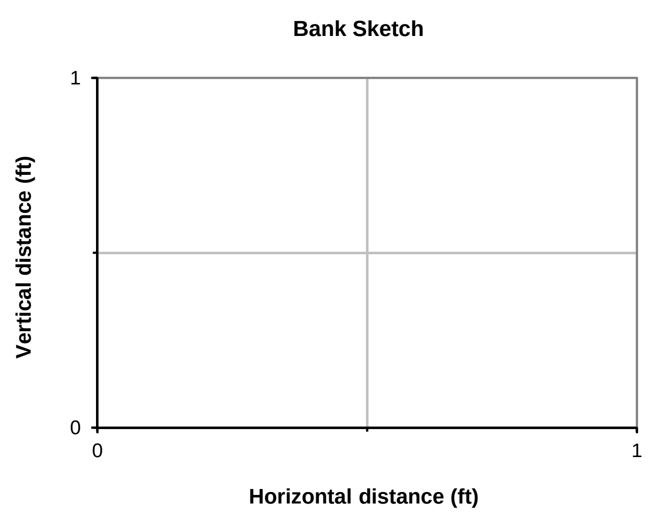
Bank Material Adjustment:

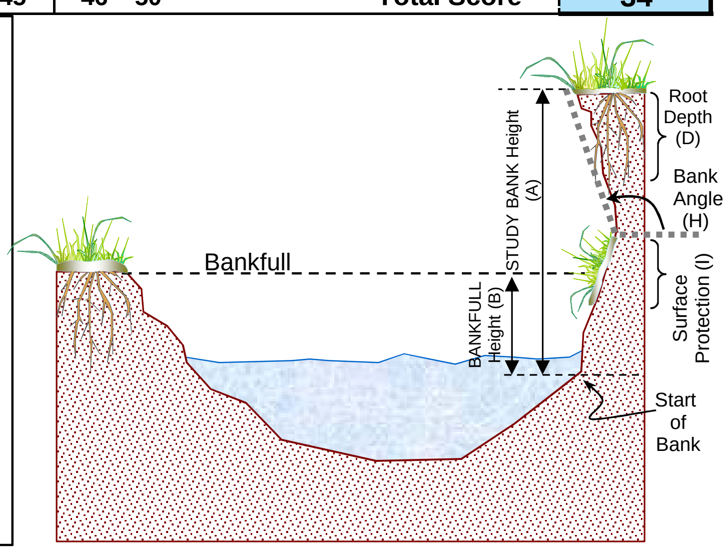
Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

Bank Material Adjustment: 5

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**	**High**
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50	and **Total Score**	**34**





Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Rush River**	Location: **Rush River-2-6.15**	
Station: **0**	Stream Type: **E6**	Valley Type: **X**
Observers: **KP, AL**		Date: **9/27/11**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})...	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S)......................................	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})..	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})............................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient...	Level IV	Validation

Level I

(1)
- Transverse and/or central bars-short and/or discontinuous.......................................NBS = High / Very High
- Extensive deposition (continuous, cross-channel).......................................NBS = Extreme
- Chute cutoffs, down-valley meander migration, converging flow.......................................NBS = Extreme

Level II

	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)
(2)				

	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)
(3)				

	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)
(4)				

Dominant Near-Bank Stress
Very Low

Level III

	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)
(5)				

	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)
(6)								

Level IV

	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
(7)		**Very Low**

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating — **Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Rush River**			Location:	**Rush River-2-6.15**		
Graph Used:	**Fig 3-9**	Total Bank Length (ft):	**3519.8**			Date:	**9/27/2011**
Observers:	**KP, AL**	Valley Type:	**X**			Stream Type:	**E6**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**3519.8**	**5.2**	**3020**	**0.04**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**3020**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**112**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**145**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.04**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Rush River**			Stream Type:	**E6**
Location:	**Rush River-2-6.15**			Valley Type:	**X**
Observers:	**KP, AL**			Date:	**9/27/2011**
Enter Required Information for Existing Condition					
	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
0	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			
Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress					
#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$	
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$	
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress		EQUATION USED:	**#DIV/0!**
Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample					
#DIV/0!	**d**	Required bankfull mean depth (ft)	$d = \frac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)	
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample					
#DIV/0!	**S**	Required bankfull water surface slope (ft/ft)	$S = \frac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)	
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Sediment Competence Using Dimensional Shear Stress					
0	Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope				
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**				
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**				
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope			$d = \frac{\tau}{\gamma S}$	
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth			$S = \frac{\tau}{\gamma d}$	

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis | Observers: **KP, AL**

Stream: **Rush River** | Location: **Rush River-2-6.15** | Date: **9/27/2011**

Sub-samples	Catch Pan or BUCKET / Tare weight / Sample weights Total	Net	Sieve SIZE mm / Tare weight / Sample weights Total	Net	Sieve SIZE mm / Tare weight / Sample weights Total	Net	Sieve SIZE mm / Tare weight / Sample weights Total	Net	Sieve SIZE mm / Tare weight / Sample weights Total	Net	Sieve SIZE mm / Tare weight / Sample weights Total	Net	Sieve SIZE mm / Tare weight / Sample weights Total	Net	Sieve SIZE mm / Tare weight / Sample weights Total	Net	Sieve SIZE mm / Tare weight / Sample weights Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		**100%**

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	**0**
Materials less than:	mm

Be sure to add separate material weights to grand total

0

GRAND TOTAL

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Rush River**	Stream Type: **E6**
Location: **Rush River-2-6.15**	Valley Type: **X**
Observers: **KP, AL**	Date: **9/27/2011**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream: **Rush River**			Stream Type: **E6**		
Location: **Rush River-2-6.15**			Valley Type: **X**		
Observers: **KP, AL**			Date: **9/27/2011**		
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 3-8)**	< 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	> 1.6 **(8)**	**2**
2 **Depositional pattern (Worksheet 3-5)**	B1, B2 **(1)**	B4, B8 **(2)**	B3 **(3)**	B5, B6, B7 **(4)**	**1**
3 **Meander pattern (Worksheet 3-4)**	M1, M3, M4 **(1)**		M2, M5, M6, M7, M8 **(3)**		**1**
4 **Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL **(2)**	M/L, M/M, M/H, L/Ex, H/L **(4)**	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL **(6)**	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex **(8)**	**4**
5 **Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.8 – 1.0 **(1)**	0.3 – 0.79 **(2)**	0.1 – 0.29 **(3)**	< 0.1 **(4)**	**1**
				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** ☐	

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Rush River**	Stream Type:	**E6**
Location:	**Rush River-2-6.15**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**9/27/2011**

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 3-14)**	Sufficient depth and/or slope to transport largest size available **(2)**	Trend toward insufficient depth and/or slope-slightly incompetent **(4)**	Cannot move D_{35} of bed material and/or D_{100} of bar material **(6)**	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size **(8)**	**2**
2	**Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load **(2)**	Trend toward insufficient sediment capacity **(4)**	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand **(6)**	Reduction over 25% of annual sediment yield for bedload and/or suspended sand **(8)**	**2**
3	**W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	>1.6 **(8)**	**2**
4	**Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation **(2)**	(E→C) **(4)**	(C→High W/d C), (B→High W/d B), (C→F) **(6)**	(C→D), (F→D) **(8)**	**2**
5	**Depositional patterns (Worksheet 3-5)**	B1 **(1)**	B2, B4 **(2)**	B3, B5 **(3)**	B6, B7, B8 **(4)**	**1**
6	**Debris / blockages (Worksheet 3-6)**	D1, D2, D3 **(1)**	D4, D7 **(2)**	D5, D8 **(3)**	D6, D9, D10 **(4)**	**1**
					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** ☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream:	**Rush River**	Stream Type:	**E6**
Location:	**Rush River-2-6.15**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**9/27/2011**

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 3-14)**	Does not indicate excess competence **(2)**	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed **(4)**	D_{100} of bed moved **(6)**	Particles much larger than D_{100} of bed moved **(8)**	**2**
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity **(2)**	Slight excess energy: up to 10% increase above reference **(4)**	Excess energy sufficient to increase load up to 50% of annual load **(6)**	Excess energy transporting more than 50% of annual load **(8)**	**2**
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 **(2)**	1.11 – 1.30 **(4)**	1.31 – 1.50 **(6)**	> 1.50 **(8)**	**2**
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation **(2)**	If BHR > 1.1 and stream type has w/d between 5–10 **(4)**	If BHR > 1.1 and stream type has w/d less than 5 **(6)**	(B→G), (C→G), (E→G), (D→G) **(8)**	**2**
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 **(1)**	0.30 – 0.79 **(2)**	0.10 – 0.29 **(3)**	< 0.10 **(4)**	**1**
				Total points	**9**

	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** ☐

Worksheet 3-20. Channel enlargement prediction summary.

Stream:	**Rush River**			Stream Type:	**E6**
Location:	**Rush River-2-6.15**			Valley Type:	**X**
Observers:	**KP, AL**			Date:	**9/27/2011**

Channel enlargement prediction criteria (choose one stability category for each criterion 1–4)	**Channel Enlargement Prediction Categories**				**Selected points** (from each row)
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) (2)	(C→High W/d C), (E→C) (4)	(G→F), (F→D) (6)	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) (8)	2
2 **Lateral stability (Worksheet 3-17)**	Stable (2)	Moderately unstable (4)	Unstable (6)	Highly unstable (8)	2
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition (2)	Moderate deposition (4)	Excess deposition (6)	Aggradation (8)	2
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised (2)	Slightly incised (4)	Moderately incised (6)	Degradation (8)	2
				Total points	8

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

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream: **Rush River**		Stream Type:	**E6**
Location: **Rush River-2-6.15**		Valley Type:	**X**
Observers: **KP, AL**		Date:	**9/27/2011**

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	Stability Rating	Points	Selected Points
1 Lateral stability (Worksheet 3-17)	Stable	1	1
	Mod. unstable	2	
	Unstable	3	
	Highly unstable	4	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition	1	1
	Mod. deposition	2	
	Excess deposition	3	
	Aggradation	4	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	1
	Slightly incised	2	
	Mod. Incised	3	
	Degradation	4	
4 Channel enlargement prediction (Worksheet 3-20)	No increase	1	1
	Slight increase	2	
	Mod. increase	3	
	Extensive	4	
5 Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	2
	Fair: mod unstable	2	
	Poor: unstable	4	
		Total Points	6

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

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Rush River**	Location:	**Rush River-2-6.15**
Observers:	**KP, AL**	Date: **9/27/2011**	Stream Type: **E6** Valley Type: **X**

Channel Dimension	Mean bankfull depth (ft):	**3.1**	Mean bankfull width (ft):	**26.98**	Cross-section area (ft^2):	**84.43**	Width of flood-prone area (ft):	**79.25**	Entrenchment ratio: **2.9**
Channel Pattern	Mean: / Range: MWR:	**86.9**	Lm/W_{bkf}:	**86.9**	Rc/W_{bkf}:	**8.7**	Sinuosity:	**1.43**	

River Profile and Bed Features

Check: ☐ Riffle/pool ☐ Step/pool ☐ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed

Max bankfull depth (ft): Riffle	Pool	Depth ratio (max/mean): Riffle	Pool	Pool to pool spacing: Ratio	Slope: Valley	Average bankfull
5.0		**1.6**				**0.00067**

Level III Stream Stability Indices

Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:

Flow regime:	**P1, 2, 9**	Stream size and order:	**S-4**	Meander pattern(s):	**M1**	Depositional pattern(s):	**NONE**	Debris/channel blockage(s):	**D2**

Degree of incision (Bank-Height Ratio):	**1.0**	Degree of incision stability rating:	**Stable**	Modified Pfankuch stability rating (numeric and adjective rating):	**Fair**

Width/depth ratio (W/d):	**8.7**	Reference W/d ratio (W/d_{ref}):	**8.7**	Width/depth ratio state $(W/d) / (W/d_{ref})$:	**1.0**	W/d ratio state stability rating:	**Stable**
Meander Width Ratio (MWR):	**86.9**	Reference MWR_{ref}:	**86.9**	Degree of confinement (MWR / MWR_{ref}):	**1.0**	MWR / MWR_{ref} stability rating:	**Unconfined**

Bank Erosion Summary	Length of reach studied (ft): **3520**	Annual streambank erosion rate: **145** (tons/yr) **0.04** (tons/yr/ft)	Curve used: **Fig 3-9**	Remarks:
Sediment Capacity (POWERSED)	☑ Sufficient capacity ☐ Insufficient capacity ☐ Excess capacity			Remarks:

Entrainment/ Competence	Largest particle from bar sample (mm):	$\tau =$	$\tau^* =$	Existing $depth_{bkf}$:	Required $depth_{bkf}$:	Existing $slope_{bkf}$:	Required $slope_{bkf}$:

Successional Stage Shift	→ → → → →	Existing stream state (type): **E6**	Potential stream state (type): **E6**
Lateral Stability	☑ Stable ☐ Mod. unstable ☐ Unstable ☐ Highly unstable	Remarks/causes:	
Vertical Stability (Aggradation)	☑ No deposition ☐ Mod. deposition ☐ Ex. deposition ☐ Aggradation	Remarks/causes:	
Vertical Stability (Degradation)	☑ Not incised ☐ Slightly incised ☐ Mod. incised ☐ Degradation	Remarks/causes:	
Channel Enlargement	☑ No increase ☐ Slight increase ☐ Mod. increase ☐ Extensive	Remarks/causes:	
Sediment Supply (Channel Source)	☐ Low ☑ Moderate ☐ High ☐ Very high	Remarks/causes:	

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Sheyenne River**			Location: **Sheyenne River-1-4.20**	
Observers: **KP, AL**	Reference reach:	Disturbed (impacted reach): **X**	Date: **10/6/2011**	
Existing species composition:			Potential species composition:	

	Riparian cover categories	Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**20%**	**2%**		
					100%
2. Understory	Shrub layer		**10%**		
					100%
3. Ground level	Herbaceous		**22%**		
					100%
	Leaf or needle litter		**6%**	**Remarks:** Condition, vigor and/or usage of existing reach:	
	Bare ground		**60%**		
			Column total = 100%		

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

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Sheyenne River**			Location: **Sheyenne River-1-4.20**					
Observers: **KP, AL**						Date: **10/6/2011**		
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P7**	**P9**				

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order

Stream:	**Sheyenne River**
Location:	**Sheyenne River-1-4.20**
Observers:	**KP, AL**
Date:	**10/6/2011**
Stream Size Category and Order ☞	**S-7**

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).

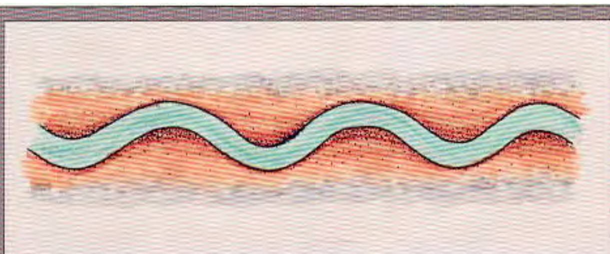
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Sheyenne River**	Reach:	**Sheyenne River-1-4.20**
Observers:	**KP, AL**	Date:	**10/6/2011**

List ALL CATEGORIES that APPLY ☞	**M2**				

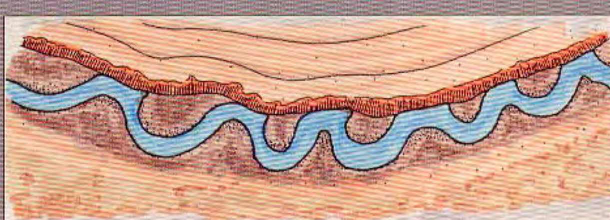
Various Meander Pattern variables modified from Galay et al. (1973)



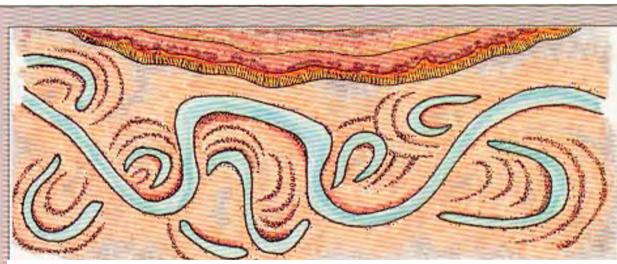
M1 REGULAR MEANDERS

M2 TORTUOUS MEANDERS

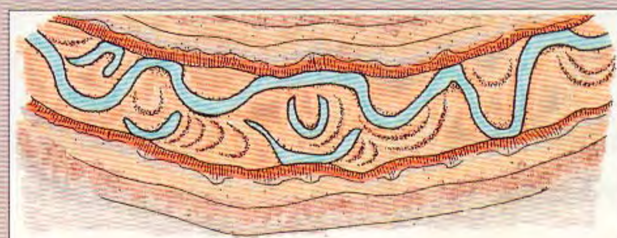
M3 IRREGULAR MEANDERS



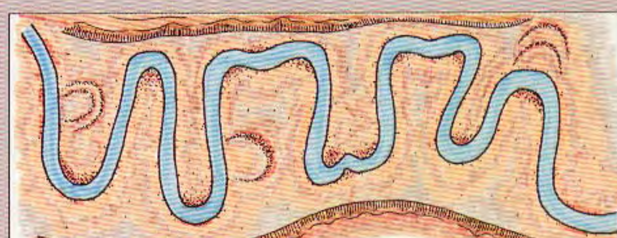
M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS



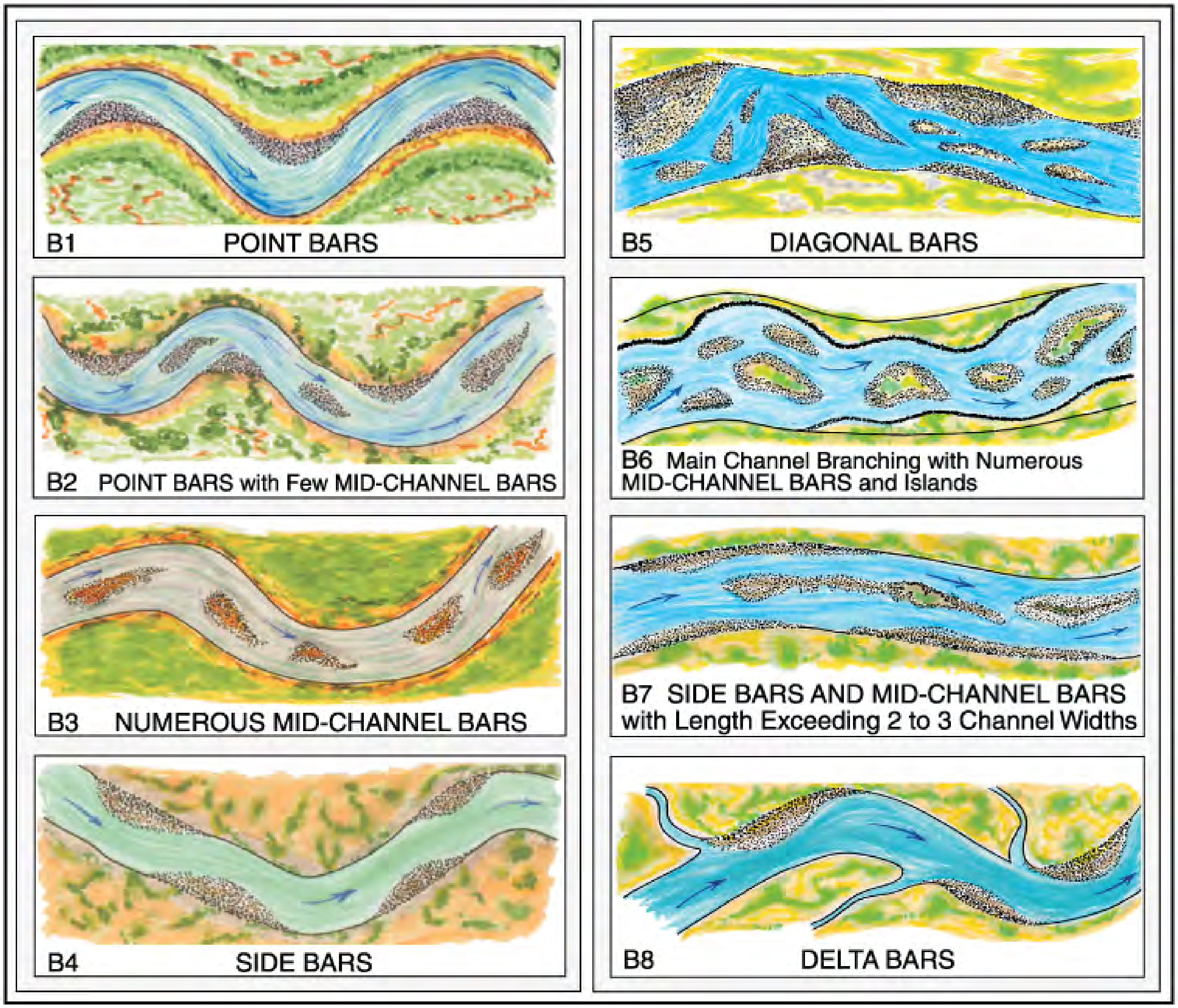
M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns						
Stream: **Sheyenne River**			Reach: **Sheyenne River-1-4.20**			
Observers: **KP, AL**			Date: **10/6/2011**			
List ALL CATEGORIES that APPLY ☞	**N/A**					

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



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages				
Stream:	**Sheyenne River**	Location: **Sheyenne River-1-4.20**		
Observers:	**KP, AL**	Date: **10/6/2011**		
Description/extent		**Materials that 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.	☐	

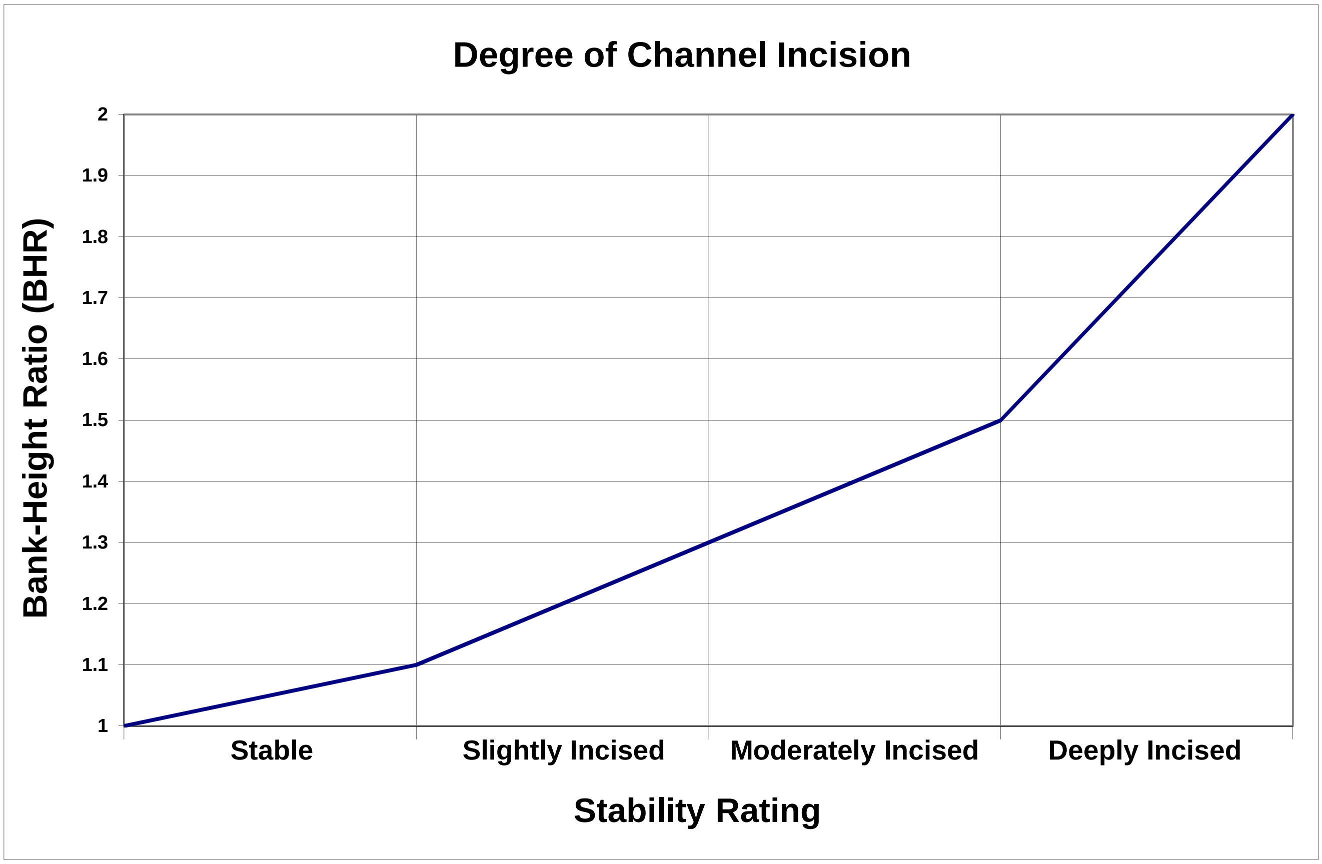
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision

Low Bank Height:	**19**
Max Bankfull Depth:	**14.65**

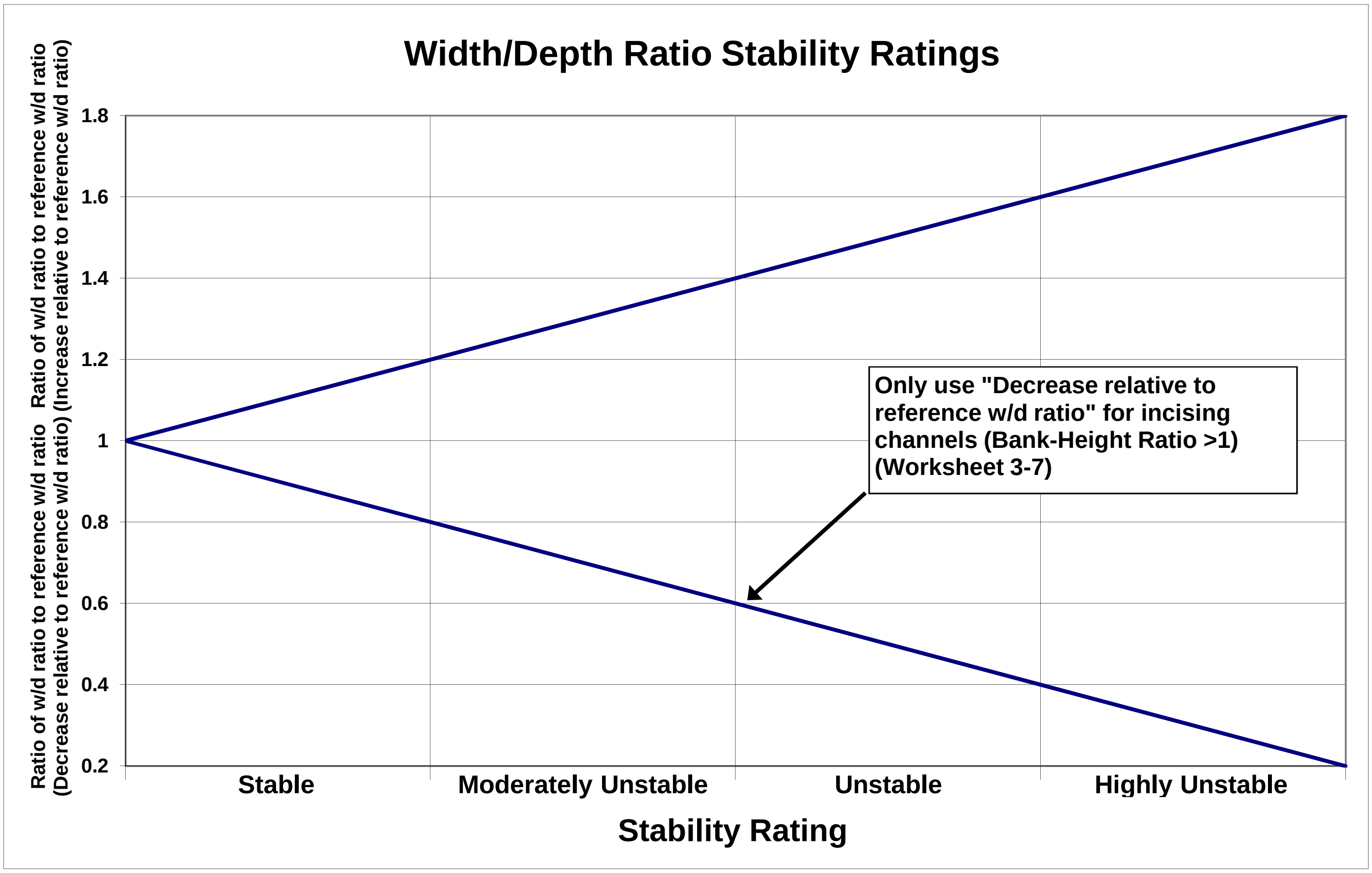
Bank-Height Ratio:	**1.3**

Degree of Channel Incision Stability Rating ☞ **Slightly Incised**



Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State			
Existing Width/Depth Ratio:	9.2	Ratio of existing W/d to reference W/d:	1
Reference Width/Depth Ratio:	9.2		
Width/Depth Ratio State Stability Rating ☞		Stable	

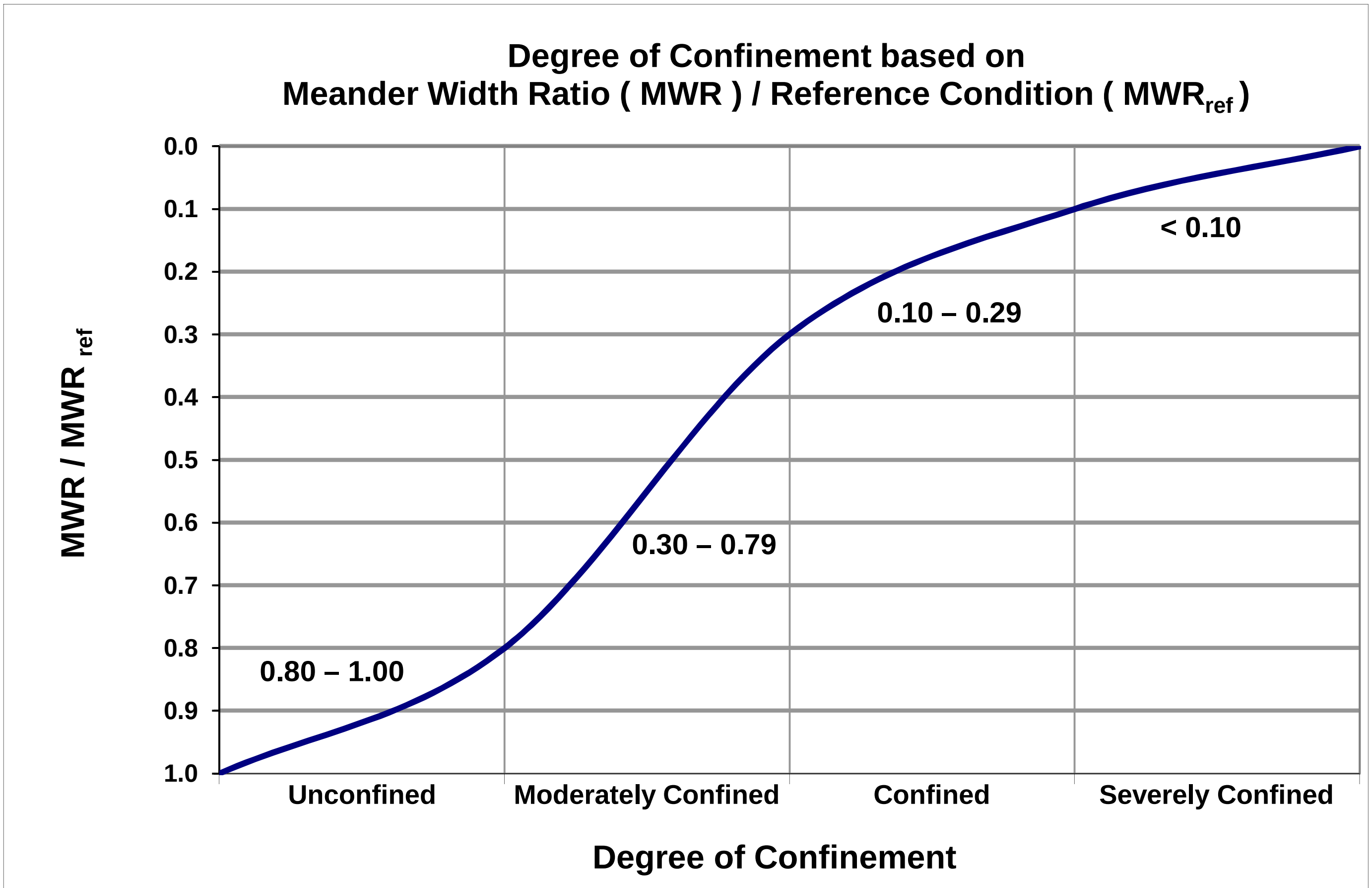


Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement

Existing Meander Width Ratio (MWR):	14.3	Ratio of MWR to MWR_{ref}:	1
Reference Meander Width Ratio (MWR_{ref}):	14.3		

Degree of Confinement Stability Rating ☞ **Unconfined**



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Sheyenne River **Location:** Sheyenne River-1-4.2(**Valley Type:** X **Observers:** KP, AL **Date:** 10/6/2011

Location	Key	Category	Excellent Description	Rating	Good Description	Rating	Fair Description	Rating	Poor Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	1	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	4	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	1	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	1	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	2	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	4	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	6	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	4
			Excellent total =	19	Good total =	4	Fair total =	21	Poor total =	40

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	84
Existing stream type =	E6
*Potential stream type =	E6
Modified channel stability rating =	Fair

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream: **Sheyenne River**		Location: **Sheyenne River-1-4.20**	
Station:		Observers: **KP, AL**	
Date: **10/6/2011**	Stream Type: **E6**	Valley Type: **X**	

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	20.6 (A)	**Bankfull Height** (ft) =	11.9 (B)	(A) / (B) =	1.7 (C)	6

Root Depth / Study Bank Height (E)

Root Depth (ft) =	3 (D)	**Study Bank Height** (ft) =	20.6 (A)	(D) / (A) =	0.1 (E)	8

Weighted Root Density (G)

Root Density as **%** =	20% (F)	(F) x (E) =	3% (G)	10

Bank Angle (H)

Bank Angle as *Degrees* =	28 (H)	2

Surface Protection (I)

Surface Protection as **%** =	5% (I)	10

Bank Material Adjustment:

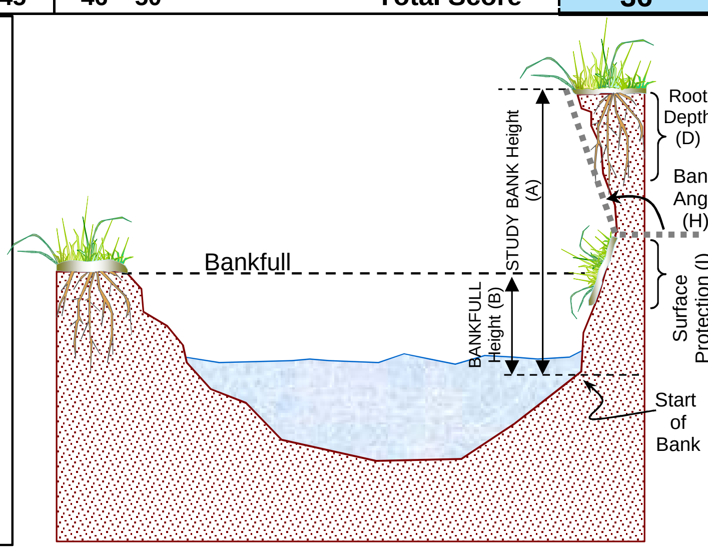
- **Bedrock** (Overall Very Low BEHI)
- **Boulders** (Overall Low BEHI)
- **Cobble** (Subtract 10 points if uniform medium to large cobble)
- **Gravel or Composite Matrix** (Add 5–10 points depending on percentage of bank material that is composed of sand)
- **Sand** (Add 10 points)
- **Silt/Clay** (no 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** 36

Bank Sketch



Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Sheyenne River**	Location: **Sheyenne River-1-4.20**	
Station: **0**	Stream Type: **E6**	Valley Type: **X**
Observers: **KP, AL**		Date: **10/6/11**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})......................................	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S).....................................	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})...	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})........................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient..	Level IV	Validation

Level I

(1)
- Transverse and/or central bars-short and/or discontinuous........................NBS = High / Very High
- Extensive deposition (continuous, cross-channel)...................................NBS = Extreme
- Chute cutoffs, down-valley meander migration, converging flow.....................NBS = Extreme

Level II

	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)
(2)				

	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)
(3)				

	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)
(4)				

Dominant Near-Bank Stress
Very Low

Level III

	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)
(5)				

	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)
(6)								

Level IV

	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
(7)		**Very Low**

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating: Very Low

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Sheyenne River**			Location: **Sheyenne River-1-4.20**			
Graph Used:	**Fig 3-9**	Total Bank Length (ft): **6253.7**				Date: **10/6/2011**	
Observers:	**KP, AL**		Valley Type: **X**			Stream Type: **E6**	
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (ft/yr)**	**Length of bank (ft)**	**Study bank height (ft)**	**Erosion subtotal [(4)×(5)×(6)] (ft³/yr)**	**Erosion Rate (tons/yr/ft) {[(7)/27] × 1.3 / (5)}**
1.	**High**	**Very Low**	**0.165**	**6253.7**	**20.6**	**21256**	**0.16**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft³/yr)**	**21256**	
Convert erosion in ft³/yr to yds³/yr {divide Total Erosion (ft³/yr) by 27}					**Total Erosion (yds³/yr)**	**787**	
Convert erosion in yds³/yr to tons/yr {multiply Total Erosion (yds³/yr) by 1.3}					**Total Erosion (tons/yr)**	**1023**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.16**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Sheyenne River**		Stream Type: **E6**		
Location:	**Sheyenne River-1-4.20**		Valley Type: **X**		
Observers:	**KP, AL**		Date: **10/6/2011**		
Enter Required Information for Existing Condition					
	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
0	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			
Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress					
#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1: $\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$		
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2: $\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$		
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:		**#DIV/0!**
Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample					
#DIV/0!	**d**	Required bankfull mean depth (ft) $d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)		
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample					
#DIV/0!	**S**	Required bankfull water surface slope (ft/ft) $S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)		
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Sediment Competence Using Dimensional Shear Stress					
0	Bankfull shear stress $\tau = \gamma d S$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope				
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**				
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**				
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope	$d = \dfrac{\tau}{\gamma S}$			
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth	$S = \dfrac{\tau}{\gamma d}$			

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis	Observers: **KP, AL**
Stream: **Sheyenne River**	Location: **Sheyenne River-1-4.20**
Date: **10/6/2011**	

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		0		0		0		0		0		0		0		0		0
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		100%

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	0
Materials less than:	mm

Be sure to add separate material weights to grand total

GRAND TOTAL: 0

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Sheyenne River**	Stream Type: **E6**
Location: **Sheyenne River-1-4.20**	Valley Type: **X**
Observers: **KP, AL**	Date: **10/6/2011**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream:	**Sheyenne River**	Stream Type:	**E6**
Location:	**Sheyenne River-1-4.20**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**10/6/2011**

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 3-8)**	< 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	> 1.6 **(8)**	**2**
2 **Depositional pattern (Worksheet 3-5)**	B1, B2 **(1)**	B4, B8 **(2)**	B3 **(3)**	B5, B6, B7 **(4)**	**1**
3 **Meander pattern (Worksheet 3-4)**	M1, M3, M4 **(1)**		M2, M5, M6, M7, M8 **(3)**		**3**
4 **Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL **(2)**	M/L, M/M, M/H, L/Ex, H/L **(4)**	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL **(6)**	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex **(8)**	**4**
5 **Degree of confinement (MWR / MWR$_{ref}$) (Worksheet 3-9)**	0.8 – 1.0 **(1)**	0.3 – 0.79 **(2)**	0.1 – 0.29 **(3)**	< 0.1 **(4)**	**1**
				Total points	**11**

	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** ☐

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream: **Sheyenne River**			Stream Type: **E6**		
Location: **Sheyenne River-1-4.20**			Valley Type: **X**		
Observers: **KP, AL**			Date: **10/6/2011**		
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 3-14)**	Sufficient depth and/or slope to transport largest size available **(2)**	Trend toward insufficient depth and/or slope-slightly incompetent **(4)**	Cannot move D_{35} of bed material and/or D_{100} of bar material **(6)**	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size **(8)**	**2**
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load **(2)**	Trend toward insufficient sediment capacity **(4)**	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand **(6)**	Reduction over 25% of annual sediment yield for bedload and/or suspended sand **(8)**	**2**
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	>1.6 **(8)**	**2**
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation **(2)**	(E→C) **(4)**	(C→High W/d C), (B→High W/d B), (C→F) **(6)**	(C→D), (F→D) **(8)**	**2**
5 **Depositional patterns (Worksheet 3-5)**	B1 **(1)**	B2, B4 **(2)**	B3, B5 **(3)**	B6, B7, B8 **(4)**	**1**
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 **(1)**	D4, D7 **(2)**	D5, D8 **(3)**	D6, D9, D10 **(4)**	**1**
				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** ☐	

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream: **Sheyenne River**			Stream Type: **E6**		
Location: **Sheyenne River-1-4.20**			Valley Type: **X**		
Observers: **KP, AL**			Date: **10/6/2011**		
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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	**2**
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	**2**
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	**4**
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	**4**
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	**1**
				Total points	**13**
	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** ☐	

Worksheet 3-20. Channel enlargement prediction summary.

Stream: **Sheyenne River**				Stream Type: **E6**	
Location: **Sheyenne River-1-4.20**				Valley Type: **X**	
Observers: **KP, AL**				Date: **10/6/2011**	
Channel enlargement prediction criteria **(choose one stability category for each criterion 1–4)**	**Channel Enlargement Prediction Categories**				**Selected points (from each row)**
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) **(2)**	(C→High W/d C), (E→C) **(4)**	(G→F), (F→D) **(6)**	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) **(8)**	**2**
2 **Lateral stability (Worksheet 3-17)**	Stable **(2)**	Moderately unstable **(4)**	Unstable **(6)**	Highly unstable **(8)**	**4**
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition **(2)**	Moderate deposition **(4)**	Excess deposition **(6)**	Aggradation **(8)**	**2**
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised **(2)**	Slightly incised **(4)**	Moderately incised **(6)**	Degradation **(8)**	**4**
				Total points	**12**
	Category point range				
Channel enlargement prediction (use total points and check stability rating)	**No increase 8 – 10** ☐	**Slight increase 11 – 16** ☑	**Moderate increase 17 – 24** ☐	**Extensive > 24** ☐	

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream: **Sheyenne River**		Stream Type:	**E6**
Location: **Sheyenne River-1-4.20**		Valley Type:	**X**
Observers: **KP, AL**		Date:	**10/6/2011**

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	Stability Rating	Points	Selected Points
1 Lateral stability (Worksheet 3-17)	Stable	1	2
	Mod. unstable	2	
	Unstable	3	
	Highly unstable	4	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition	1	1
	Mod. deposition	2	
	Excess deposition	3	
	Aggradation	4	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	2
	Slightly incised	2	
	Mod. Incised	3	
	Degradation	4	
4 Channel enlargement prediction (Worksheet 3-20)	No increase	1	2
	Slight increase	2	
	Mod. increase	3	
	Extensive	4	
5 Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	2
	Fair: mod unstable	2	
	Poor: unstable	4	
		Total Points	9

	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 ☐

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Sheyenne River**		Location: **Sheyenne River-1-4.20**	
Observers:	**KP, AL**	Date: **10/6/2011**	Stream Type: **E6**	Valley Type: **X**

Channel Dimension	Mean bankfull depth (ft): **9.45**	Mean bankfull width (ft): **86.86**	Cross-section area (ft^2): **820.3**	Width of flood-prone area (ft): **437.3333**	Entrenchment ratio: **5.0**
Channel Pattern	Mean: Range:	MWR: **14.3**	Lm/W_{bkf}: **14.3**	Rc/W_{bkf}: **3.3**	Sinuosity: **2.79**

River Profile and Bed Features

Check: ☐ Riffle/pool ☐ Step/pool ☐ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed

Max bankfull depth (ft): Riffle	Max bankfull depth (ft): Pool	Depth ratio (max/mean): Riffle	Depth ratio (max/mean): Pool	Pool to pool spacing: Ratio	Slope: Valley	Slope: Average bankfull
14.7		**1.6**				**0.00017**

Level III Stream Stability Indices

Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:

Flow regime: **P1, 2, 7, 9**	Stream size and order: **S-7**	Meander pattern(s): **M2**	Depositional pattern(s): **NONE**	Debris/channel blockage(s): **D3**
Degree of incision (Bank-Height Ratio): **1.3**	Degree of incision stability rating: **Slightly Incised**	Modified Pfankuch stability rating (numeric and adjective rating): **Fair**		
Width/depth ratio (W/d): **9.2**	Reference W/d ratio (W/d_{ref}): **9.2**	Width/depth ratio state $(W/d) / (W/d_{ref})$: **1.0**	W/d ratio state stability rating: **Stable**	
Meander Width Ratio (MWR): **14.3**	Reference MWR_{ref}: **14.3**	Degree of confinement (MWR / MWR_{ref}): **1.0**	MWR / MWR_{ref} stability rating: **Unconfined**	

Bank Erosion Summary	Length of reach studied (ft): **6254**	Annual streambank erosion rate: **1023** (tons/yr) **0.16** (tons/yr/ft)	Curve used: **Fig 3-9**	Remarks:
Sediment Capacity (POWERSED)	☐ Sufficient capacity ☐ Insufficient capacity ☐ Excess capacity			Remarks:
Entrainment/ Competence	Largest particle from bar sample (mm): **0**	$\tau =$ **0** $\tau^* =$ **#####**	Existing $depth_{bkf}$: / Required $depth_{bkf}$:	Existing $slope_{bkf}$: / Required $slope_{bkf}$:
Successional Stage Shift	→ → → → →		Existing stream state (type): **E6**	Potential stream state (type): **E6**
Lateral Stability	☐ Stable ☑ Mod. unstable ☐ Unstable ☐ Highly unstable			Remarks/causes:
Vertical Stability (Aggradation)	☑ No deposition ☐ Mod. deposition ☐ Ex. deposition ☐ Aggradation			Remarks/causes:
Vertical Stability (Degradation)	☐ Not incised ☑ Slightly incised ☐ Mod. incised ☐ Degradation			Remarks/causes:
Channel Enlargement	☐ No increase ☑ Slight increase ☐ Mod. increase ☐ Extensive			Remarks/causes:
Sediment Supply (Channel Source)	☐ Low ☑ Moderate ☐ High ☐ Very high			Remarks/causes:

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Sheyenne River**			Location: **Sheyenne River-2-11.56**	
Observers: **KP, AL**	Reference reach		Disturbed (impacted reach) **X**	Date: **10/3/2011**
Existing species composition:			Potential species composition:	

Riparian cover categories		Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**80%**	**2%**		
					100%
2. Understory	Shrub layer		**3%**		
					100%
3. Ground level	Herbaceous		**10%**		
					100%
	Leaf or needle litter		**10%**	**Remarks:** Condition, vigor and/or usage of existing reach:	
	Bare ground		**75%**		
			Column total = 100%		

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

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Sheyenne River**				Location: **Sheyenne River-2-11.56**				
Observers: **KP, AL**						Date: **10/3/2011**		
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P7**	**P9**				

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order			
Stream:	**Sheyenne River**		
Location:	**Sheyenne River-2-11.56**		
Observers:	**KP, AL**		
Date:	**10/3/2011**		
Stream Size Category and Order ☞			**S-8**
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).			

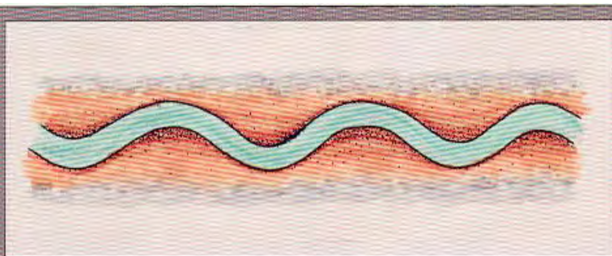
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Sheyenne River**	Reach:	**Sheyenne River-2-11.56**
Observers:	**KP, AL**	Date:	**10/3/2011**

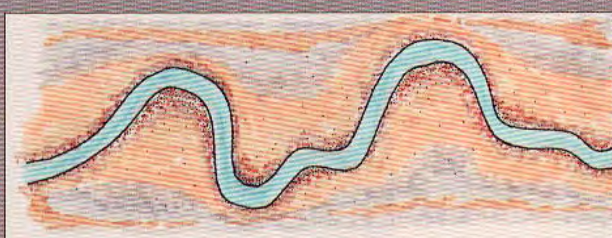
List ALL CATEGORIES that APPLY ☞	M2				

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

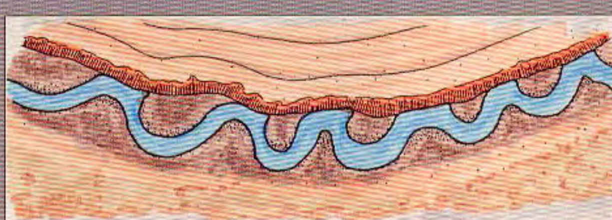


M1 REGULAR MEANDERS

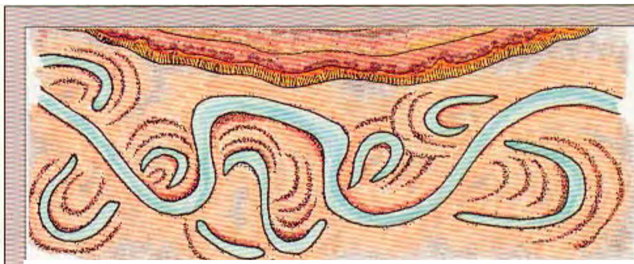
M2 TORTUOUS MEANDERS



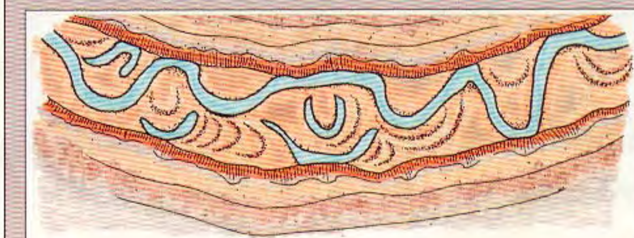
M3 IRREGULAR MEANDERS



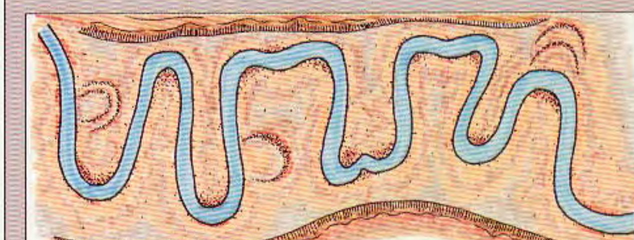
M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS



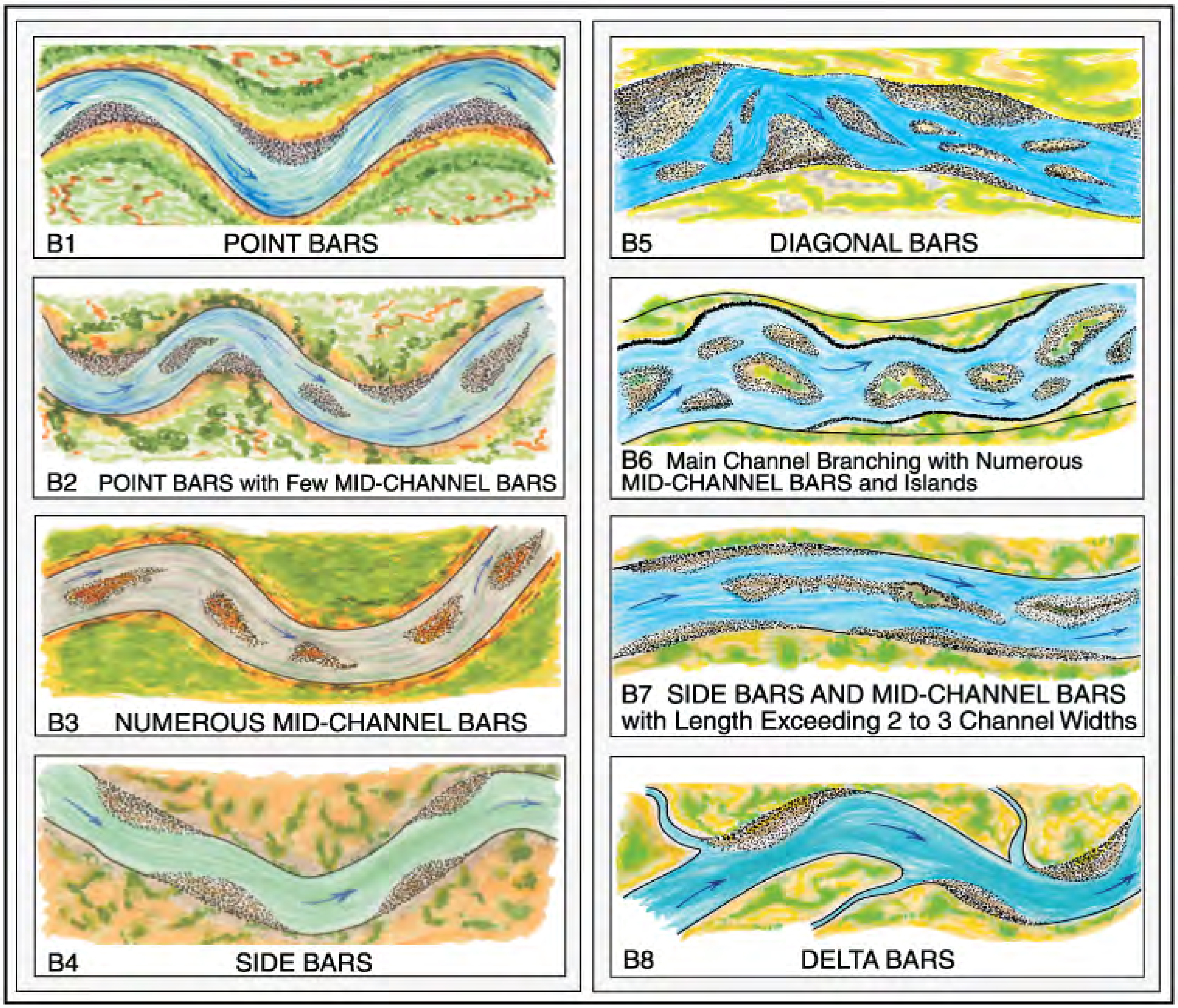
M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns					
Stream: **Sheyenne River**			Reach: **Sheyenne River-2-11.56**		
Observers: **KP, AL**			Date: **10/3/2011**		
List ALL CATEGORIES that APPLY ☞	**N/A**				

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

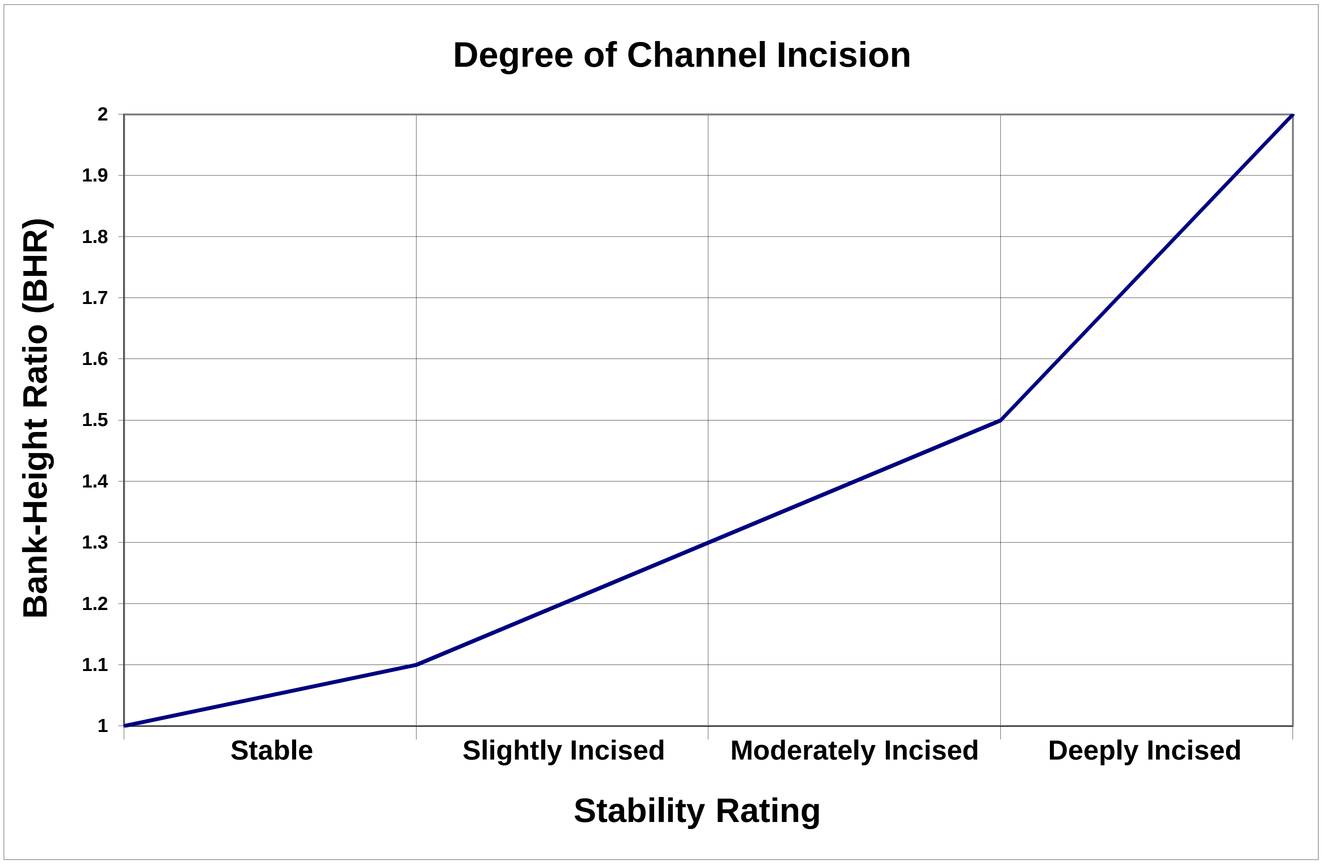


Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Sheyenne River**		Location: **Sheyenne River-2-11.56**	
Observers: **KP, AL**		Date: **10/3/2011**	
Description/extent		**Materials that 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.	☐

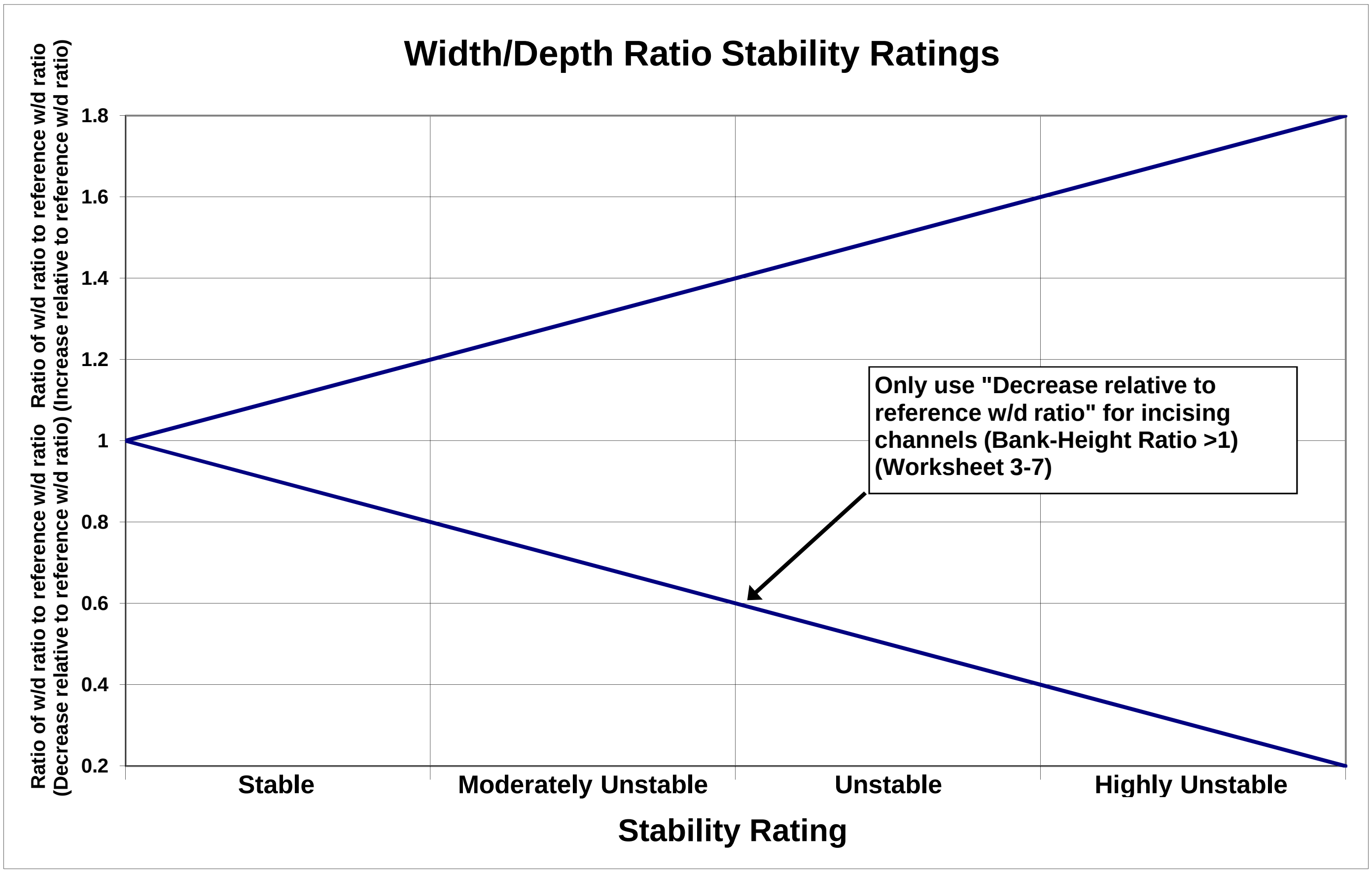
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision			
Low Bank Height:	20.1	Bank-Height Ratio:	1.5
Max Bankfull Depth:	13.01		
Degree of Channel Incision Stability Rating ☞		Moderately Incised	



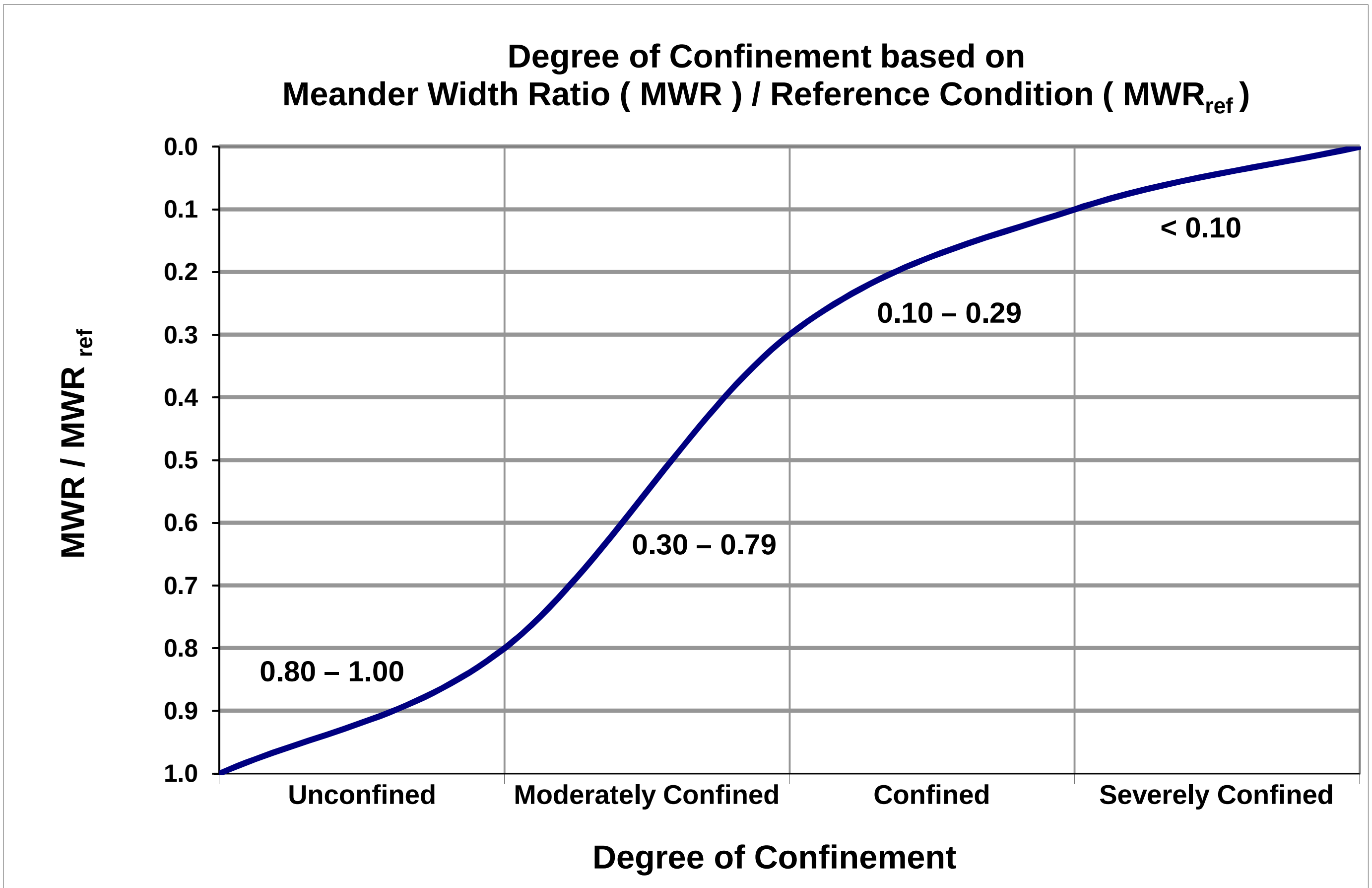
Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State			
Existing Width/Depth Ratio:	12.6	Ratio of existing W/d to reference W/d:	1
Reference Width/Depth Ratio:	12.6		
Width/Depth Ratio State Stability Rating ☞			Stable



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	13.2	Ratio of MWR to MWR_{ref}:	1
Reference Meander Width Ratio (MWR_{ref}):	13.2		
Degree of Confinement Stability Rating ☞	Unconfined		



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Sheyenne River **Location:** Sheyenne River-2-11.5 **Valley Type:** X **Observers:** KP, AL **Date:** 10/3/2011

Location	Key	Category	Excellent – Description	Rating	Good – Description	Rating	Fair – Description	Rating	Poor – Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	**6**	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	**9**	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	**4**	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	**12**
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	**8**
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	**4**	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	**12**	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	19	Good total =	8	Fair total =	27	Poor total =	24

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	78
Existing stream type =	E5
*Potential stream type =	E5
Modified channel stability rating =	Fair

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream:	**Sheyenne River**	Location:	**Sheyenne River-2-11.56**
Station:		Observers:	**KP, AL**
Date: **10/3/2011**	Stream Type: **E5**	Valley Type: **X**	

Variable	Inputs	Calculation	Result	BEHI Score (Fig. 3-7)
Study Bank Height / Bankfull Height (C)	**Study Bank Height** (ft) = **20.2** **(A)**; **Bankfull Height** (ft) = **11** **(B)**	(A) / (B) =	**1.8** **(C)**	**7**
Root Depth / Study Bank Height (E)	**Root Depth** (ft) = **1.5** **(D)**; **Study Bank Height** (ft) = **20.2** **(A)**	(D) / (A) =	**0.1** **(E)**	**8**
Weighted Root Density (G)	**Root Density** as **%** = **20%** **(F)**	(F) x (E) =	**1%** **(G)**	**10**
Bank Angle (H)	**Bank Angle** as *Degrees* =		**22** **(H)**	**2**
Surface Protection (I)	**Surface Protection** as **%** =		**5%** **(I)**	**10**

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)

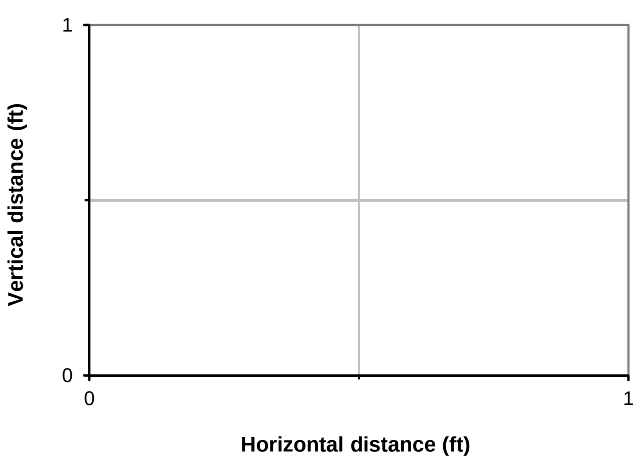
Bank Material Adjustment: **0**

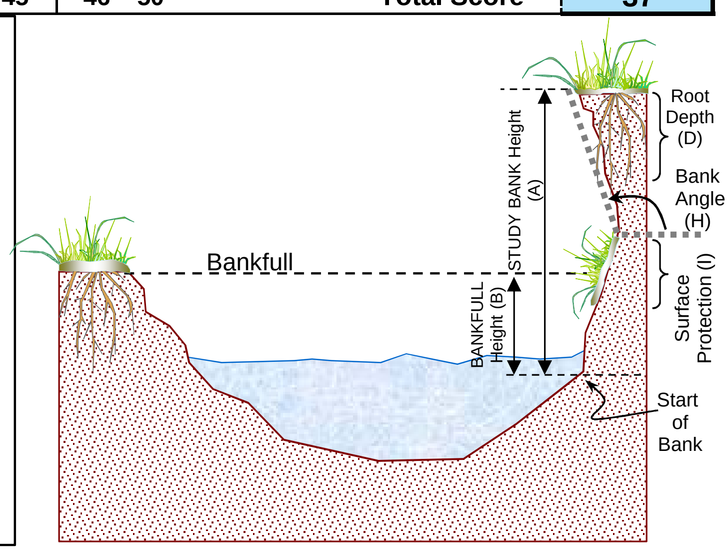
Stratification Adjustment
Add 5–10 points, depending on position of unstable layers in relation to bankfull stage: **0**

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: **High**
and
Total Score: **37**

Bank Sketch





Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Sheyenne River** Location: **Sheyenne River-2-11.56**

Station: **0** Stream Type: **E5** Valley Type: **X**

Observers: **KP, AL** Date: **10/3/11**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})...	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S)...................................	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})..	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf}).........................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient..	Level IV	Validation

Level I

(1)
Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
Extensive deposition (continuous, cross-channel)...................................... ....NBS = Extreme
Chute cutoffs, down-valley meander migration, converging flow...NBS = Extreme

Level II

(2)	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)

(3)	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)

(4)	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)

Dominant Near-Bank Stress
Very Low

Level III

(5)	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)

(6)	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)

Level IV

(7)	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
		Very Low

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating	Very Low

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Sheyenne River**			Location: **Sheyenne River-2-11.56**			
Graph Used:	**Fig 3-9**	Total Bank Length (ft): **5264.9**				Date: **10/3/2011**	
Observers:	**KP, AL**		Valley Type: **X**			Stream Type: **E5**	
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**5264.9**	**20.2**	**17548**	**0.16**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**17548**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**650**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**845**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.16**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Sheyenne River**		Stream Type:	**E5**	
Location:	**Sheyenne River-2-11.56**		Valley Type:	**X**	
Observers:	**KP, AL**		Date:	**10/3/2011**	
Enter Required Information for Existing Condition					
	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
0	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			
Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress					
#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$	
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$	
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	**#DIV/0!**	
Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample					
#DIV/0!	d	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)	
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample					
#DIV/0!	S	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)	
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Sediment Competence Using Dimensional Shear Stress					
0	Bankfull shear stress $\tau = \gamma d S$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope				
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**				
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**				
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope		$d = \dfrac{\tau}{\gamma S}$		
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth		$S = \dfrac{\tau}{\gamma d}$		

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis	Observers: **KP, AL**	
Stream: **Sheyenne River**	Location: **Sheyenne River-2-11.56**	Date: **10/3/2011**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		0		0		0		0		0		0		0		0		0
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		100%

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	0
Materials less than:	mm

Be sure to add separate material weights to grand total

GRAND TOTAL: 0

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Sheyenne River**	Stream Type: **E5**
Location: **Sheyenne River-2-11.56**	Valley Type: **X**
Observers: **KP, AL**	Date: **10/3/2011**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream:	Sheyenne River				Stream Type:	E5
Location:	Sheyenne River-2-11.56				Valley Type:	X
Observers:	KP, AL				Date:	10/3/2011

Lateral stability criteria (choose one stability category for each criterion 1–5)	Lateral Stability Categories: Stable	Moderately unstable	Unstable	Highly unstable	Selected points (from each row)
1 W/d ratio state (Worksheet 3-8)	< 1.2 (2)	1.2 – 1.4 (4)	1.4 – 1.6 (6)	> 1.6 (8)	2
2 Depositional pattern (Worksheet 3-5)	B1, B2 (1)	B4, B8 (2)	B3 (3)	B5, B6, B7 (4)	1
3 Meander pattern (Worksheet 3-4)	M1, M3, M4 (1)		M2, M5, M6, M7, M8 (3)		3
4 Dominant BEHI / NBS (Worksheet 3-13)	L/VL, L/L, L/M, L/H, L/VH, M/VL (2)	M/L, M/M, M/H, L/Ex, H/L (4)	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL (6)	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex (8)	4
5 Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)	0.8 – 1.0 (1)	0.3 – 0.79 (2)	0.1 – 0.29 (3)	< 0.1 (4)	1
				Total points	**11**

	Lateral stability category point range: Stable	Moderately unstable	Unstable	Highly unstable
Overall lateral stability category (use total points and check stability rating)	Stable 7 – 9 ☐	Moderately unstable 10 – 12 ☑	Unstable 13 – 21 ☐	Highly unstable > 21 ☐

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream: **Sheyenne River**			Stream Type: **E5**		
Location: **Sheyenne River-2-11.56**			Valley Type: **X**		
Observers: **KP, AL**			Date: **10/3/2011**		
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 3-14)**	Sufficient depth and/or slope to transport largest size available **(2)**	Trend toward insufficient depth and/or slope-slightly incompetent **(4)**	Cannot move D_{35} of bed material and/or D_{100} of bar material **(6)**	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size **(8)**	2
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load **(2)**	Trend toward insufficient sediment capacity **(4)**	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand **(6)**	Reduction over 25% of annual sediment yield for bedload and/or suspended sand **(8)**	2
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	>1.6 **(8)**	2
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation **(2)**	(E→C) **(4)**	(C→High W/d C), (B→High W/d B), (C→F) **(6)**	(C→D), (F→D) **(8)**	2
5 **Depositional patterns (Worksheet 3-5)**	B1 **(1)**	B2, B4 **(2)**	B3, B5 **(3)**	B6, B7, B8 **(4)**	1
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 **(1)**	D4, D7 **(2)**	D5, D8 **(3)**	D6, D9, D10 **(4)**	1
				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** ☐	

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream:	**Sheyenne River**	Stream Type:	**E5**
Location:	**Sheyenne River-2-11.56**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**10/3/2011**

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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	2
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	2
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	6
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	4
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	1
				Total points	**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 ☐

Worksheet 3-20. Channel enlargement prediction summary.

Stream:	**Sheyenne River**	Stream Type:	**E5**
Location:	**Sheyenne River-2-11.56**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**10/3/2011**

Channel enlargement prediction criteria (choose one stability category for each criterion 1–4)	**Channel Enlargement Prediction Categories**				**Selected points** (from each row)
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C)	(C→High W/d C), (E→C)	(G→F), (F→D)	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F)	**2**
	(2)	**(4)**	**(6)**	**(8)**	
2 **Lateral stability (Worksheet 3-17)**	Stable	Moderately unstable	Unstable	Highly unstable	**4**
	(2)	**(4)**	**(6)**	**(8)**	
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition	Moderate deposition	Excess deposition	Aggradation	**2**
	(2)	**(4)**	**(6)**	**(8)**	
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised	Slightly incised	Moderately incised	Degradation	**4**
	(2)	**(4)**	**(6)**	**(8)**	
				Total points	**12**

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

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream:	**Sheyenne River**	Stream Type:	**E5**
Location:	**Sheyenne River-2-11.56**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**10/3/2011**

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	Stability Rating	Points	Selected Points
1 Lateral stability (Worksheet 3-17)	Stable	1	2
	Mod. unstable	2	
	Unstable	3	
	Highly unstable	4	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition	1	1
	Mod. deposition	2	
	Excess deposition	3	
	Aggradation	4	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	2
	Slightly incised	2	
	Mod. Incised	3	
	Degradation	4	
4 Channel enlargement prediction (Worksheet 3-20)	No increase	1	2
	Slight increase	2	
	Mod. increase	3	
	Extensive	4	
5 Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	2
	Fair: mod unstable	2	
	Poor: unstable	4	
		Total Points	9

	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 ☐

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Sheyenne River**			Location:	**Sheyenne River-2-11.56**		
Observers:	**KP, AL**	Date:	**10/3/2011**	Stream Type:	**E5**	Valley Type:	**X**

Channel Dimension	Mean bankfull depth (ft):	**8.84**	Mean bankfull width (ft):	**111.5**	Cross-section area (ft^2):	**988.1**	Width of flood-prone area (ft):	**787.6667**	Entrenchment ratio:	**7.1**
Channel Pattern	Mean: / Range:	MWR:	**13.2**	Lm/W_{bkf}:	**13.2**	Rc/W_{bkf}:	**2.6**	Sinuosity:		

River Profile and Bed Features

Check: ☐ Riffle/pool ☐ Step/pool ☐ Plane bed ☐ Convergence/divergence ☐ Dunes/antidunes/smooth bed

Max bankfull depth (ft): Riffle	Max bankfull depth (ft): Pool	Depth ratio (max/mean): Riffle	Depth ratio (max/mean): Pool	Pool to pool spacing: Ratio	Slope: Valley	Slope: Average bankfull
13.0		**1.5**				**0.00016**

Level III Stream Stability Indices

Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:

Flow regime:	**P1, 2, 7, 9**	Stream size and order:	**S-8**	Meander pattern(s):	**M2**	Depositional pattern(s):	**NONE**	Debris/channel blockage(s):	**D3**

Degree of incision (Bank-Height Ratio):	**1.5**	Degree of incision stability rating:	**Moderately Incised**	Modified Pfankuch stability rating (numeric and adjective rating):	**Fair**
Width/depth ratio (W/d):	**12.6**	Reference W/d ratio (W/d_{ref}):	**12.6**	Width/depth ratio state (W/d) / (W/d_{ref}): **1.0**	W/d ratio state stability rating: **Stable**
Meander Width Ratio (MWR):	**13.2**	Reference MWR_{ref}:	**13.2**	Degree of confinement (MWR / MWR_{ref}): **1.0**	MWR / MWR_{ref} stability rating: **Unconfined**

Bank Erosion Summary	Length of reach studied (ft):	**5265**	Annual streambank erosion rate:	**845** (tons/yr)	**0.16** (tons/yr/ft)	Curve used: **Fig 3-9**	Remarks:

Sediment Capacity (POWERSED)	☐ Sufficient capacity ☐ Insufficient capacity ☐ Excess capacity	Remarks:
Entrainment/ Competence	Largest particle from bar sample (mm): **0** ; $\tau =$ **0** ; $\tau^* =$ **#####** ; Existing $depth_{bkf}$: ; Required $depth_{bkf}$: ; Existing $slope_{bkf}$: ; Required $slope_{bkf}$:	
Successional Stage Shift	→ → → → →	Existing stream state (type): **E5** ; Potential stream state (type): **E5**
Lateral Stability	☐ Stable ☑ Mod. unstable ☐ Unstable ☐ Highly unstable	Remarks/causes:
Vertical Stability (Aggradation)	☑ No deposition ☐ Mod. deposition ☐ Ex. deposition ☐ Aggradation	Remarks/causes:
Vertical Stability (Degradation)	☐ Not incised ☑ Slightly incised ☐ Mod. incised ☐ Degradation	Remarks/causes:
Channel Enlargement	☐ No increase ☑ Slight increase ☐ Mod. increase ☐ Extensive	Remarks/causes:
Sediment Supply (Channel Source)	☐ Low ☑ Moderate ☐ High ☐ Very high	Remarks/causes:

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Sheyenne River**

Location: **Sheyenne River - 3 - 18.15**

Observers: **KD, JB**

Reference reach: [ ]

Disturbed (impacted reach): **X**

Date: **11/17/2010**

Existing species composition: **Trees, grass**

Potential species composition: **Trees, grass**

	Riparian cover categories	Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**15% without leaves, 65% with leaves**	**1%**	**trees**	**100%**
					100%
2. Understory	Shrub layer		**0%**		
					100%
3. Ground level	Herbaceous		**5%**	**tall grass**	**100%**
					100%
	Leaf or needle litter		**0%**		
	Bare ground		**94%**		
			Column total = 100%		

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

Remarks:
Condition, vigor and/or usage of existing reach:
None

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Sheyenne River**				Location: **Sheyenne River - 3 - 18.15**				
Observers: **KD, JB**							Date: **11/17/2010**	
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P7**	**P9**				

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order

Stream:	**Sheyenne River**
Location:	**Sheyenne River - 3 - 18.15**
Observers:	**KD, JB**
Date:	**11/17/2010**
Stream Size Category and Order ☞	**S-7**

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).

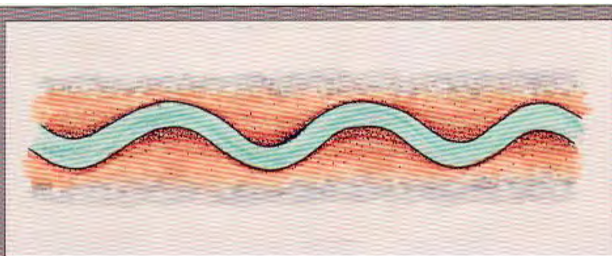
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Sheyenne River**	Reach:	**Sheyenne River - 3 - 18.15**
Observers:	**KD, JB**	Date:	**11/17/2010**

List ALL CATEGORIES that APPLY ☞	**M2**				

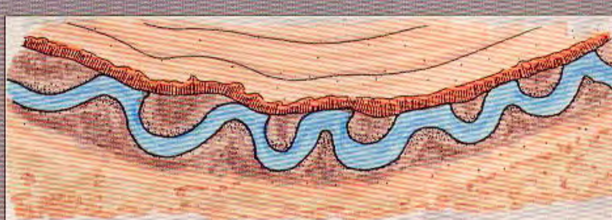
Various Meander Pattern variables modified from Galay et al. (1973)



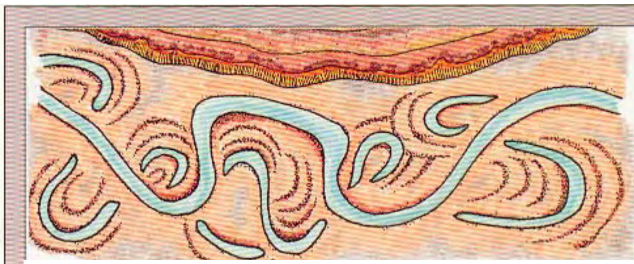
M1 REGULAR MEANDERS

M2 TORTUOUS MEANDERS

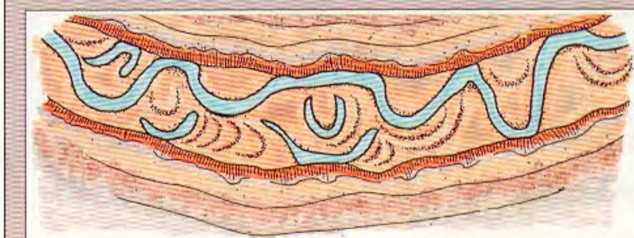
M3 IRREGULAR MEANDERS



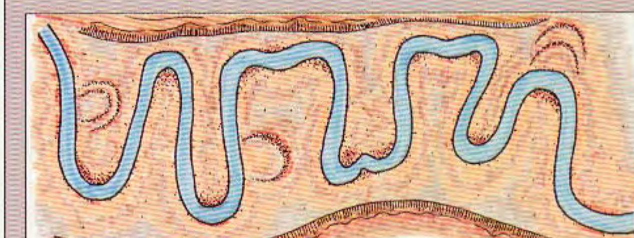
M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS



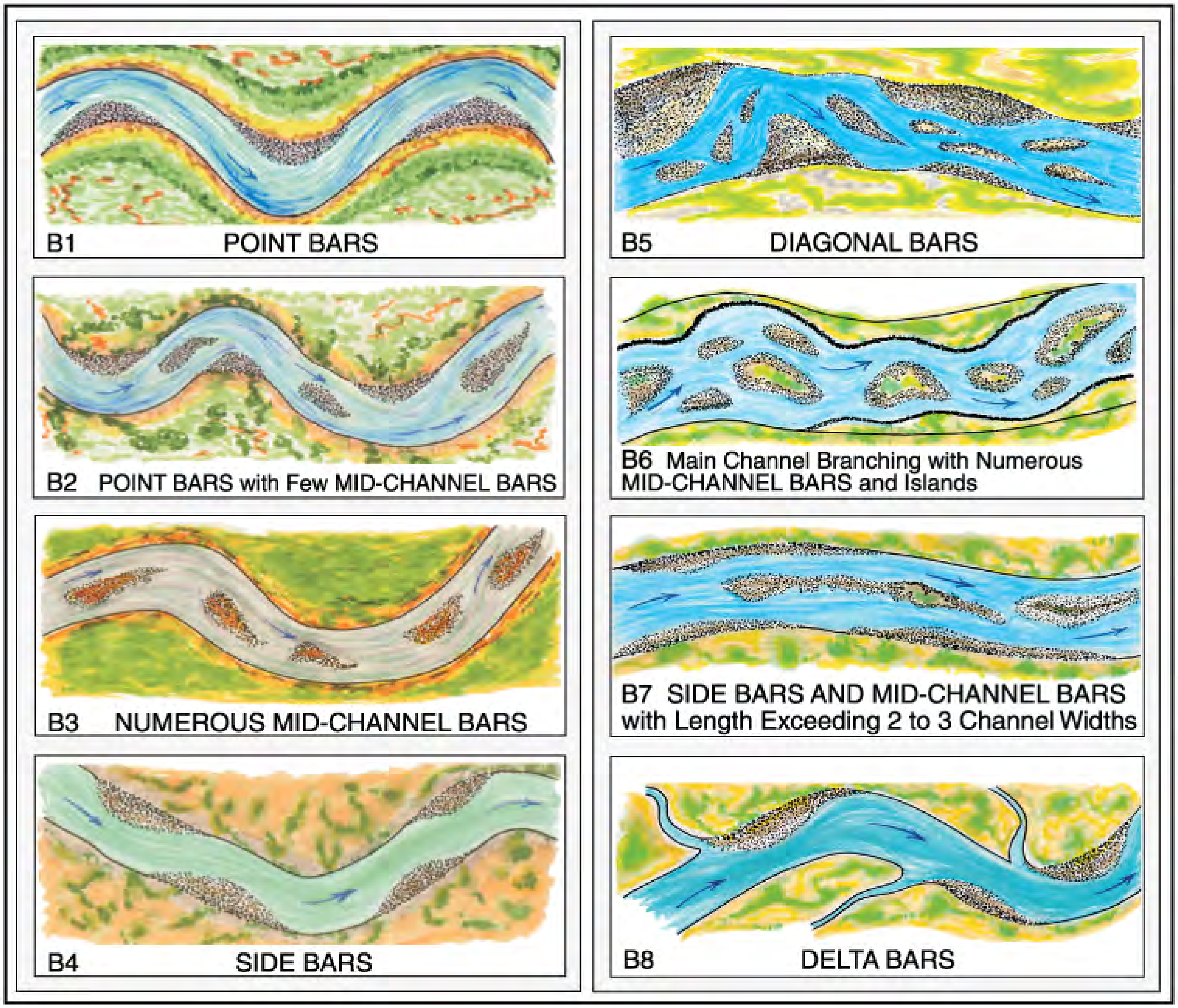
M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns					
Stream: **Sheyenne River**		Reach: **Sheyenne River - 3 - 18.15**			
Observers: **KD, JB**		Date: **11/17/2010**			
List ALL CATEGORIES that APPLY ☞	**NONE**				

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



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Sheyenne River**		Location: **Sheyenne River - 3 - 18.15**	
Observers: **KD, JB**		Date: **11/17/2010**	
Description/extent		**Materials that 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.	☐

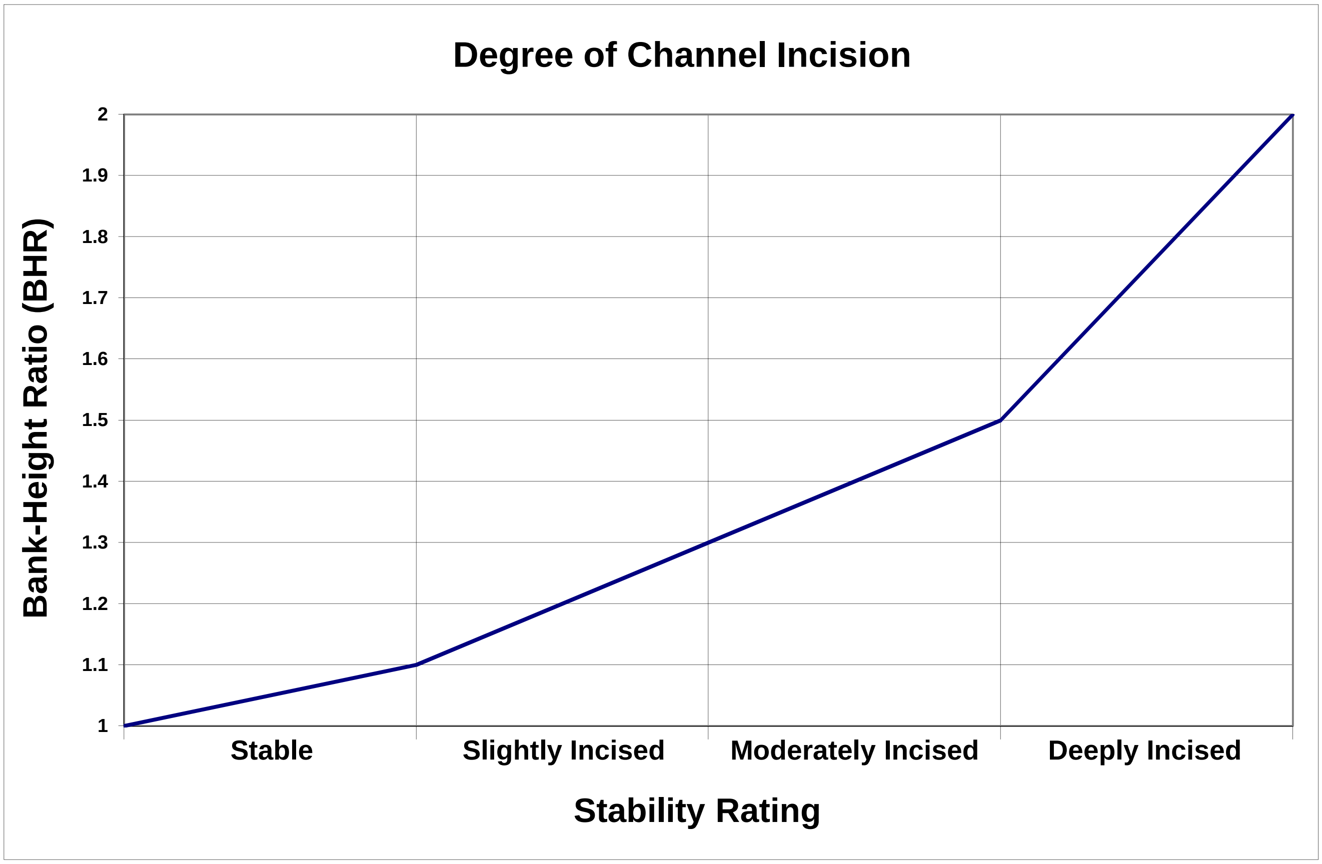
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision

Low Bank Height:	**16.9**
Max Bankfull Depth:	**12.94**

Bank-Height Ratio:	**1.3**

Degree of Channel Incision Stability Rating ☞ **Slightly Incised**

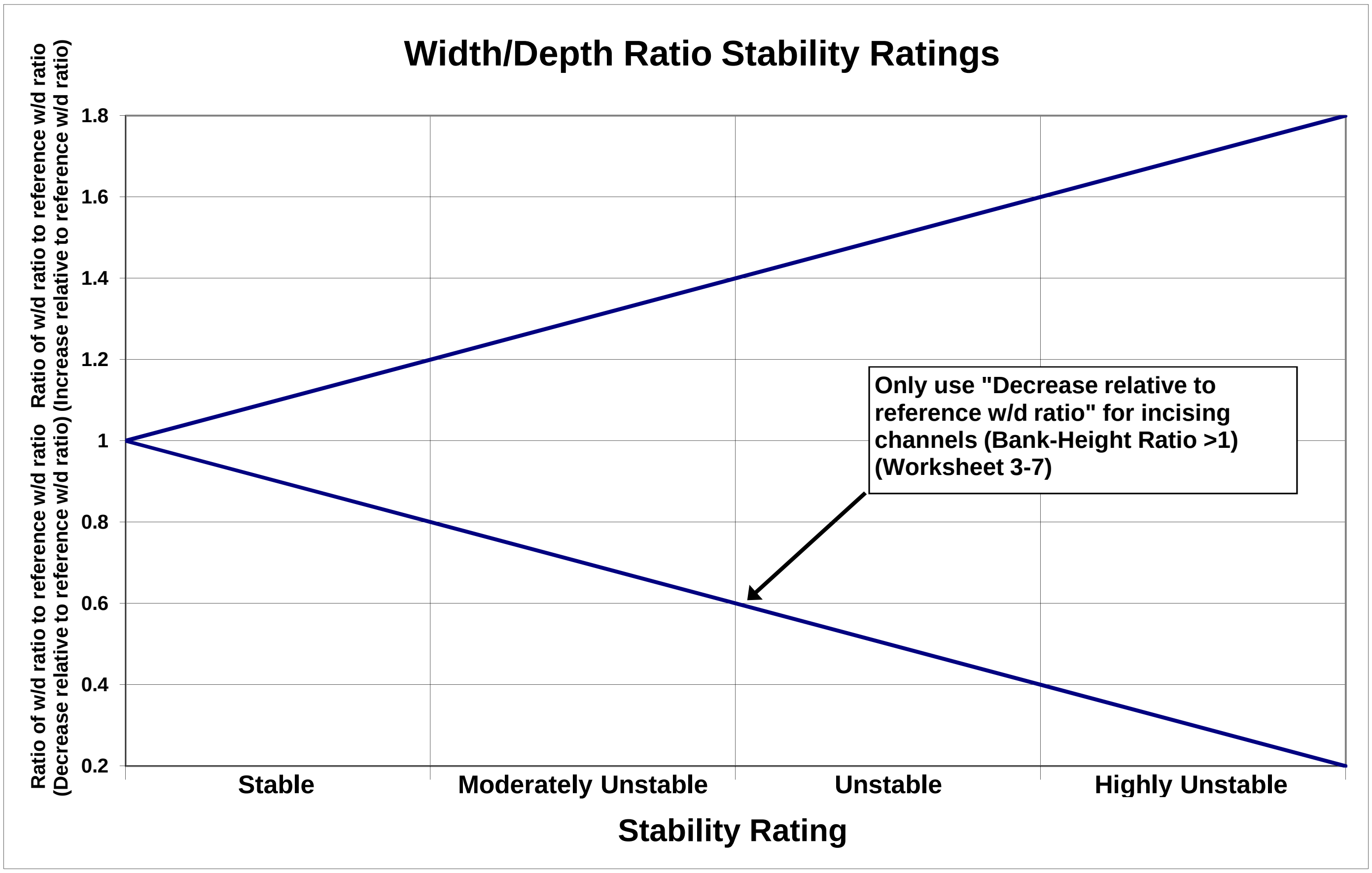


Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State

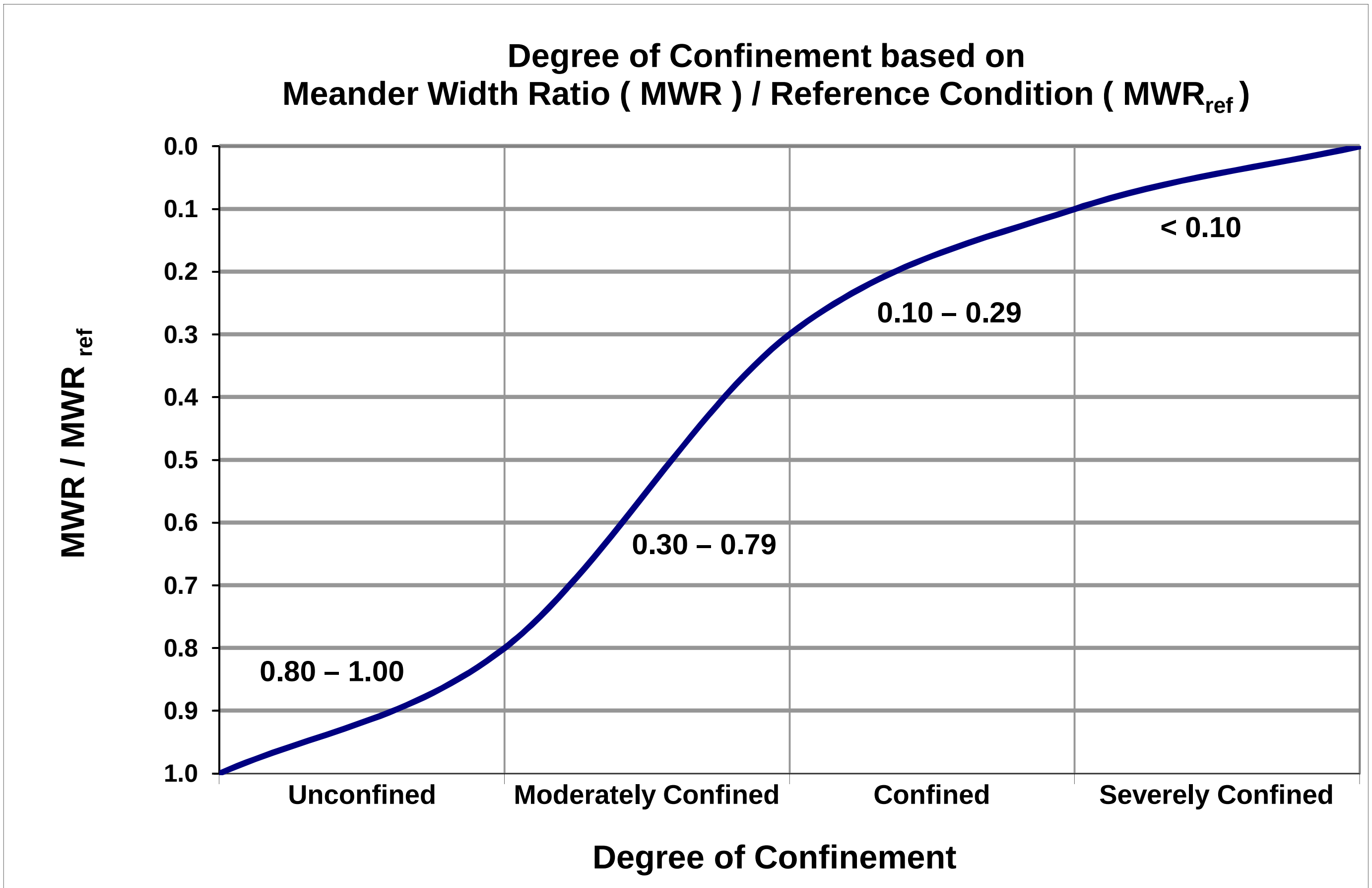
Existing Width/Depth Ratio:	10.0	Ratio of existing W/d to reference W/d:	1.001
Reference Width/Depth Ratio:	10.0		

Width/Depth Ratio State Stability Rating ☞ **Stable**



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	16.4	Ratio of MWR to MWR_{ref}:	0.993
Reference Meander Width Ratio (MWR_{ref}):	16.5		
Degree of Confinement Stability Rating ☞		**Unconfined**	



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Sheyenne River **Location:** Sheyenne River - 3 - 1 **Valley Type:** X **Observers:** KD, JB **Date:** 11/17/2010

Location	Key	Category	Excellent Description	Excellent Rating	Good Description	Good Rating	Fair Description	Fair Rating	Poor Description	Poor Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	**4**	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	**12**
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	**6**	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	**6**	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	**8**
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	**4**	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	**16**
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	19	Good total =	14	Fair total =	6	Poor total =	40

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	79
Existing stream type =	E6
*Potential stream type =	E6
Modified channel stability rating =	Fair

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream:	**Sheyenne River**	Location:	**Sheyenne River - 3 - 18.15**
Station:		Observers:	**KD, JB**
Date: **11/17/2010**	Stream Type: **E6**	Valley Type: **X**	

Variable	Input 1	Input 2	Calculation	Result	BEHI Score (Fig. 3-7)
Study Bank Height / Bankfull Height (C)	Study Bank Height (ft) = 16.9 (A)	Bankfull Height (ft) = 11.2 (B)	(A) / (B) =	1.5 (C)	6
Root Depth / Study Bank Height (E)	Root Depth (ft) = 2 (D)	Study Bank Height (ft) = 16.9 (A)	(D) / (A) =	0.1 (E)	8
Weighted Root Density (G)		Root Density as % = 25% (F)	(F) x (E) =	3% (G)	10
Bank Angle (H)			Bank Angle as *Degrees* =	32 (H)	3
Surface Protection (I)			Surface Protection as % =	3% (I)	10

Bank Material Adjustment:

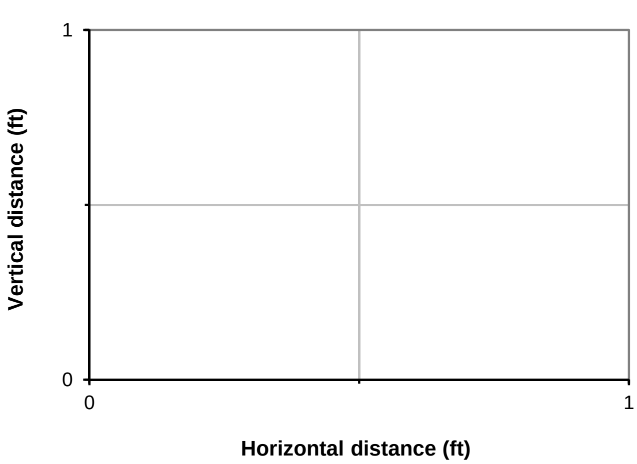
- **Bedrock** (Overall Very Low BEHI)
- **Boulders** (Overall Low BEHI)
- **Cobble** (Subtract 10 points if uniform medium to large cobble)
- **Gravel or Composite Matrix** (Add 5–10 points depending on percentage of bank material that is composed of sand)
- **Sand** (Add 10 points)
- **Silt/Clay** (no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

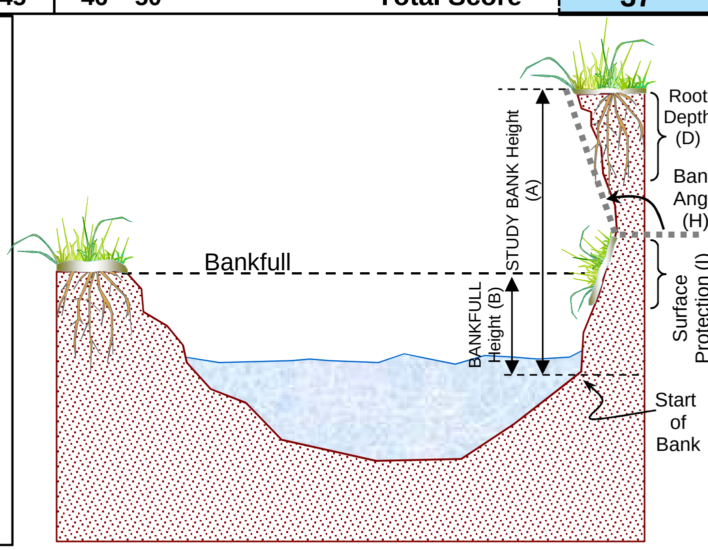
Bank Material Adjustment: 0

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 / 37

Bank Sketch





Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Sheyenne River**	Location: **Sheyenne River - 3 - 18.15**	
Station: **0**	Stream Type: **E6**	Valley Type: **X**
Observers: **KD, JB**		Date: **11/17/10**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})..	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S)...	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})...	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf}).....................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})............................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient..	Level IV	Validation

Level I

(1)
- Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
- Extensive deposition (continuous, cross-channel).. ....NBS = Extreme
- Chute cutoffs, down-valley meander migration, converging flow...NBS = Extreme

Level II

	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	Ratio R_c / W_{bkf}	Near-Bank Stress (NBS)
(2)				

	Pool Slope S_p	Average Slope S	Ratio S_p / S	Near-Bank Stress (NBS)
(3)				

	Pool Slope S_p	Riffle Slope S_{rif}	Ratio S_p / S_{rif}	Near-Bank Stress (NBS)
(4)				

Dominant Near-Bank Stress
Low

Level III

	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	Ratio d_{nb} / d_{bkf}	Near-Bank Stress (NBS)
(5)	**12.9**	**9.4**	**1.37**	**Low**

	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)
(6)								

Level IV

	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
(7)	**0.03**	**Very Low**

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating	**Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Sheyenne River**			Location:	**Sheyenne River - 3 - 18.15**		
Graph Used:	**Fig 3-9**	Total Bank Length (ft):	**6608.7**			Date:	**11/17/2010**
Observers:	**KD, JB**	Valley Type:	**X**			Stream Type:	**E6**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Low**	**0.165**	**6608.7**	**16.9**	**18428**	**0.13**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**18428**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**683**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**887**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.13**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Sheyenne River**			Stream Type:	**E6**
Location:	**Sheyenne River - 3 - 18.15**			Valley Type:	**X**
Observers:	**KD, JB**			Date:	**11/17/2010**

Enter Required Information for Existing Condition

	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	**#DIV/0!**

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	**d**	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	**S**	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Sediment Competence Using Dimensional Shear Stress

0	Bankfull shear stress $\tau = \gamma d S$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope	
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**	
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**	
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope	$d = \dfrac{\tau}{\gamma S}$
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth	$S = \dfrac{\tau}{\gamma d}$

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis

Observers: **KD, JB**

Stream: **Sheyenne River**

Location: **Sheyenne River - 3 - 18.15**

Date: **11/17/2010**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		**100%**

SURFACE MATERIALS DATA (Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	**0**
Materials less than:	mm

Be sure to add separate material weights to grand total

0

GRAND TOTAL

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Sheyenne River**	Stream Type: **E6**
Location: **Sheyenne River - 3 - 18.15**	Valley Type: **X**
Observers: **KD, JB**	Date: **11/17/2010**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream:	**Sheyenne River**		Stream Type:	**E6**	
Location:	**Sheyenne River - 3 - 18.15**		Valley Type:	**X**	
Observers:	**KD, JB**		Date:	**11/17/2010**	

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 3-8)**	< 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	> 1.6 **(8)**	**2**
2 **Depositional pattern (Worksheet 3-5)**	B1, B2 **(1)**	B4, B8 **(2)**	B3 **(3)**	B5, B6, B7 **(4)**	**1**
3 **Meander pattern (Worksheet 3-4)**	M1, M3, M4 **(1)**		M2, M5, M6, M7, M8 **(3)**		**3**
4 **Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL **(2)**	M/L, M/M, M/H, L/Ex, H/L **(4)**	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL **(6)**	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex **(8)**	**4**
5 **Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.8 – 1.0 **(1)**	0.3 – 0.79 **(2)**	0.1 – 0.29 **(3)**	< 0.1 **(4)**	**1**
				Total points	**11**

	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** ☐

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Sheyenne River**	Stream Type:	**E6**
Location:	**Sheyenne River - 3 - 18.15**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**11/17/2010**

	Vertical stability criteria (choose one stability category for each criterion 1–6)	Vertical Stability Categories for Excess Deposition / Aggradation: No deposition	Moderate deposition	Excess deposition	Aggradation	Selected points (from each row)
1	**Sediment competence (Worksheet 3-14)**	Sufficient depth and/or slope to transport largest size available **(2)**	Trend toward insufficient depth and/or slope-slightly incompetent **(4)**	Cannot move D_{35} of bed material and/or D_{100} of bar material **(6)**	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size **(8)**	**2**
2	**Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load **(2)**	Trend toward insufficient sediment capacity **(4)**	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand **(6)**	Reduction over 25% of annual sediment yield for bedload and/or suspended sand **(8)**	**2**
3	**W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	>1.6 **(8)**	**2**
4	**Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation **(2)**	(E→C) **(4)**	(C→High W/d C), (B→High W/d B), (C→F) **(6)**	(C→D), (F→D) **(8)**	**2**
5	**Depositional patterns (Worksheet 3-5)**	B1 **(1)**	B2, B4 **(2)**	B3, B5 **(3)**	B6, B7, B8 **(4)**	**1**
6	**Debris / blockages (Worksheet 3-6)**	D1, D2, D3 **(1)**	D4, D7 **(2)**	D5, D8 **(3)**	D6, D9, D10 **(4)**	**1**
					Total points	**10**

Vertical stability for excess deposition / aggradation (use total points and check stability rating)	Vertical stability category point range for excess deposition / aggradation: No deposition 10 – 14	Moderate deposition 15 – 20	Excess deposition 21 – 30	Aggradation > 30
	☑	☐	☐	☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream: **Sheyenne River**			Stream Type: **E6**		
Location: **Sheyenne River - 3 - 18.15**			Valley Type: **X**		
Observers: **KD, JB**			Date: **11/17/2010**		
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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	2
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	2
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	4
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	4
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	1
				Total points	**13**
	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** ☐	

Worksheet 3-20. Channel enlargement prediction summary.

Stream:	**Sheyenne River**			Stream Type:	**E6**
Location:	**Sheyenne River - 3 - 18.15**			Valley Type:	**X**
Observers:	**KD, JB**			Date:	**11/17/2010**

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 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) **(2)**	(C→High W/d C), (E→C) **(4)**	(G→F), (F→D) **(6)**	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) **(8)**	**2**
2 **Lateral stability (Worksheet 3-17)**	Stable **(2)**	Moderately unstable **(4)**	Unstable **(6)**	Highly unstable **(8)**	**4**
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition **(2)**	Moderate deposition **(4)**	Excess deposition **(6)**	Aggradation **(8)**	**2**
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised **(2)**	Slightly incised **(4)**	Moderately incised **(6)**	Degradation **(8)**	**4**
				Total points	**12**

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

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream: **Sheyenne River**		Stream Type:	**E6**
Location: **Sheyenne River - 3 - 18.15**		Valley Type:	**X**
Observers: **KD, JB**		Date:	**11/17/2010**

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	**Stability Rating**	**Points**	**Selected Points**
1 Lateral stability (Worksheet 3-17)	**Stable**	**1**	**2**
	Mod. unstable	**2**	
	Unstable	**3**	
	Highly unstable	**4**	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	**No deposition**	**1**	**1**
	Mod. deposition	**2**	
	Excess deposition	**3**	
	Aggradation	**4**	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	**Not incised**	**1**	**2**
	Slightly incised	**2**	
	Mod. Incised	**3**	
	Degradation	**4**	
4 Channel enlargement prediction (Worksheet 3-20)	**No increase**	**1**	**2**
	Slight increase	**2**	
	Mod. increase	**3**	
	Extensive	**4**	
5 Pfankuch channel stability (Worksheet 3-10)	**Good: stable**	**1**	**2**
	Fair: mod unstable	**2**	
	Poor: unstable	**4**	
		Total Points	**9**

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

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Sheyenne River**	Location:	**Sheyenne River - 3 - 18.15**
Observers:	**KD, JB**	Date: **11/17/2010**	Stream Type: **E6** Valley Type: **X**

Channel Dimension	Mean bankfull depth (ft):	**9.41**	Mean bankfull width (ft):	**93.82**	Cross-section area (ft^2):	**881.1**	Width of flood-prone area (ft):	**534.6667**	Entrenchment ratio:	**5.7**
Channel Pattern	Mean: Range:	MWR: **16.4**	Lm/W_{bkf}:	**16.4**	Rc/W_{bkf}:	**2.6**	Sinuosity:	**1.88**		

River Profile and Bed Features

Check: ☐ Riffle/pool ☐ Step/pool ☑ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed

Max bankfull depth (ft):	Riffle	Pool	Depth ratio (max/mean):	Riffle	Pool	Pool to pool spacing:	Ratio	Slope: Valley:	Average bankfull:
	12.9			**1.4**					**0.00022**

Level III Stream Stability Indices

Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:

Flow regime:	**P1, 2, 7, 9**	Stream size and order:	**S-7**	Meander pattern(s):	**M2**	Depositional pattern(s):	**NONE**	Debris/channel blockage(s):	**D3**
Degree of incision (Bank-Height Ratio):	**1.3**	Degree of incision stability rating:	**Slightly Incised**	Modified Pfankuch stability rating (numeric and adjective rating):	**Fair**				
Width/depth ratio (W/d):	**10.0**	Reference W/d ratio (W/d_{ref}):	**10.0**	Width/depth ratio state $(W/d) / (W/d_{ref})$:	**1.0**	W/d ratio state stability rating:	**Stable**		
Meander Width Ratio (MWR):	**16.4**	Reference MWR_{ref}:	**16.5**	Degree of confinement (MWR / MWR_{ref}):	**1.0**	MWR / MWR_{ref} stability rating:	**Unconfined**		

Bank Erosion Summary	Length of reach studied (ft): **6609**	Annual streambank erosion rate: **887** (tons/yr) **0.13** (tons/yr/ft)	Curve used: **Fig 3-9**	Remarks:
Sediment Capacity (POWERSED)	☐ Sufficient capacity ☐ Insufficient capacity ☐ Excess capacity			Remarks:
Entrainment/ Competence	Largest particle from bar sample (mm): **0**	$\tau =$ **0** $\tau^* =$ **#####**	Existing $depth_{bkf}$: Required $depth_{bkf}$:	Existing $slope_{bkf}$: Required $slope_{bkf}$:
Successional Stage Shift	→ → → → →		Existing stream state (type): **E6**	Potential stream state (type): **E6**
Lateral Stability	☐ Stable ☑ Mod. unstable ☐ Unstable ☐ Highly unstable			Remarks/causes: **None**
Vertical Stability (Aggradation)	☑ No deposition ☐ Mod. deposition ☐ Ex. deposition ☐ Aggradation			Remarks/causes: **None**
Vertical Stability (Degradation)	☐ Not incised ☑ Slightly incised ☐ Mod. incised ☐ Degradation			Remarks/causes: **None**
Channel Enlargement	☐ No increase ☑ Slight increase ☐ Mod. increase ☐ Extensive			Remarks/causes: **None**
Sediment Supply (Channel Source)	☐ Low ☑ Moderate ☐ High ☐ Very high			Remarks/causes: **None**

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Sheyenne River**			Location: **Sheyenne River-4-22.27**		
Observers: **KP, AL**	Reference reach		Disturbed (impacted reach)	**X**	Date: **10/1/2011**
Existing species composition:			Potential species composition:		

	Riparian cover categories	Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**75%**	**3%**		**100%**
2. Understory	Shrub layer		**10%**		**100%**
3. Ground level	Herbaceous		**7%**		**100%**
3. Ground level	Leaf or needle litter		**20%**		
3. Ground level	Bare ground		**60%**		
			Column total = 100%		

Remarks:
Condition, vigor and/or usage of existing reach:

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

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Sheyenne River**				Location: **Sheyenne River-4-22.27**				
Observers: **KP, AL**							Date: **10/1/2011**	
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P7**	**P9**				

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order			
Stream:	**Sheyenne River**		
Location:	**Sheyenne River-4-22.27**		
Observers:	**KP, AL**		
Date:	**10/1/2011**		
Stream Size Category and Order ☞			**S-4**
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).			

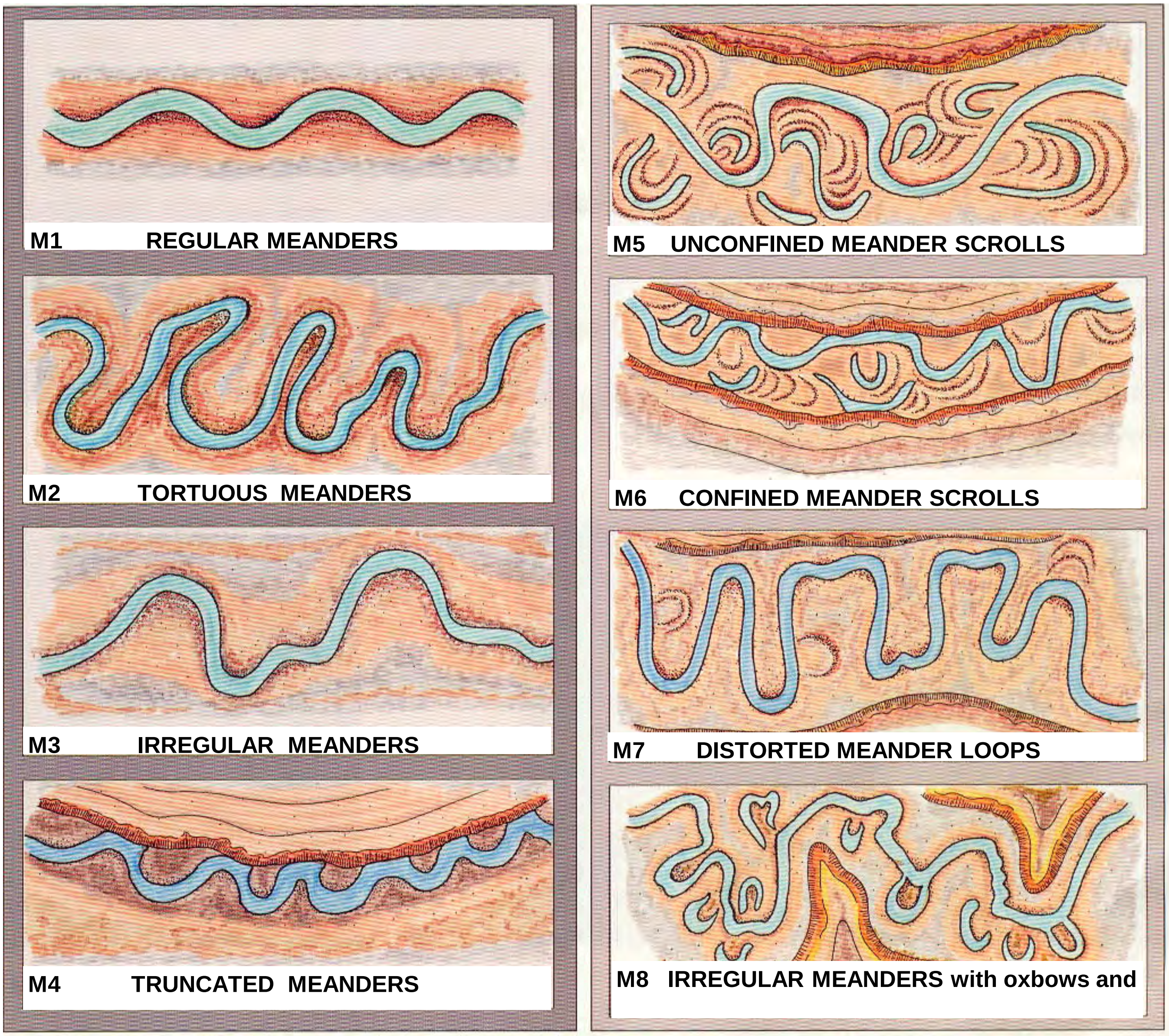
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Sheyenne River**	Reach:	**Sheyenne River-4-22.27**
Observers:	**KP, AL**	Date:	**10/1/2011**

List ALL CATEGORIES that APPLY ☞	M2				

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

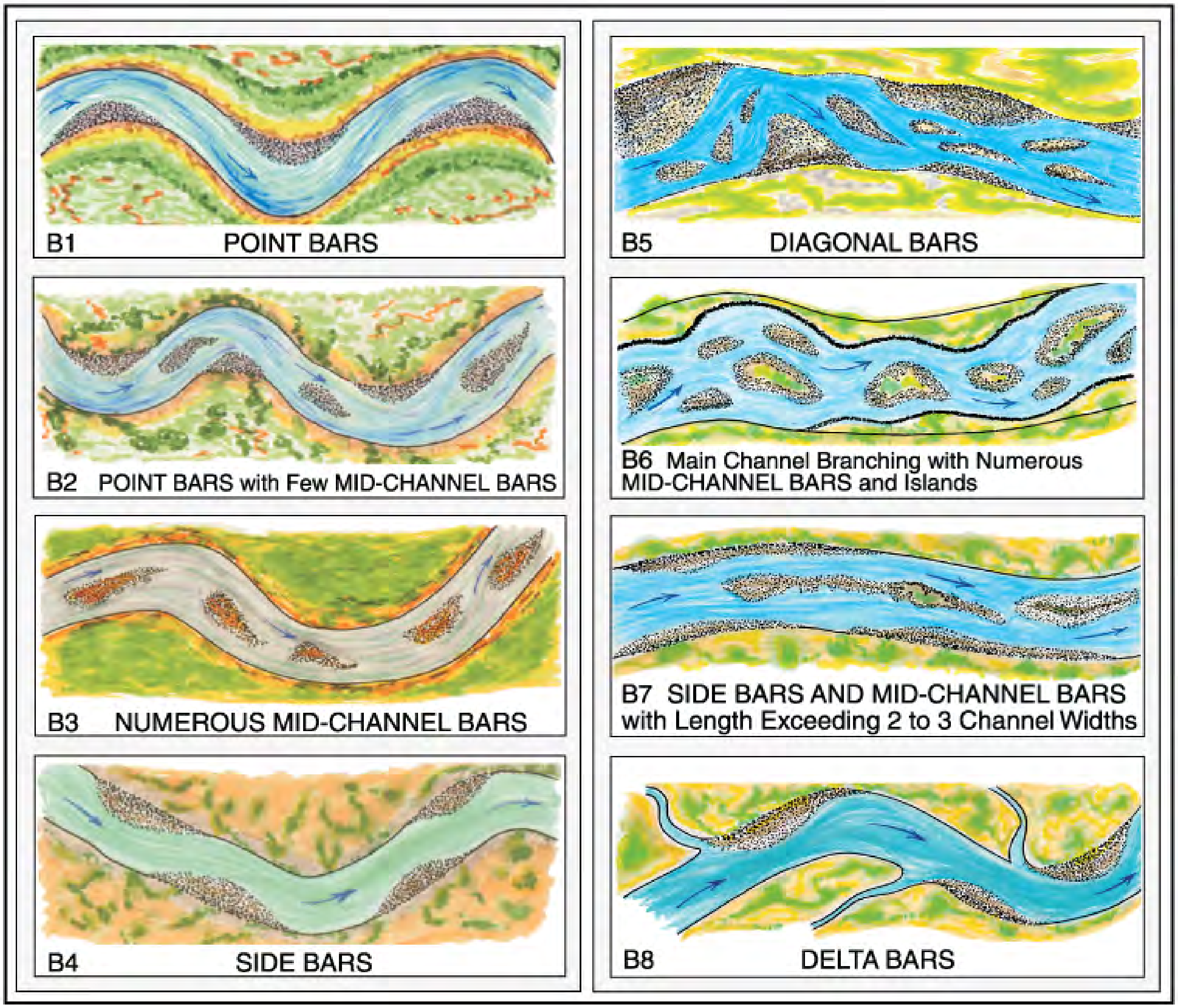


Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns			
Stream:	**Sheyenne River**	Reach:	**Sheyenne River-4-22.27**
Observers:	**KP, AL**	Date:	**10/1/2011**

List ALL CATEGORIES that APPLY ☞	**N/A**				

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

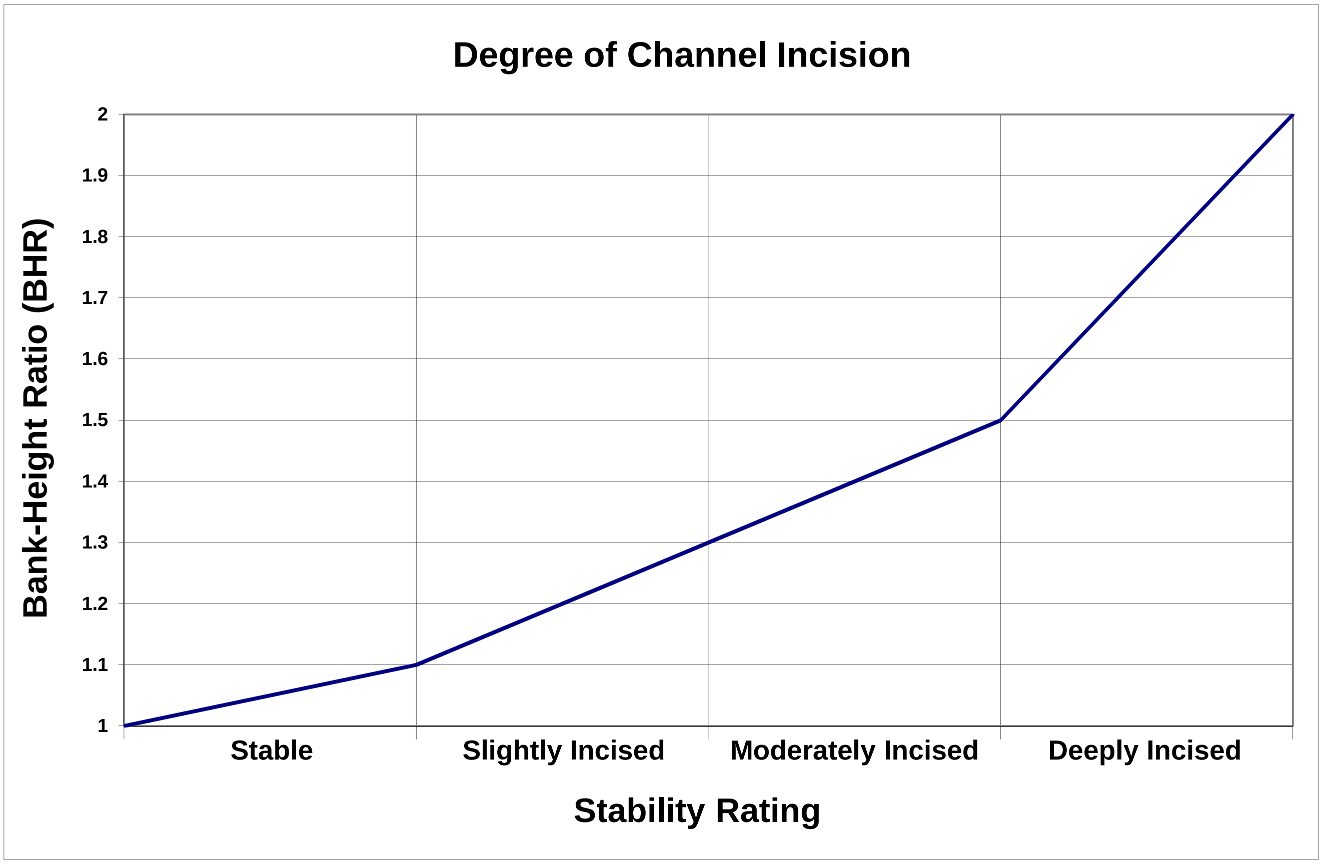


Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Sheyenne River**		Location: **Sheyenne River-4-22.27**	
Observers: **KP, AL**		Date: **10/1/2011**	
Description/extent		**Materials that 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.	☐

Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision	
Low Bank Height:	17.7
Max Bankfull Depth:	12.81
Bank-Height Ratio:	1.4
Degree of Channel Incision Stability Rating ☞	Moderately Incised

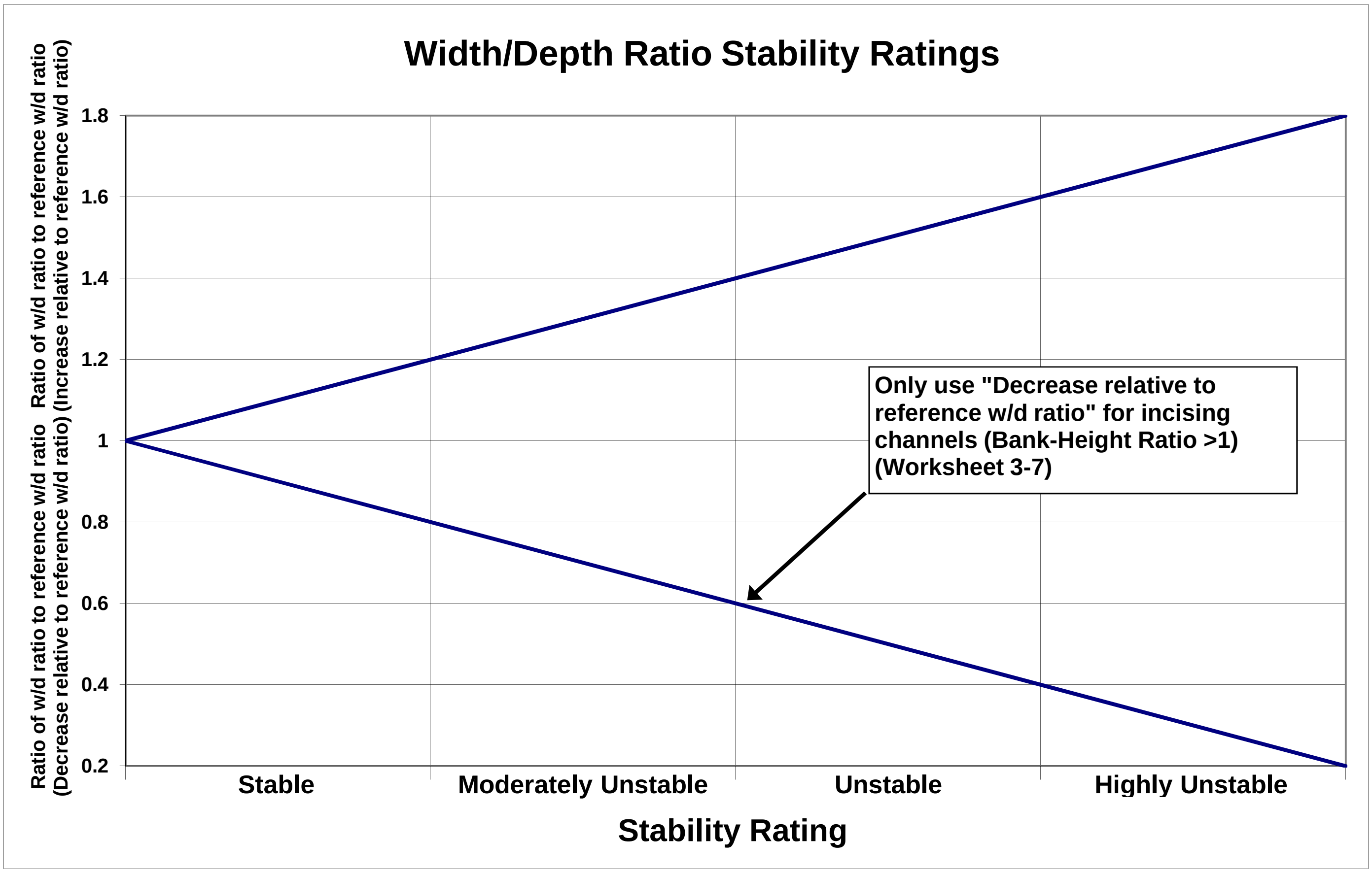


Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State

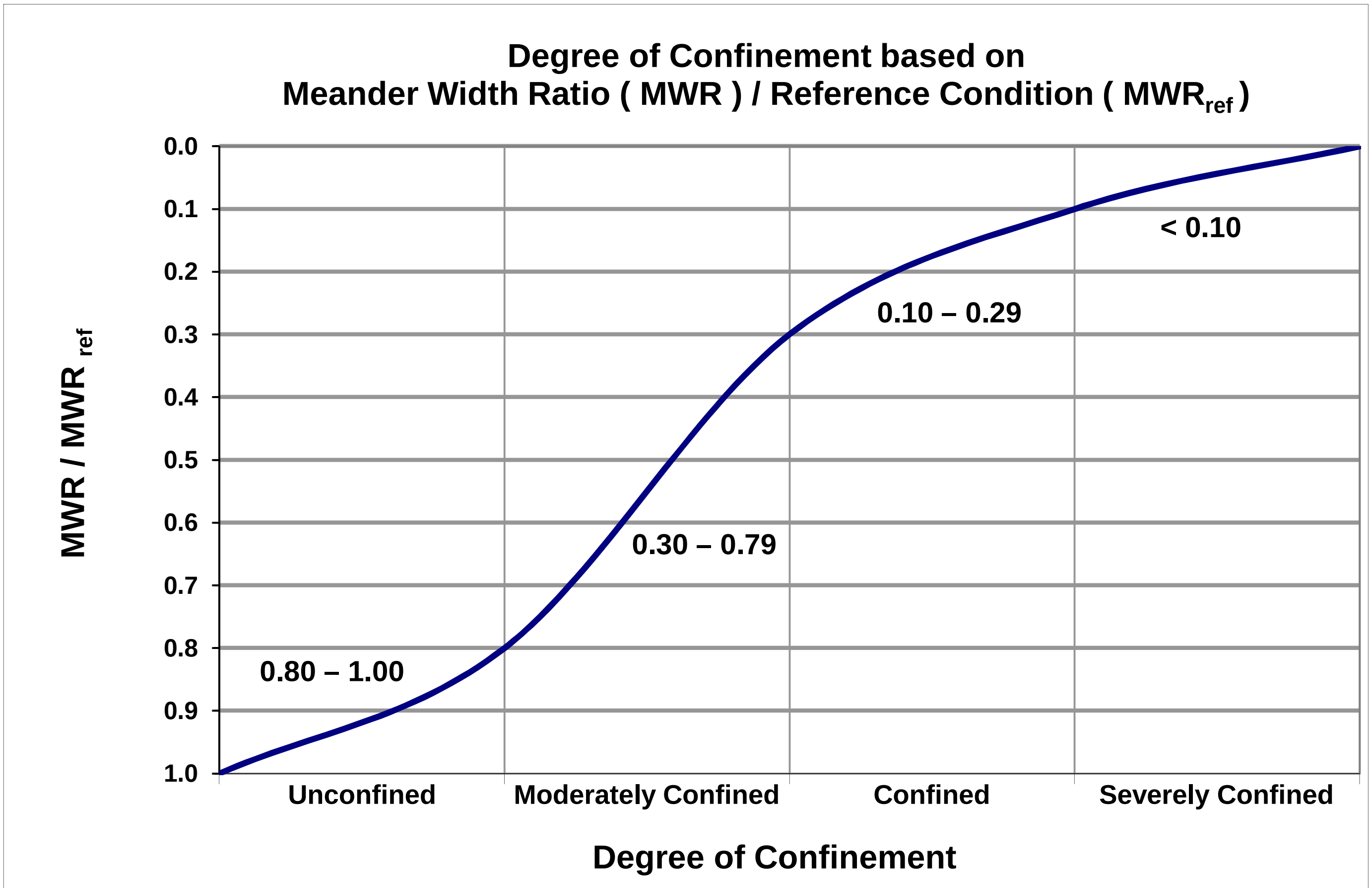
Existing Width/Depth Ratio:	8.4	Ratio of existing W/d to reference W/d:	1
Reference Width/Depth Ratio:	8.4		

Width/Depth Ratio State Stability Rating ☞	**Stable**



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	12.9	Ratio of MWR to MWR_{ref}:	1
Reference Meander Width Ratio (MWR_{ref}):	12.9		
Degree of Confinement Stability Rating ☞	**Unconfined**		



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Sheyenne River **Location:** Sheyenne River-4-22.2 **Valley Type:** X **Observers:** KP, AL **Date:** 10/1/2011

Location	Key	Category	Excellent Description	Excellent Rating	Good Description	Good Rating	Fair Description	Fair Rating	Poor Description	Poor Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	**6**	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	**12**
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	**2**	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	**12**
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	**8**
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	**2**	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	**16**
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	**23**	**Good total =**	**0**	**Fair total =**	**6**	**Poor total =**	**52**

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	**81**
Existing stream type =	**E6**
***Potential stream type =**	**E6**
Modified channel stability rating =	**Fair**

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream:	**Sheyenne River**	Location:	**Sheyenne River-4-22.27**
Station:		Observers:	**KP, AL**
Date: **10/1/2011**	Stream Type: **E6**	Valley Type: **X**	

Variable					Result	BEHI Score (Fig. 3-7)
Study Bank Height / Bankfull Height (C)	**Study Bank Height** (ft) = **17.7 (A)**	**Bankfull Height** (ft) = **10.1 (B)**		(A) / (B) =	**1.8 (C)**	**7**
Root Depth / Study Bank Height (E)	**Root Depth** (ft) = **1 (D)**	**Study Bank Height** (ft) = **17.7 (A)**		(D) / (A) =	**0.1 (E)**	**8**
Weighted Root Density (G)		**Root Density** as **%** = **20% (F)**		(F) x (E) =	**1% (G)**	**10**
Bank Angle (H)				**Bank Angle** as *Degrees* =	**31 (H)**	**2**
Surface Protection (I)				**Surface Protection** as **%** =	**2% (I)**	**10**

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)

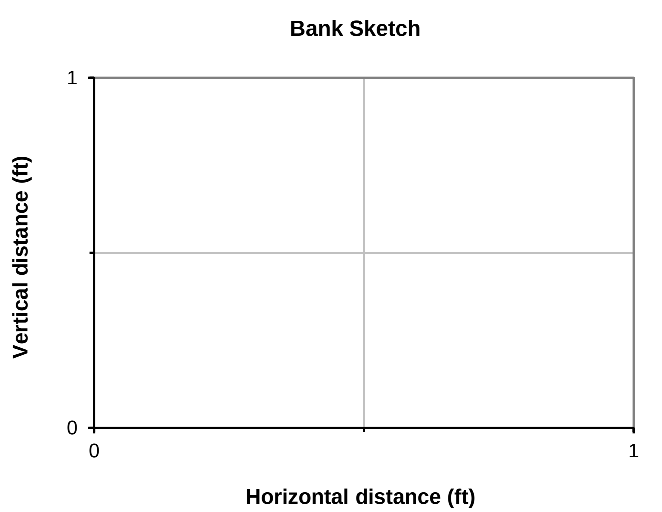
Bank Material Adjustment: **0**

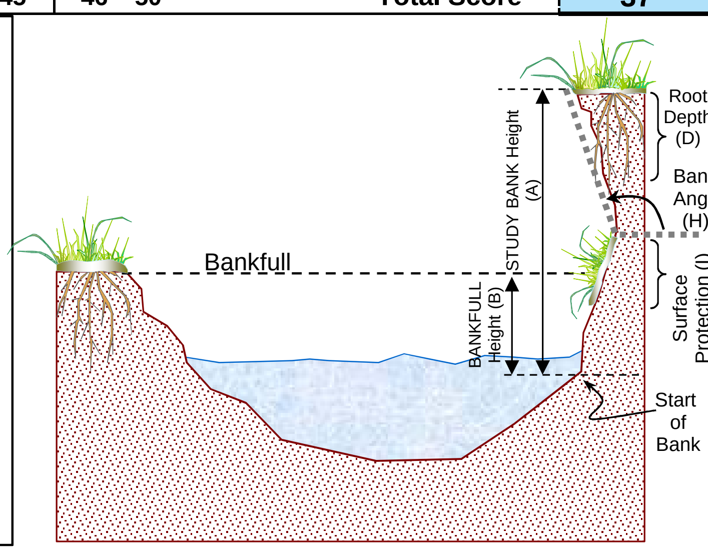
Stratification Adjustment

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**: **High** / **37**





Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Sheyenne River** Location: **Sheyenne River-4-22.27**

Station: **0** Stream Type: **E6** Valley Type: **X**

Observers: **KP, AL** Date: **10/1/11**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})..	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S).....................................	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})...	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})...........................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient...	Level IV	Validation

Level I

(1)
- Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
- Extensive deposition (continuous, cross-channel)................................... ....NBS = Extreme
- Chute cutoffs, down-valley meander migration, converging flow.......................................NBS = Extreme

Level II

	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)
(2)				

	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)
(3)				

	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)
(4)				

Dominant Near-Bank Stress
Very Low

Level III

	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)
(5)				

	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)
(6)								

Level IV

	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
(7)		**Very Low**

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating	Very Low

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Sheyenne River**			Location: **Sheyenne River-4-22.27**			
Graph Used:	**Fig 3-9**	Total Bank Length (ft): **2881.7**				Date: **10/1/2011**	
Observers:	**KP, AL**		Valley Type: **X**			Stream Type: **E6**	
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**2881.7**	**17.7**	**8416**	**0.14**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**8416**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**312**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**405**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.14**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Sheyenne River**			Stream Type:	**E6**
Location:	**Sheyenne River-4-22.27**			Valley Type:	**X**
Observers:	**KP, AL**			Date:	**10/1/2011**

Enter Required Information for Existing Condition

	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
0	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	**#DIV/0!**

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	d	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	S	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Sediment Competence Using Dimensional Shear Stress

0	Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope	
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**	
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**	
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope	$d = \dfrac{\tau}{\gamma S}$
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth	$S = \dfrac{\tau}{\gamma d}$

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis

Observers: **KP, AL**

Stream: **Sheyenne River** | Location: **Sheyenne River-4-22.27** | Date: **10/1/2011**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		**100%**

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	**0**
Materials less than:	mm

Be sure to add separate material weights to grand total

0

GRAND TOTAL

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Sheyenne River**	Stream Type: **E6**
Location: **Sheyenne River-4-22.27**	Valley Type: **X**
Observers: **KP, AL**	Date: **10/1/2011**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream:	Sheyenne River	Stream Type:	E6
Location:	Sheyenne River-4-22.27	Valley Type:	X
Observers:	KP, AL	Date:	10/1/2011

Lateral stability criteria (choose one stability category for each criterion 1–5)	Lateral Stability Categories: Stable	Moderately unstable	Unstable	Highly unstable	Selected points (from each row)
1 W/d ratio state (Worksheet 3-8)	< 1.2 (2)	1.2 – 1.4 (4)	1.4 – 1.6 (6)	> 1.6 (8)	2
2 Depositional pattern (Worksheet 3-5)	B1, B2 (1)	B4, B8 (2)	B3 (3)	B5, B6, B7 (4)	1
3 Meander pattern (Worksheet 3-4)	M1, M3, M4 (1)		M2, M5, M6, M7, M8 (3)		3
4 Dominant BEHI / NBS (Worksheet 3-13)	L/VL, L/L, L/M, L/H, L/VH, M/VL (2)	M/L, M/M, M/H, L/Ex, H/L (4)	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL (6)	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex (8)	4
5 Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)	0.8 – 1.0 (1)	0.3 – 0.79 (2)	0.1 – 0.29 (3)	< 0.1 (4)	1
				Total points	11

	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 ☐

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream: **Sheyenne River**			Stream Type: **E6**		
Location: **Sheyenne River-4-22.27**			Valley Type: **X**		
Observers: **KP, AL**			Date: **10/1/2011**		
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 3-14)**	Sufficient depth and/or slope to transport largest size available **(2)**	Trend toward insufficient depth and/or slope-slightly incompetent **(4)**	Cannot move D_{35} of bed material and/or D_{100} of bar material **(6)**	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size **(8)**	**2**
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load **(2)**	Trend toward insufficient sediment capacity **(4)**	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand **(6)**	Reduction over 25% of annual sediment yield for bedload and/or suspended sand **(8)**	**6**
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	>1.6 **(8)**	**2**
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation **(2)**	(E→C) **(4)**	(C→High W/d C), (B→High W/d B), (C→F) **(6)**	(C→D), (F→D) **(8)**	**2**
5 **Depositional patterns (Worksheet 3-5)**	B1 **(1)**	B2, B4 **(2)**	B3, B5 **(3)**	B6, B7, B8 **(4)**	**1**
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 **(1)**	D4, D7 **(2)**	D5, D8 **(3)**	D6, D9, D10 **(4)**	**1**
				Total points	**14**
	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** ☐	

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream: **Sheyenne River**			Stream Type: **E6**		
Location: **Sheyenne River-4-22.27**			Valley Type: **X**		
Observers: **KP, AL**			Date: **10/1/2011**		
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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	**2**
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	**2**
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	**6**
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	**4**
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	**1**
				Total points	**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** ☐	

Worksheet 3-20. Channel enlargement prediction summary.

Stream:	**Sheyenne River**			Stream Type:	**E6**
Location:	**Sheyenne River-4-22.27**			Valley Type:	**X**
Observers:	**KP, AL**			Date:	**10/1/2011**

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 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) **(2)**	(C→High W/d C), (E→C) **(4)**	(G→F), (F→D) **(6)**	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) **(8)**	**2**
2 **Lateral stability (Worksheet 3-17)**	Stable **(2)**	Moderately unstable **(4)**	Unstable **(6)**	Highly unstable **(8)**	**4**
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition **(2)**	Moderate deposition **(4)**	Excess deposition **(6)**	Aggradation **(8)**	**2**
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised **(2)**	Slightly incised **(4)**	Moderately incised **(6)**	Degradation **(8)**	**4**
				Total points	**12**

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

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream: **Sheyenne River**		Stream Type:	**E6**
Location: **Sheyenne River-4-22.27**		Valley Type:	**X**
Observers: **KP, AL**		Date:	**10/1/2011**

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	Stability Rating	Points	Selected Points
1 Lateral stability (Worksheet 3-17)	Stable	1	2
	Mod. unstable	2	
	Unstable	3	
	Highly unstable	4	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition	1	1
	Mod. deposition	2	
	Excess deposition	3	
	Aggradation	4	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	2
	Slightly incised	2	
	Mod. Incised	3	
	Degradation	4	
4 Channel enlargement prediction (Worksheet 3-20)	No increase	1	2
	Slight increase	2	
	Mod. increase	3	
	Extensive	4	
5 Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	2
	Fair: mod unstable	2	
	Poor: unstable	4	
		Total Points	9

	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 ☐

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Sheyenne River**		Location: **Sheyenne River-4-22.27**		
Observers:	**KP, AL**	Date: **10/1/2011**	Stream Type: **E6**	Valley Type: **X**	
Channel Dimension	Mean bankfull depth (ft): **8.56**	Mean bankfull width (ft): **71.48**	Cross-section area (ft^2): **571.8**	Width of flood-prone area (ft): **535.6667**	Entrenchment ratio: **7.5**
Channel Pattern	Mean: / Range:	MWR: **12.9**	Lm/W_{bkf}: **12.9**	Rc/W_{bkf}: **2.5**	Sinuosity: **1.75**
River Profile and Bed Features	Check: [ ] Riffle/pool [ ] Step/pool [ ] Plane bed [ ] Convergence/divergence [x] Dunes/antidunes/smooth bed				
	Max bankfull depth (ft): Riffle **12.8**; Pool	Depth ratio (max/mean): Riffle **1.5**; Pool	Pool to pool spacing: Ratio	Slope: Valley:	Average bankfull: **0.00033**
Level III Stream Stability Indices	Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:	
	Flow regime: **P1, 2, 7, 9**	Stream size and order: **S-4**	Meander pattern(s): **M2**	Depositional pattern(s): **NONE**	Debris/channel blockage(s): **D2**
	Degree of incision (Bank-Height Ratio): **1.4**	Degree of incision stability rating: **Moderately Incised**	Modified Pfankuch stability rating (numeric and adjective rating): **Fair**		
	Width/depth ratio (W/d): **8.4**	Reference W/d ratio (W/d_{ref}): **8.4**	Width/depth ratio state $(W/d) / (W/d_{ref})$: **1.0**	W/d ratio state stability rating: **Stable**	
	Meander Width Ratio (MWR): **12.9**	Reference MWR_{ref}: **12.9**	Degree of confinement (MWR / MWR_{ref}): **1.0**	MWR / MWR_{ref} stability rating: **Unconfined**	
Bank Erosion Summary	Length of reach studied (ft): **2882**	Annual streambank erosion rate: **405** (tons/yr) **0.14** (tons/yr/ft)	Curve used: **Fig 3-9**	Remarks:	
Sediment Capacity (POWERSED)	[ ] Sufficient capacity	[ ] Insufficient capacity	[ ] Excess capacity	Remarks:	
Entrainment/ Competence	Largest particle from bar sample (mm): **0**	$\tau =$ **0**	$\tau^* =$ **#####**	Existing $depth_{bkf}$: / Required $depth_{bkf}$:	Existing $slope_{bkf}$: / Required $slope_{bkf}$:
Successional Stage Shift	→ → → → →		Existing stream state (type): **E6**	Potential stream state (type): **E6**	
Lateral Stability	[ ] Stable	[x] Mod. unstable	[ ] Unstable	[ ] Highly unstable	Remarks/causes:
Vertical Stability (Aggradation)	[x] No deposition	[ ] Mod. deposition	[ ] Ex. deposition	[ ] Aggradation	Remarks/causes:
Vertical Stability (Degradation)	[ ] Not incised	[x] Slightly incised	[ ] Mod. incised	[ ] Degradation	Remarks/causes:
Channel Enlargement	[ ] No increase	[x] Slight increase	[ ] Mod. increase	[ ] Extensive	Remarks/causes:
Sediment Supply (Channel Source)	[ ] Low	[x] Moderate	[ ] High	[ ] Very high	Remarks/causes:

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Sheyenne River**			Location: **Sheyenne River-5-26.47**	
Observers: **KP, AL**	Reference reach		Disturbed (impacted reach) **X**	Date: **10/5/2011**
Existing species composition:			Potential species composition:	

Riparian cover categories		Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**80%**	**3%**		
					100%
2. Understory	Shrub layer		**40%**		
					100%
3. Ground level	Herbaceous		**27%**		
					100%
	Leaf or needle litter		**10%**	**Remarks:** Condition, vigor and/or usage of existing reach:	
	Bare ground		**20%**		
			Column total = 100%		

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

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Sheyenne River**			Location: **Sheyenne River-5-26.47**					
Observers: **KP, AL**						Date: **10/5/2011**		
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P7**	**P8**	**P9**			

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order			
Stream:	**Sheyenne River**		
Location:	**Sheyenne River-5-26.47**		
Observers:	**KP, AL**		
Date:	**10/5/2011**		
Stream Size Category and Order ☞			**S-6**
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).			

Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

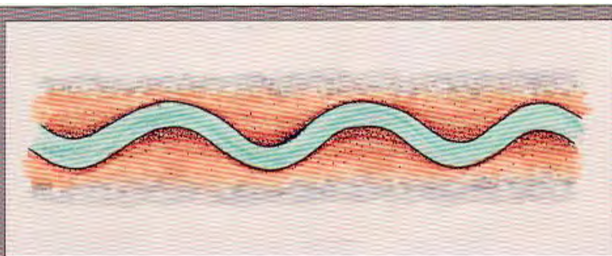
Meander Patterns

Stream: **Sheyenne River** Reach: **Sheyenne River-5-26.47**

Observers: **KP, AL** Date: **10/5/2011**

List ALL CATEGORIES that APPLY ☞	M2				

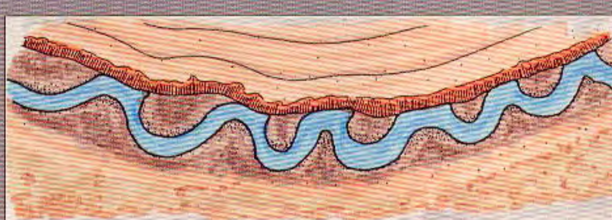
Various Meander Pattern variables modified from Galay et al. (1973)



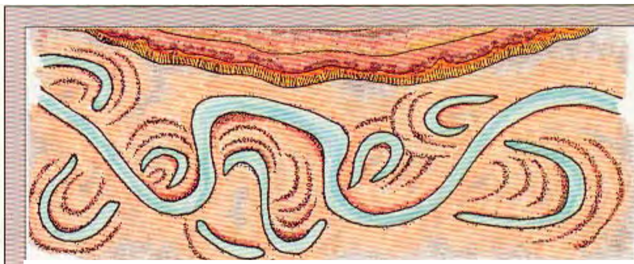
M1 REGULAR MEANDERS

M2 TORTUOUS MEANDERS

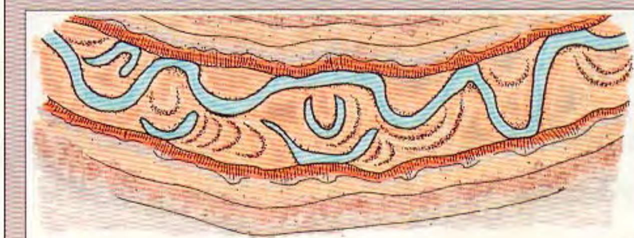
M3 IRREGULAR MEANDERS



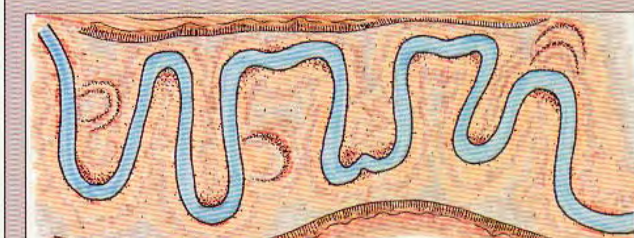
M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS



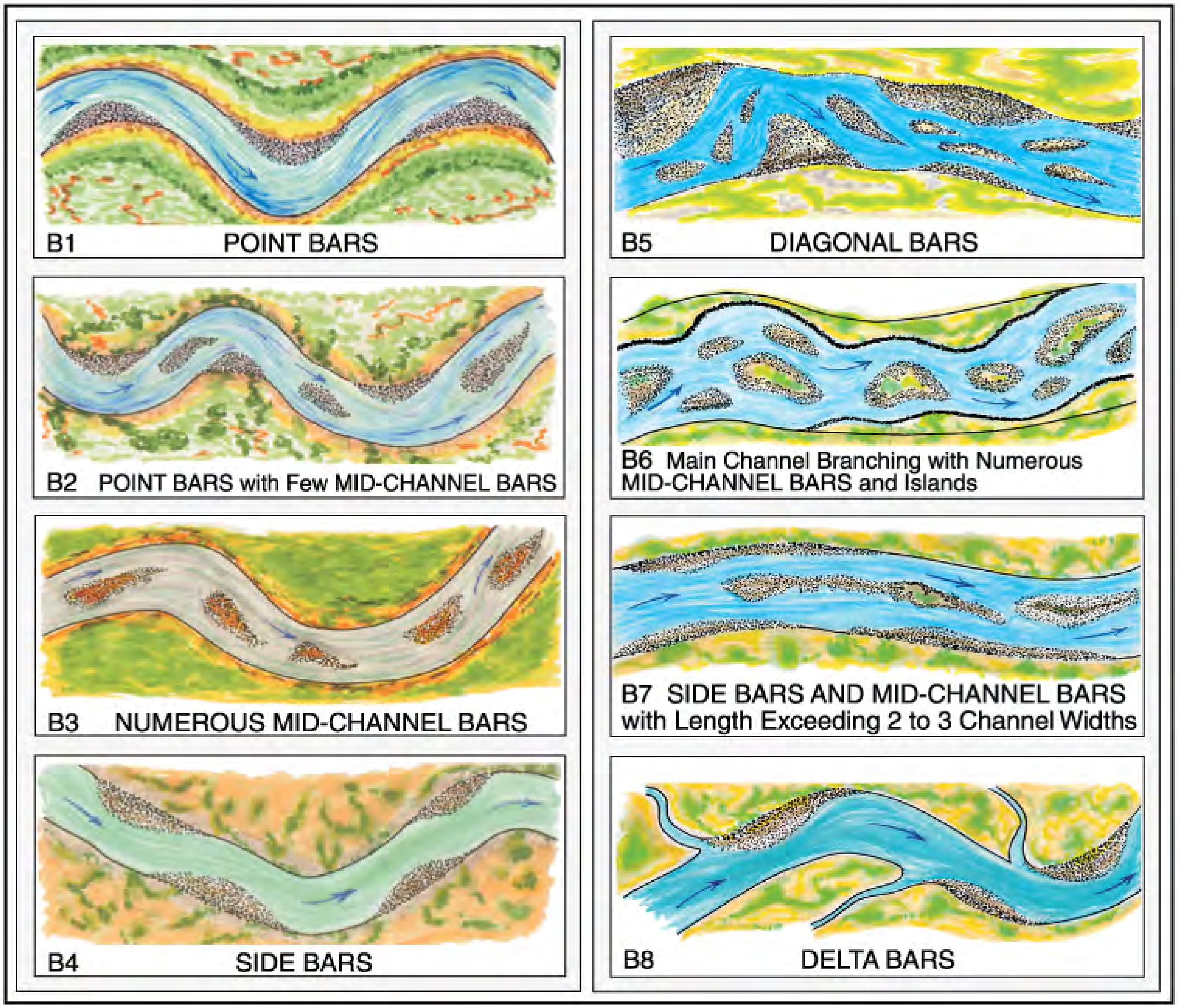
M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns						
Stream: **Sheyenne River**			Reach: **Sheyenne River-5-26.47**			
Observers: **KP, AL**			Date: **10/5/2011**			
List ALL CATEGORIES that APPLY ☞	**N/A**					

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



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Sheyenne River**		Location: **Sheyenne River-5-26.47**	
Observers: **KP, AL**		Date: **10/5/2011**	
Description/extent		**Materials that 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.	☐

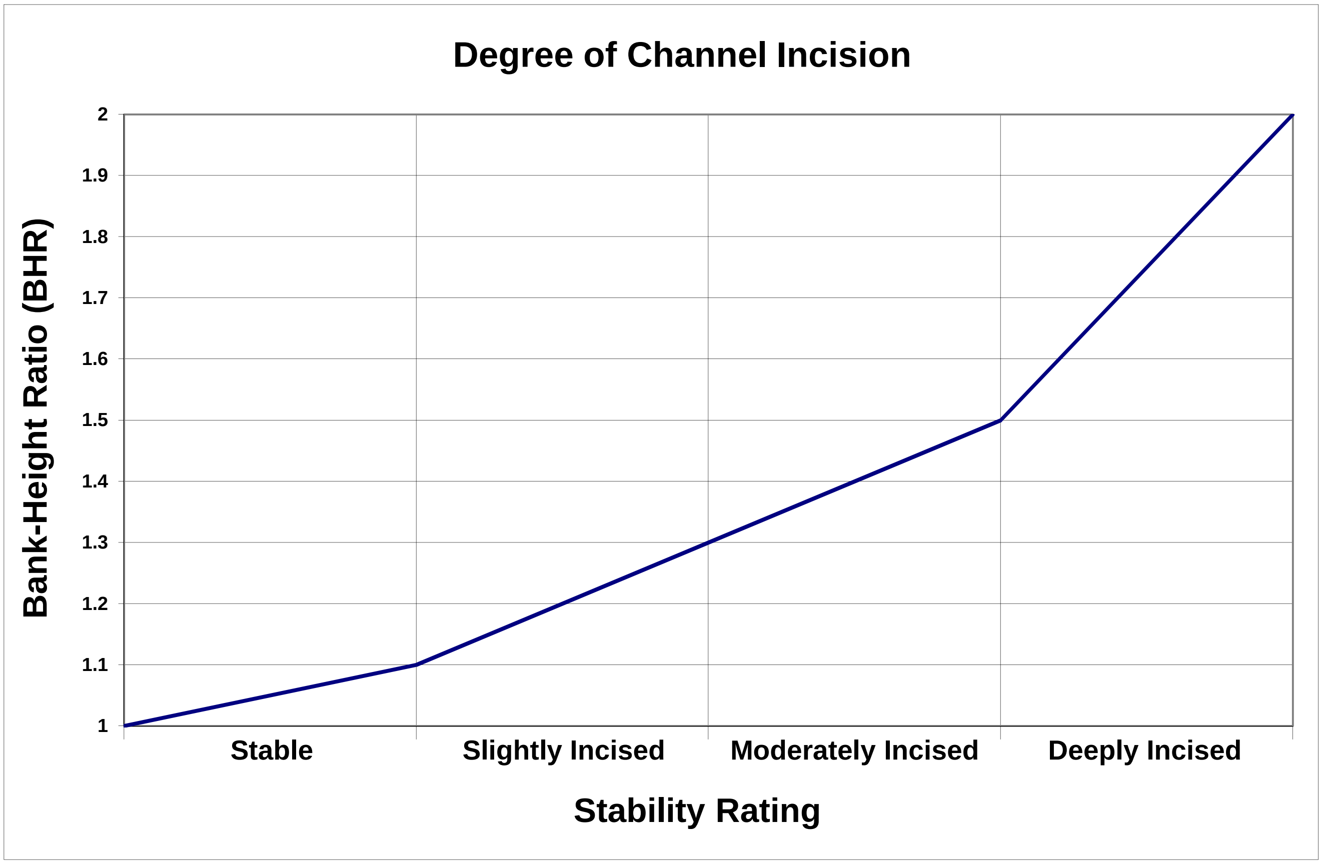
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision

Low Bank Height:	**11.8**
Max Bankfull Depth:	**9.887**

Bank-Height Ratio:	**1.2**

Degree of Channel Incision Stability Rating ☞	**Slightly Incised**

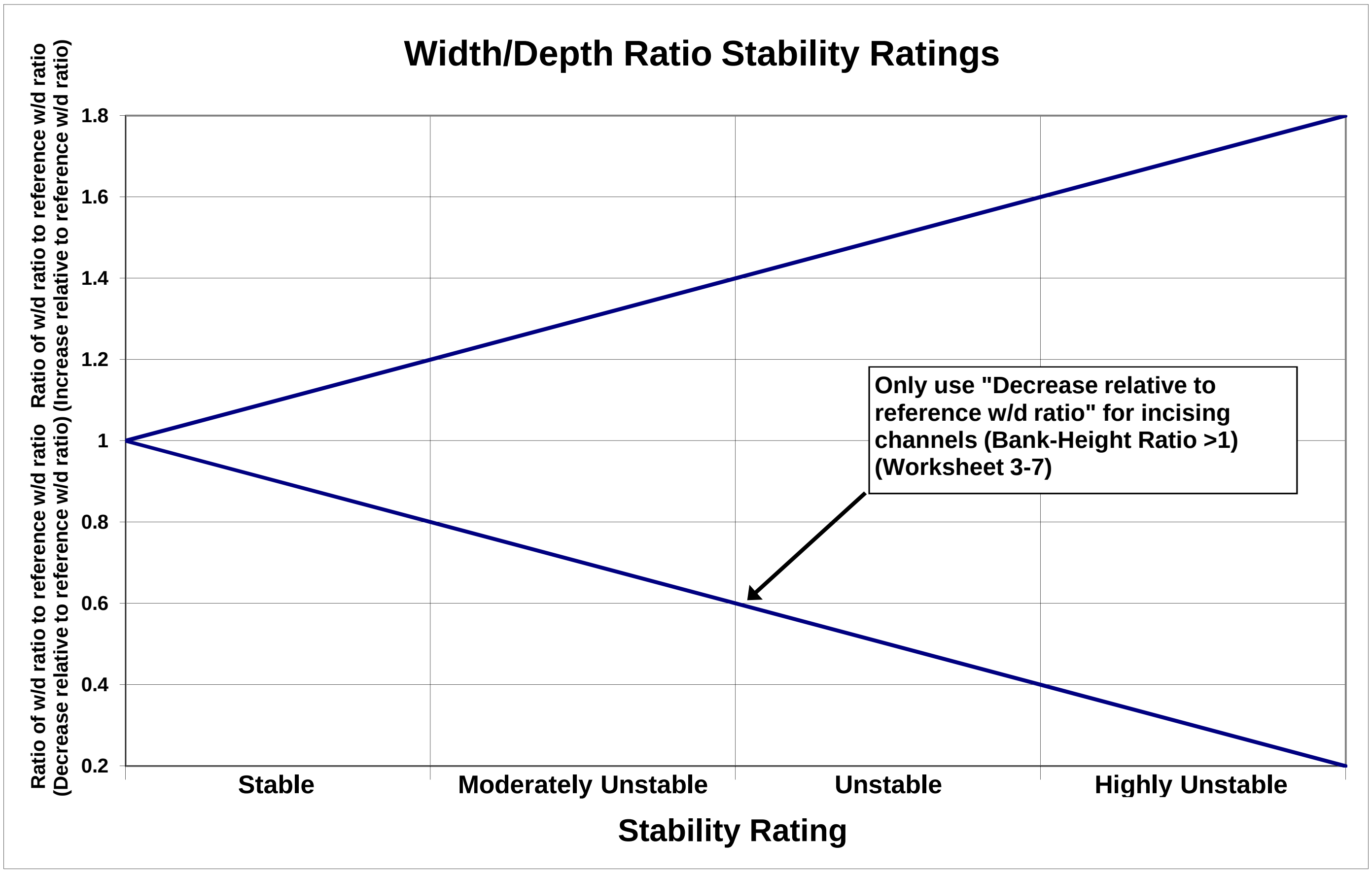


Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State

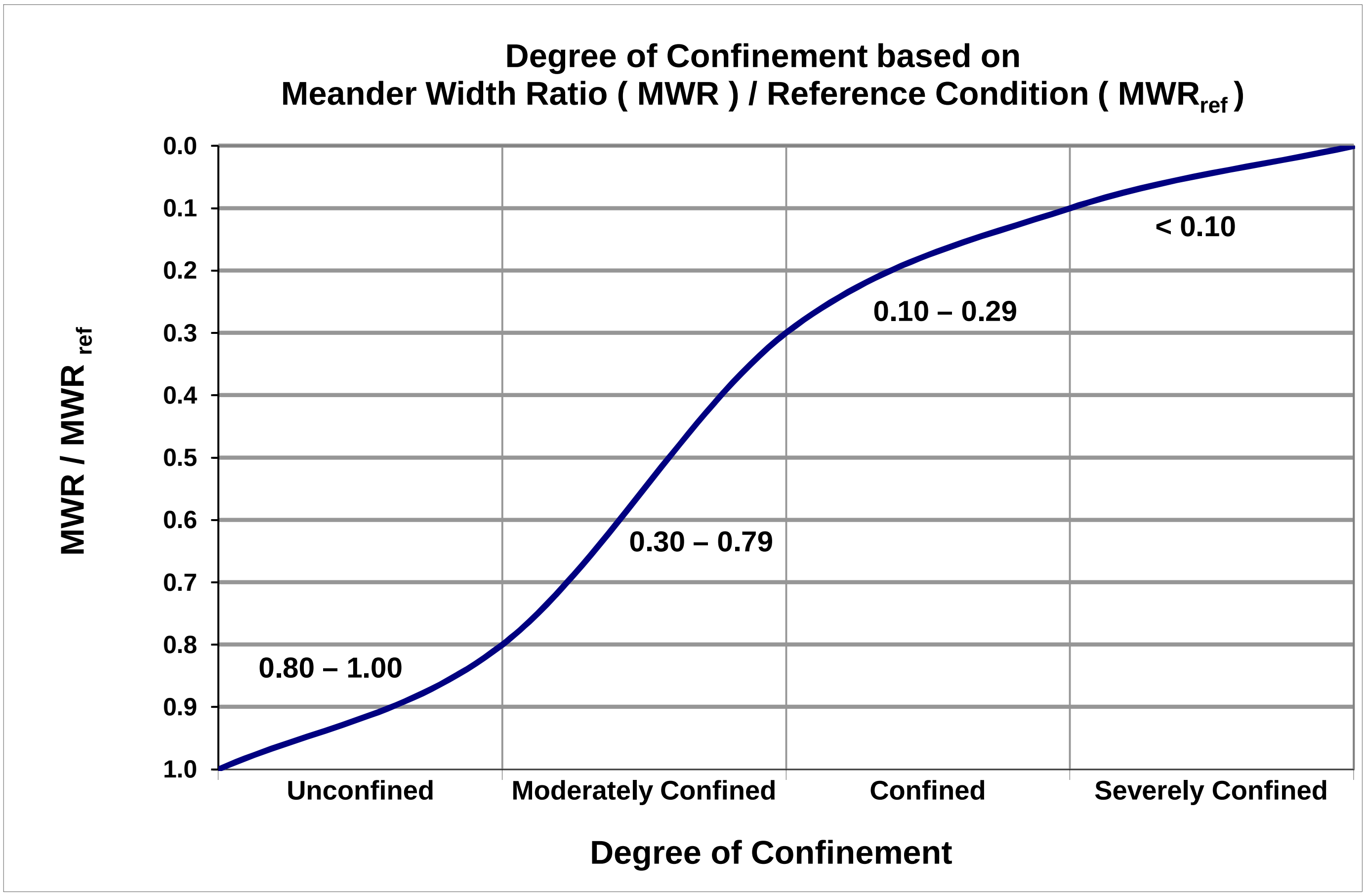
Existing Width/Depth Ratio:	**10.4**	Ratio of existing W/d to reference W/d:	**1**
Reference Width/Depth Ratio:	**10.4**		

Width/Depth Ratio State Stability Rating ☞	**Stable**



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	**13.5**	Ratio of MWR to MWR_{ref}:	**1**
Reference Meander Width Ratio (MWR_{ref}):	**13.5**		
Degree of Confinement Stability Rating ☞		**Unconfined**	



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Sheyenne River **Location:** Sheyenne River-5-26.4 **Valley Type:** X **Observers:** KP, AL **Date:** 10/5/2011

Location	Key	Category	Excellent Description	Excellent Rating	Good Description	Good Rating	Fair Description	Fair Rating	Poor Description	Poor Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	**6**	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	**9**	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	**6**	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	**9**	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	1	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	**2**	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	**8**
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	**4**	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	**12**	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	18	Good total =	6	Fair total =	42	Poor total =	12

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	78
Existing stream type =	E5
*Potential stream type =	E5
Modified channel stability rating =	Fair

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream: **Sheyenne River**	Location: **Sheyenne River-5-26.47**
Station:	Observers: **KP, AL**
Date: **10/5/2011** Stream Type: **E5**	Valley Type: **X**

Variable	Input 1		Input 2		Formula	Result	BEHI Score (Fig. 3-7)
Study Bank Height / Bankfull Height (C)	**Study Bank Height** (ft) =	**14.2** **(A)**	**Bankfull Height** (ft) =	**8.2** **(B)**	(**A**) / (**B**) =	**1.7** **(C)**	**7**
Root Depth / Study Bank Height (E)	**Root Depth** (ft) =	**3** **(D)**	**Study Bank Height** (ft) =	**14.2** **(A)**	(**D**) / (**A**) =	**0.2** **(E)**	**7**
Weighted Root Density (G)			**Root Density** as **%** =	**30%** **(F)**	(**F**) x (**E**) =	**6%** **(G)**	**9**
Bank Angle (H)					**Bank Angle** as *Degrees* =	**32** **(H)**	**3**
Surface Protection (I)					**Surface Protection** as **%** =	**0%** **(I)**	**10**

Bank Material Adjustment:

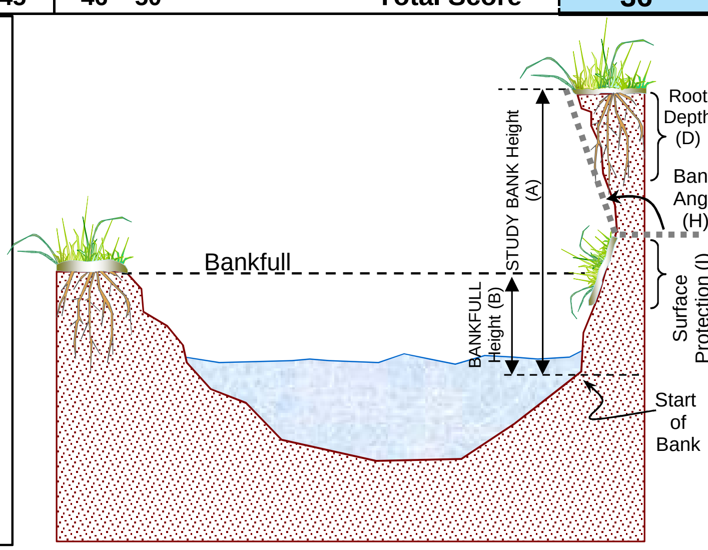
- **Bedrock** (Overall Very Low BEHI)
- **Boulders** (Overall Low BEHI)
- **Cobble** (Subtract 10 points if uniform medium to large cobble)
- **Gravel or Composite Matrix** (Add 5–10 points depending on percentage of bank material that is composed of sand)
- **Sand** (Add 10 points)
- **Silt/Clay** (no 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** **36**

Bank Sketch



Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Sheyenne River**	Location: **Sheyenne River-5-26.47**	
Station: **0**	Stream Type: **E5**	Valley Type: **X**
Observers: **KP, AL**		Date: **10/5/11**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})......................	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S)......................	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})......................	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})......................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient......................	Level IV	Validation

Level I

(1)
Transverse and/or central bars-short and/or discontinuous........................NBS = High / Very High
Extensive deposition (continuous, cross-channel)........................NBS = Extreme
Chute cutoffs, down-valley meander migration, converging flow........................NBS = Extreme

Level II

	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)
(2)				

	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)
(3)				

	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)
(4)				

Dominant Near-Bank Stress
Very Low

Level III

	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)
(5)				

	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)
(6)								

Level IV

	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
(7)		**Very Low**

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating | **Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Sheyenne River**			Location:	**Sheyenne River-5-26.47**		
Graph Used:	**Fig 3-9**	Total Bank Length (ft):	**4082**			Date:	**10/5/2011**
Observers:	**KP, AL**	Valley Type:	**X**			Stream Type:	**E5**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**4082**	**14.2**	**9564**	**0.11**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**9564**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**354**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**460**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.11**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Sheyenne River**		Stream Type: **E5**		
Location:	**Sheyenne River-5-26.47**		Valley Type: **X**		
Observers:	**KP, AL**		Date: **10/5/2011**		
Enter Required Information for Existing Condition					
	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
0	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			
Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress					
#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1: $\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$		
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2: $\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$		
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:		**#DIV/0!**
Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample					
#DIV/0!	**d**	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)	
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample					
#DIV/0!	**S**	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)	
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Sediment Competence Using Dimensional Shear Stress					
0	Bankfull shear stress $\tau = \gamma d S$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope				
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**				
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**				
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope		$d = \dfrac{\tau}{\gamma S}$		
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth		$S = \dfrac{\tau}{\gamma d}$		

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis

Observers: **KP, AL**

Stream: **Sheyenne River** | Location: **Sheyenne River-5-26.47** | Date: **10/5/2011**

Sub-samples	Catch Pan or BUCKET, Tare weight: Total	Net	Sieve SIZE mm, Tare weight: Total	Net	Sieve SIZE mm, Tare weight: Total	Net	Sieve SIZE mm, Tare weight: Total	Net	Sieve SIZE mm, Tare weight: Total	Net	Sieve SIZE mm, Tare weight: Total	Net	Sieve SIZE mm, Tare weight: Total	Net	Sieve SIZE mm, Tare weight: Total	Net	Sieve SIZE mm, Tare weight: Total	Net
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		0		0		0		0		0		0		0		0		0
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		100%

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	0
Materials less than:	mm

Be sure to add separate material weights to grand total

GRAND TOTAL: **0**

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Sheyenne River**	Stream Type: **E5**
Location: **Sheyenne River-5-26.47**	Valley Type: **X**
Observers: **KP, AL**	Date: **10/5/2011**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream:	**Sheyenne River**	Stream Type:	**E5**
Location:	**Sheyenne River-5-26.47**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**10/5/2011**

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 3-8)**	< 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	> 1.6 **(8)**	**2**
2 **Depositional pattern (Worksheet 3-5)**	B1, B2 **(1)**	B4, B8 **(2)**	B3 **(3)**	B5, B6, B7 **(4)**	**1**
3 **Meander pattern (Worksheet 3-4)**	M1, M3, M4 **(1)**		M2, M5, M6, M7, M8 **(3)**		**3**
4 **Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL **(2)**	M/L, M/M, M/H, L/Ex, H/L **(4)**	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL **(6)**	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex **(8)**	**4**
5 **Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.8 – 1.0 **(1)**	0.3 – 0.79 **(2)**	0.1 – 0.29 **(3)**	< 0.1 **(4)**	**1**
				Total points	**11**

	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** ☐

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Sheyenne River**	Stream Type:	**E5**
Location:	**Sheyenne River-5-26.47**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**10/5/2011**

Vertical stability criteria (choose one stability category for each criterion 1–6)	Vertical Stability Categories for Excess Deposition / Aggradation: No deposition	Moderate deposition	Excess deposition	Aggradation	Selected points (from each row)
1 **Sediment competence (Worksheet 3-14)**	Sufficient depth and/or slope to transport largest size available (2)	Trend toward insufficient depth and/or slope-slightly incompetent (4)	Cannot move D_{35} of bed material and/or D_{100} of bar material (6)	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size (8)	2
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load (2)	Trend toward insufficient sediment capacity (4)	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand (6)	Reduction over 25% of annual sediment yield for bedload and/or suspended sand (8)	2
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 (2)	1.2 – 1.4 (4)	1.4 – 1.6 (6)	>1.6 (8)	2
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation (2)	(E→C) (4)	(C→High W/d C), (B→High W/d B), (C→F) (6)	(C→D), (F→D) (8)	2
5 **Depositional patterns (Worksheet 3-5)**	B1 (1)	B2, B4 (2)	B3, B5 (3)	B6, B7, B8 (4)	1
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 (1)	D4, D7 (2)	D5, D8 (3)	D6, D9, D10 (4)	2
				Total points	11

Vertical stability for excess deposition / aggradation (use total points and check stability rating)	Vertical stability category point range for excess deposition / aggradation: No deposition 10 – 14	Moderate deposition 15 – 20	Excess deposition 21 – 30	Aggradation > 30
	☑	☐	☐	☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream: **Sheyenne River**			Stream Type: **E5**		
Location: **Sheyenne River-5-26.47**			Valley Type: **X**		
Observers: **KP, AL**			Date: **10/5/2011**		
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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	2
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	2
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	4
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	4
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	1
				Total points	**13**
	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** ☐	

Worksheet 3-20. Channel enlargement prediction summary.

Stream:	**Sheyenne River**			Stream Type:	**E5**
Location:	**Sheyenne River-5-26.47**			Valley Type:	**X**
Observers:	**KP, AL**			Date:	**10/5/2011**

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 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) **(2)**	(C→High W/d C), (E→C) **(4)**	(G→F), (F→D) **(6)**	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) **(8)**	**2**
2 **Lateral stability (Worksheet 3-17)**	Stable **(2)**	Moderately unstable **(4)**	Unstable **(6)**	Highly unstable **(8)**	**4**
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition **(2)**	Moderate deposition **(4)**	Excess deposition **(6)**	Aggradation **(8)**	**2**
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised **(2)**	Slightly incised **(4)**	Moderately incised **(6)**	Degradation **(8)**	**4**
				Total points	**12**

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

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream:	**Sheyenne River**	Stream Type:	**E5**
Location:	**Sheyenne River-5-26.47**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**10/5/2011**

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)		Stability Rating	Points	Selected Points
1	Lateral stability (Worksheet 3-17)	Stable	1	2
		Mod. unstable	2	
		Unstable	3	
		Highly unstable	4	
2	Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition	1	1
		Mod. deposition	2	
		Excess deposition	3	
		Aggradation	4	
3	Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	2
		Slightly incised	2	
		Mod. Incised	3	
		Degradation	4	
4	Channel enlargement prediction (Worksheet 3-20)	No increase	1	2
		Slight increase	2	
		Mod. increase	3	
		Extensive	4	
5	Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	2
		Fair: mod unstable	2	
		Poor: unstable	4	
			Total Points	9

	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 ☐

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Sheyenne River**	Location:	**Sheyenne River-5-26.47**
Observers:	**KP, AL**	Date: **10/5/2011**	Stream Type: **E5** Valley Type: **X**

Channel Dimension	Mean bankfull depth (ft):	**6.06**	Mean bankfull width (ft):	**62.74**	Cross-section area (ft^2):	**379.3**	Width of flood-prone area (ft):	**376.6667**	Entrenchment ratio:	**6.0**
Channel Pattern	Mean: Range:	MWR: **13.5**	Lm/W_{bkf}:	**13.5**	Rc/W_{bkf}:	**3.1**			Sinuosity:	**1.7**

River Profile and Bed Features

Check: ☐ Riffle/pool ☐ Step/pool ☐ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed

Max bankfull depth (ft):	Riffle	Pool	Depth ratio (max/mean):	Riffle	Pool	Pool to pool spacing:	Ratio	Slope: Valley:	Slope: Average bankfull:
	9.9			**1.6**					**0.00017**

Level III Stream Stability Indices

Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:

Flow regime:	**P1, 2, 7, 8, 9**	Stream size and order:	**S-6**	Meander pattern(s):	**M2**	Depositional pattern(s):	**NONE**	Debris/channel blockage(s):	**D4**
Degree of incision (Bank-Height Ratio):	**1.2**	Degree of incision stability rating:	**Slightly Incised**	Modified Pfankuch stability rating (numeric and adjective rating):	**Fair**				
Width/depth ratio (W/d):	**10.4**	Reference W/d ratio (W/d_{ref}):	**10.4**	Width/depth ratio state $(W/d) / (W/d_{ref})$:	**1.0**	W/d ratio state stability rating:	**Stable**		
Meander Width Ratio (MWR):	**13.5**	Reference MWR_{ref}:	**13.5**	Degree of confinement (MWR / MWR_{ref}):	**1.0**	MWR / MWR_{ref} stability rating:	**Unconfined**		

Bank Erosion Summary	Length of reach studied (ft): **4082**	Annual streambank erosion rate: **460** (tons/yr)	**0.11** (tons/yr/ft)	Curve used: **Fig 3-9**	Remarks:
Sediment Capacity (POWERSED)	☐ Sufficient capacity	☐ Insufficient capacity	☐ Excess capacity		Remarks:
Entrainment/ Competence	Largest particle from bar sample (mm): **0**	$\tau =$ **0**	$\tau^* =$ **#####**	Existing $depth_{bkf}$: / Required $depth_{bkf}$:	Existing $slope_{bkf}$: / Required $slope_{bkf}$:
Successional Stage Shift	→ → → → →			Existing stream state (type): **E5**	Potential stream state (type): **E5**
Lateral Stability	☐ Stable	☑ Mod. unstable	☐ Unstable	☐ Highly unstable	Remarks/causes:
Vertical Stability (Aggradation)	☑ No deposition	☐ Mod. deposition	☐ Ex. deposition	☐ Aggradation	Remarks/causes:
Vertical Stability (Degradation)	☐ Not incised	☑ Slightly incised	☐ Mod. incised	☐ Degradation	Remarks/causes:
Channel Enlargement	☐ No increase	☑ Slight increase	☐ Mod. increase	☐ Extensive	Remarks/causes:
Sediment Supply (Channel Source)	☐ Low	☑ Moderate	☐ High	☐ Very high	Remarks/causes:

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Sheyenne River**			Location: **Sheyenne River - 6 - 35.82**	
Observers: **KP, AL**	Reference reach	[ ]	Disturbed (impacted reach)	**X**
			Date: **11/21/2010**	
Existing species composition:			Potential species composition:	

	Riparian cover categories	Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer				
					100%
2. Understory	Shrub layer				
					100%
3. Ground level	Herbaceous				
					100%
	Leaf or needle litter				
	Bare ground				
			Column total = 100%		

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

Remarks:
Condition, vigor and/or usage of existing reach:
None

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Sheyenne River**				Location: **Sheyenne River - 6 - 35.82**				
Observers: **KP, AL**							Date: **11/21/2010**	
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P7**	**P9**				

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order

Stream:	**Sheyenne River**
Location:	**Sheyenne River - 6 - 35.82**
Observers:	**KP, AL**
Date:	**11/21/2010**
Stream Size Category and Order ☞	**S-6**

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).

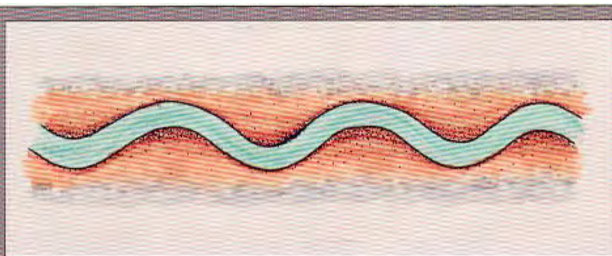
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Sheyenne River**	Reach:	**Sheyenne River - 6 - 35.82**
Observers:	**KP, AL**	Date:	**11/21/2010**

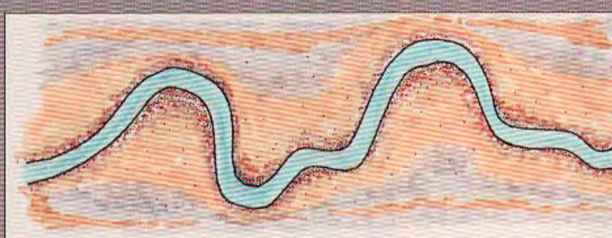
List ALL CATEGORIES that APPLY ☞	**M2**				

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

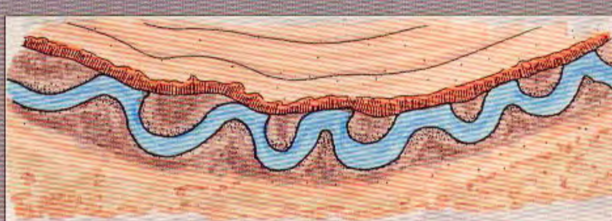


M1 REGULAR MEANDERS

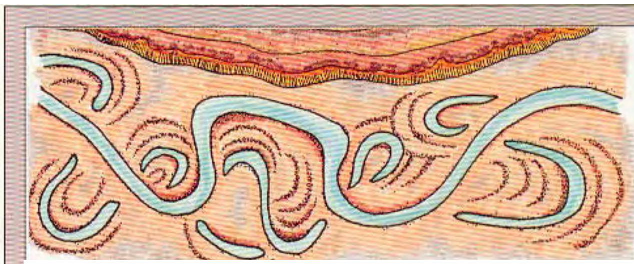
M2 TORTUOUS MEANDERS



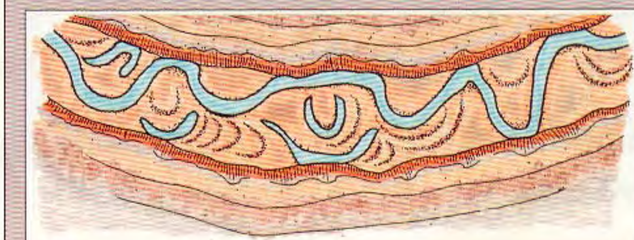
M3 IRREGULAR MEANDERS



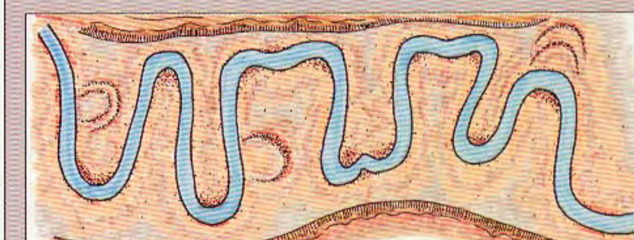
M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS



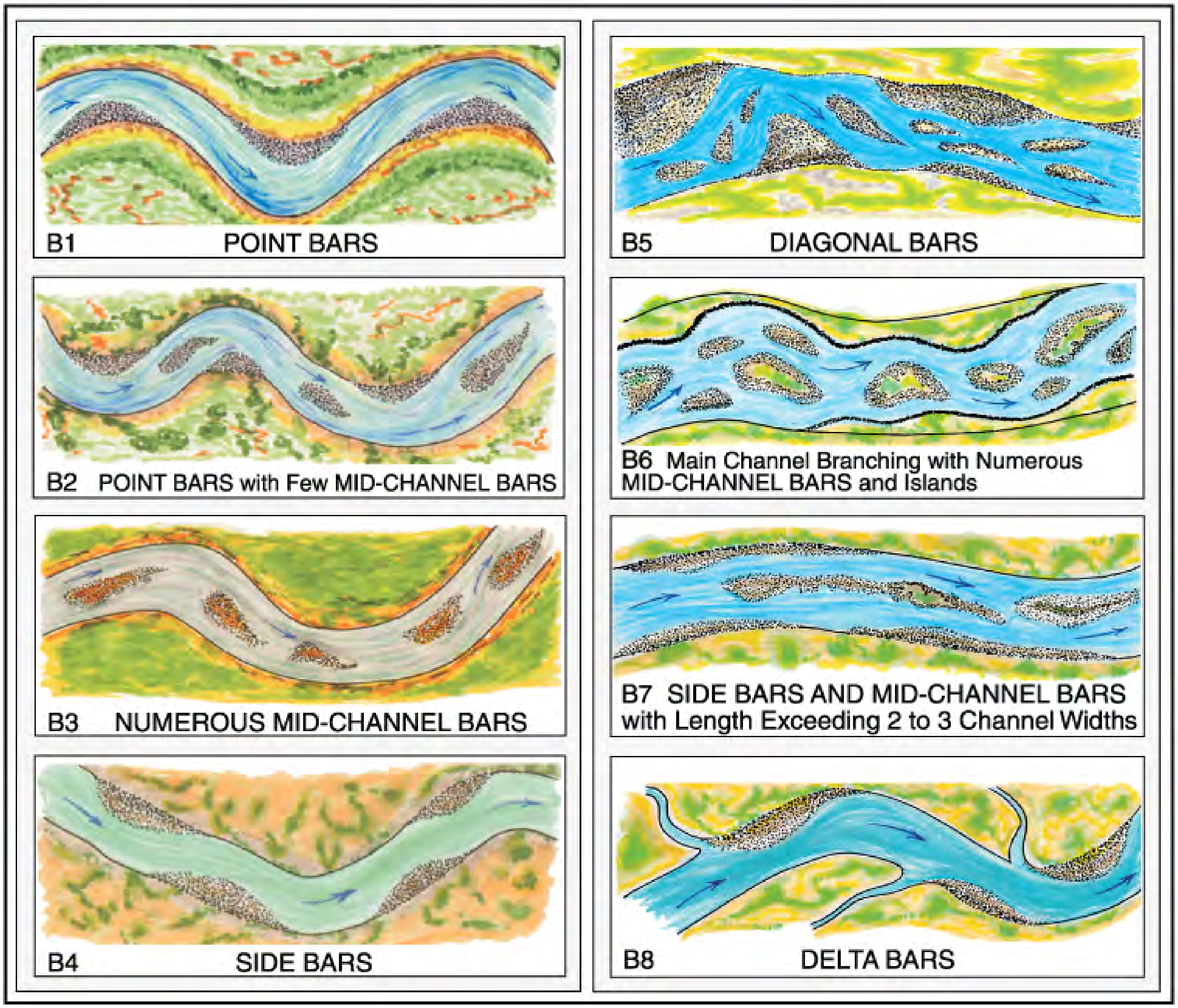
M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns					
Stream: **Sheyenne River**		Reach: **Sheyenne River - 6 - 35.82**			
Observers: **KP, AL**		Date: **11/21/2010**			
List ALL CATEGORIES that APPLY ☞	**NONE**				

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



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Sheyenne River**		Location: **Sheyenne River - 6 - 35.82**	
Observers: **KP, AL**		Date: **11/21/2010**	
Description/extent		**Materials that 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.	☐

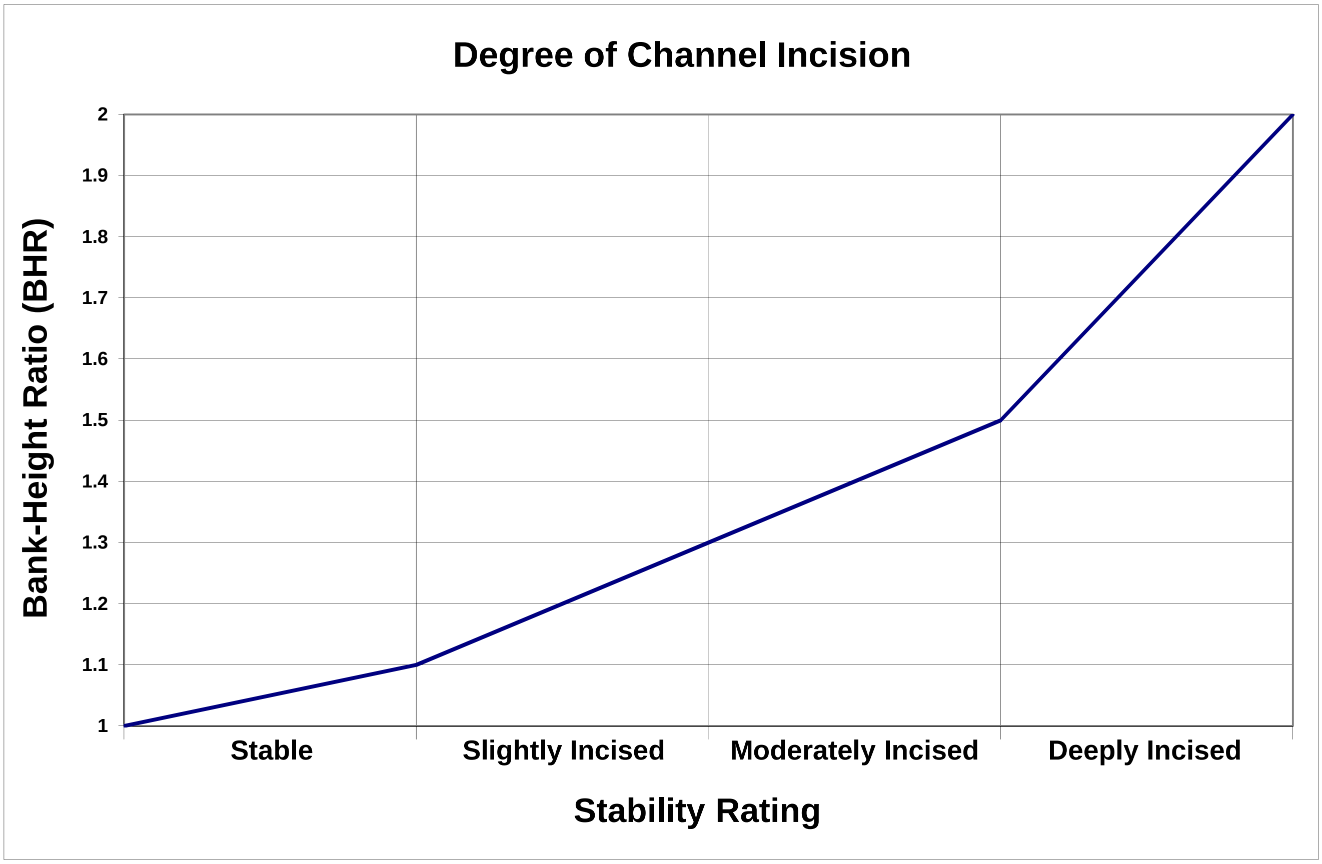
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision

Low Bank Height:	**15.9**
Max Bankfull Depth:	**11.58**

Bank-Height Ratio:	**1.4**

Degree of Channel Incision Stability Rating ☞	**Moderately Incised**

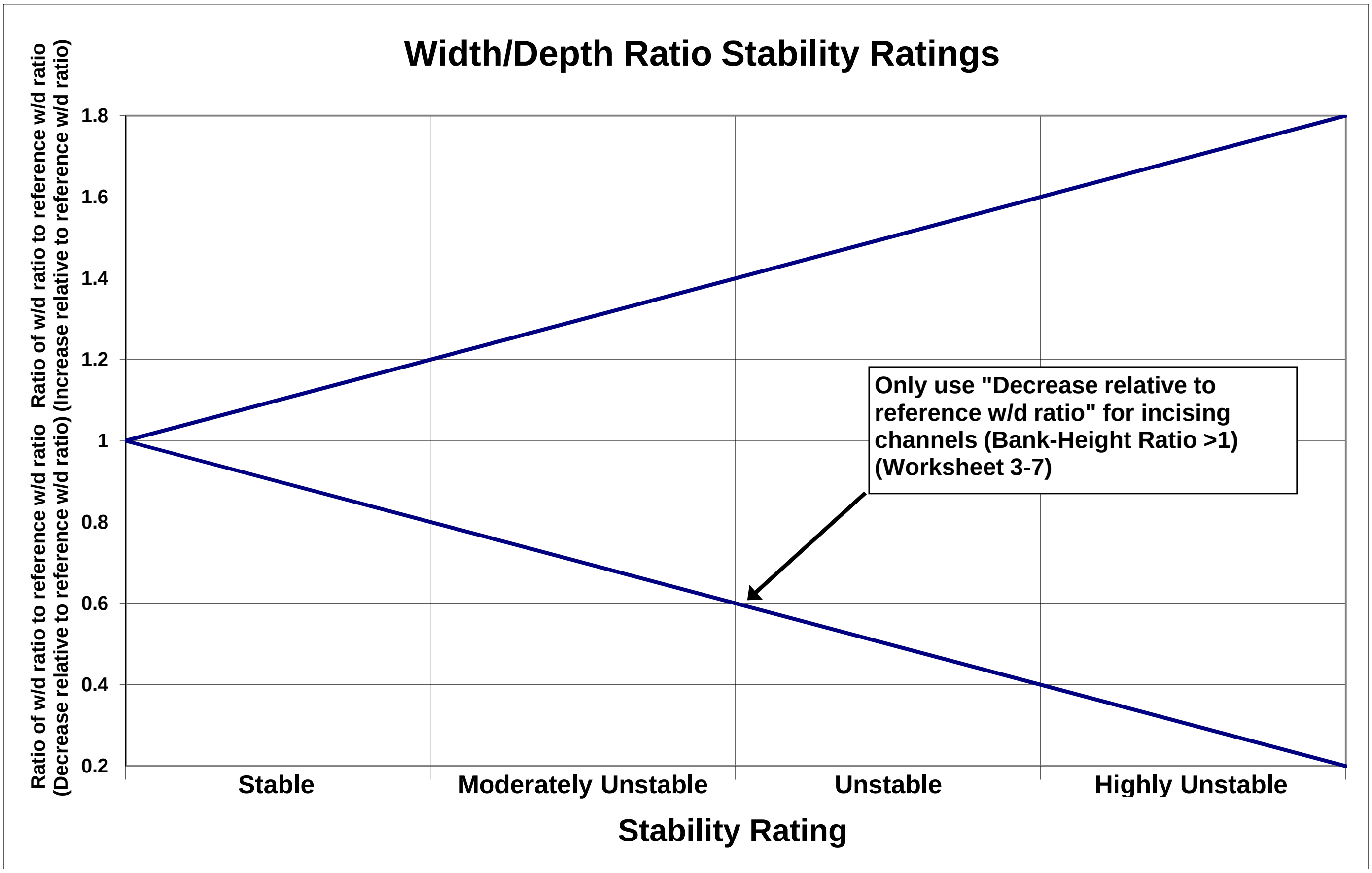


Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State

Existing Width/Depth Ratio:	9.1	Ratio of existing W/d to reference W/d:	1.049
Reference Width/Depth Ratio:	8.7		

Width/Depth Ratio State Stability Rating ☞	**Stable**

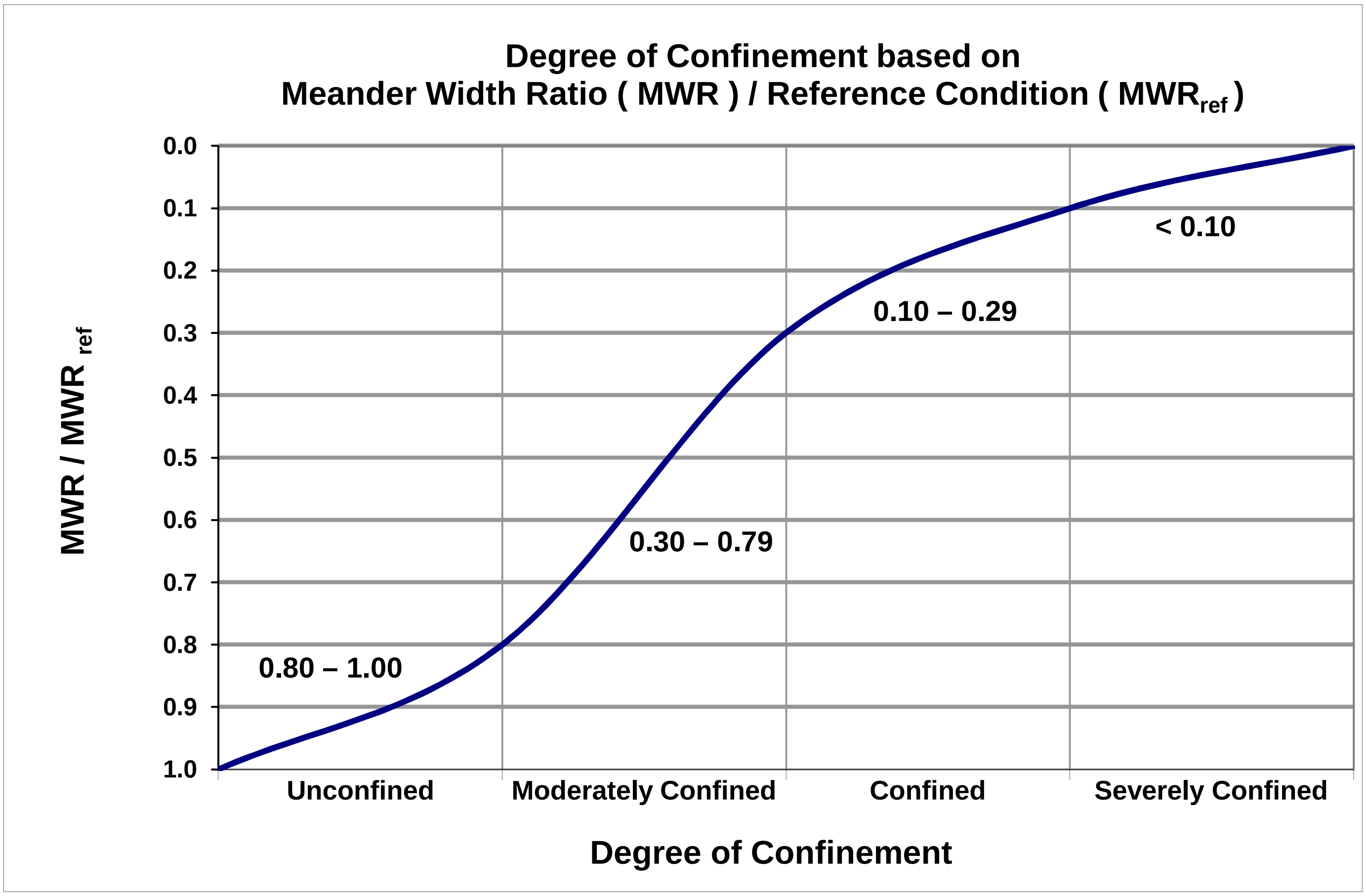


Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement

Existing Meander Width Ratio (MWR):	**13.0**		Ratio of MWR to MWR_{ref}:	**0.976**
Reference Meander Width Ratio (MWR_{ref}):	**13.3**			

Degree of Confinement Stability Rating ☞ **Unconfined**



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Sheyenne River **Location:** Sheyenne River - 6 - 3 **Valley Type:** X **Observers:** KP, AL **Date:** 11/21/2010

Location	Key	Category	Excellent: Description	Excellent: Rating	Good: Description	Good: Rating	Fair: Description	Fair: Rating	Poor: Description	Poor: Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	**8**
	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	**9**	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
	3	Debris jam potential	Essentially absent from immediate channel area.	**2**	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	**9**	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	**8**
	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	**2**	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	**12**	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	**23**	Good total =	**0**	Fair total =	**30**	Poor total =	**20**

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

*Rating is adjusted to potential stream type, not existing.

Grand total =	**73**
Existing stream type =	**E6**
*Potential stream type =	**E6**
Modified channel stability rating =	**Fair**

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream: **Sheyenne River**	Location: **Sheyenne River - 6 - 35.82**
Station:	Observers: **KP, AL**
Date: **11/21/2010** Stream Type: **E6**	Valley Type: **X**

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	16.3 (A)	Bankfull Height (ft) =	10.8 (B)	(A) / (B) =	1.5 (C)	6

Root Depth / Study Bank Height (E)

Root Depth (ft) =	5 (D)	Study Bank Height (ft) =	16.3 (A)	(D) / (A) =	0.3 (E)	6

Weighted Root Density (G)

Root Density as % =	20% (F)	(F) x (E) =	6% (G)	9

Bank Angle (H)

Bank Angle as *Degrees* =	31 (H)	2

Surface Protection (I)

Surface Protection as % =	10% (I)	9

Bank Material Adjustment:

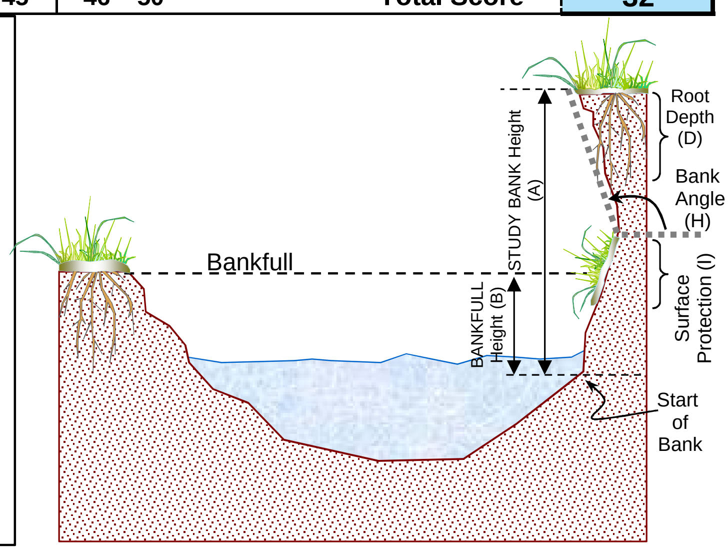
Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

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**	**High**
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50	and **Total Score**	**32**

Bank Sketch



Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Sheyenne River**	Location: **Sheyenne River - 6 - 35.82**	
Station: **0**	Stream Type: **E6**	Valley Type: **X**
Observers: **KP, AL**		Date: **11/21/10**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})......	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S)......	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})......	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})......	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient......	Level IV	Validation

Level I

(1)
- Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
- Extensive deposition (continuous, cross-channel)...... ....NBS = Extreme
- Chute cutoffs, down-valley meander migration, converging flow......NBS = Extreme

Level II

	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)
(2)				

	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)
(3)				

	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)
(4)				

Dominant Near-Bank Stress
Very Low

Level III

	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)
(5)				

	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)
(6)								

Level IV

	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
(7)		**Very Low**

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating: Very Low

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Sheyenne River**			Location: **Sheyenne River - 6 - 35.82**			
Graph Used:	**Fig 3-9**	Total Bank Length (ft): **4858.9**				Date: **11/21/2010**	
Observers:	**KP, AL**		Valley Type: **X**			Stream Type: **E6**	
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**4858.9**	**16.3**	**13068**	**0.13**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**13068**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**484**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**629**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.13**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Sheyenne River**		Stream Type: **E6**		
Location:	**Sheyenne River - 6 - 35.82**		Valley Type: **X**		
Observers:	**KP, AL**		Date: **11/21/2010**		
Enter Required Information for Existing Condition					
	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			
Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress					
#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1: $\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$		
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2: $\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$		
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:		**#DIV/0!**
Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample					
#DIV/0!	**d**	Required bankfull mean depth (ft)	$d = \frac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)	
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample					
#DIV/0!	**S**	Required bankfull water surface slope (ft/ft)	$S = \frac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)	
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Sediment Competence Using Dimensional Shear Stress					
0	Bankfull shear stress $\tau = \gamma ds$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope				
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**				
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**				
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope			$d = \frac{\tau}{\gamma S}$	
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth			$S = \frac{\tau}{\gamma d}$	

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis

Observers: **KP, AL**

Stream: **Sheyenne River** | Location: **Sheyenne River - 6 - 35.82** | Date: **11/21/2010**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		0		0		0		0		0		0		0		0		0
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		100%

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	0
Materials less than:	mm

Be sure to add separate material weights to grand total

0

GRAND TOTAL

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Sheyenne River**	Stream Type: **E6**
Location: **Sheyenne River - 6 - 35.82**	Valley Type: **X**
Observers: **KP, AL**	Date: **11/21/2010**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream:	**Sheyenne River**	Stream Type:	**E6**
Location:	**Sheyenne River - 6 - 35.82**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**11/21/2010**

	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 3-8)**	< 1.2 (2)	1.2 – 1.4 (4)	1.4 – 1.6 (6)	> 1.6 (8)	**2**
2	**Depositional pattern (Worksheet 3-5)**	B1, B2 (1)	B4, B8 (2)	B3 (3)	B5, B6, B7 (4)	**1**
3	**Meander pattern (Worksheet 3-4)**	M1, M3, M4 (1)		M2, M5, M6, M7, M8 (3)		**3**
4	**Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL (2)	M/L, M/M, M/H, L/Ex, H/L (4)	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL (6)	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex (8)	**4**
5	**Degree of confinement (MWR / MWR$_{ref}$) (Worksheet 3-9)**	0.8 – 1.0 (1)	0.3 – 0.79 (2)	0.1 – 0.29 (3)	< 0.1 (4)	**1**
					Total points	**11**

	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** ☐

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Sheyenne River**	Stream Type:	**E6**
Location:	**Sheyenne River - 6 - 35.82**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**11/21/2010**

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 3-14)**	Sufficient depth and/or slope to transport largest size available **(2)**	Trend toward insufficient depth and/or slope- slightly incompetent **(4)**	Cannot move D_{35} of bed material and/or D_{100} of bar material **(6)**	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size **(8)**	**2**
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load **(2)**	Trend toward insufficient sediment capacity **(4)**	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand **(6)**	Reduction over 25% of annual sediment yield for bedload and/or suspended sand **(8)**	**2**
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	>1.6 **(8)**	**2**
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation **(2)**	(E→C) **(4)**	(C→High W/d C), (B→High W/d B), (C→F) **(6)**	(C→D), (F→D) **(8)**	**2**
5 **Depositional patterns (Worksheet 3-5)**	B1 **(1)**	B2, B4 **(2)**	B3, B5 **(3)**	B6, B7, B8 **(4)**	**1**
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 **(1)**	D4, D7 **(2)**	D5, D8 **(3)**	D6, D9, D10 **(4)**	**1**
				Total points	**10**

Vertical stability for excess deposition / aggradation (use total points and check stability rating)	**Vertical stability category point range for excess deposition / aggradation**			
	No deposition 10 – 14 ☑	**Moderate deposition 15 – 20** ☐	**Excess deposition 21 – 30** ☐	**Aggradation > 30** ☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream:	**Sheyenne River**	Stream Type:	**E6**
Location:	**Sheyenne River - 6 - 35.82**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**11/21/2010**

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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	2
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	2
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	6
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	4
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	1
				Total points	**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** ☐

Worksheet 3-20. Channel enlargement prediction summary.

Stream:	**Sheyenne River**			Stream Type:	**E6**
Location:	**Sheyenne River - 6 - 35.82**			Valley Type:	**X**
Observers:	**KP, AL**			Date:	**11/21/2010**

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 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) **(2)**	(C→High W/d C), (E→C) **(4)**	(G→F), (F→D) **(6)**	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) **(8)**	**2**
2 **Lateral stability (Worksheet 3-17)**	Stable **(2)**	Moderately unstable **(4)**	Unstable **(6)**	Highly unstable **(8)**	**4**
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition **(2)**	Moderate deposition **(4)**	Excess deposition **(6)**	Aggradation **(8)**	**2**
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised **(2)**	Slightly incised **(4)**	Moderately incised **(6)**	Degradation **(8)**	**4**
				Total points	**12**

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

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream: **Sheyenne River**		Stream Type:	**E6**
Location: **Sheyenne River - 6 - 35.82**		Valley Type:	**X**
Observers: **KP, AL**		Date:	**11/21/2010**

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	Stability Rating	Points	Selected Points
1 Lateral stability (Worksheet 3-17)	Stable	1	2
	Mod. unstable	2	
	Unstable	3	
	Highly unstable	4	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition	1	1
	Mod. deposition	2	
	Excess deposition	3	
	Aggradation	4	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	2
	Slightly incised	2	
	Mod. Incised	3	
	Degradation	4	
4 Channel enlargement prediction (Worksheet 3-20)	No increase	1	2
	Slight increase	2	
	Mod. increase	3	
	Extensive	4	
5 Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	2
	Fair: mod unstable	2	
	Poor: unstable	4	
		Total Points	**9**

	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 ☐

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Sheyenne River**		Location: **Sheyenne River - 6 - 35.82**		
Observers:	**KP, AL**	Date: **11/21/2010**	Stream Type: **E6**	Valley Type: **X**	
Channel Dimension	Mean bankfull depth (ft): **7.9**	Mean bankfull width (ft): **72.02**	Cross-section area (ft^2): **568.9**	Width of flood-prone area (ft): **810.75**	Entrenchment ratio: **11.3**
Channel Pattern	Mean: Range: MWR: **13.0**	Lm/W_{bkf}: **13.0**	Rc/W_{bkf}: **3.1**	Sinuosity: **1.78**	
River Profile and Bed Features	Check: ☐ Riffle/pool ☐ Step/pool ☑ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed				
	Max bankfull depth (ft): Riffle **11.6**; Pool	Depth ratio (max/mean): Riffle **1.5**; Pool	Pool to pool spacing: Ratio	Slope: Valley:	Average bankfull: **0.00015**
Level III Stream Stability Indices	Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:	
	Flow regime: **P1, 2, 7, 9**	Stream size and order: **S-6**	Meander pattern(s): **M2**	Depositional pattern(s): **NONE**	Debris/channel blockage(s): **D2**
	Degree of incision (Bank-Height Ratio): **1.4**	Degree of incision stability rating: **Moderately Incised**	Modified Pfankuch stability rating (numeric and adjective rating): **Fair**		
	Width/depth ratio (W/d): **9.1**	Reference W/d ratio (W/d_{ref}): **8.7**	Width/depth ratio state $(W/d) / (W/d_{ref})$: **1.0**	W/d ratio state stability rating: **Stable**	
	Meander Width Ratio (MWR): **13.0**	Reference MWR_{ref}: **13.3**	Degree of confinement (MWR / MWR_{ref}): **1.0**	MWR / MWR_{ref} stability rating: **Unconfined**	
Bank Erosion Summary	Length of reach studied (ft): **4859**	Annual streambank erosion rate: **629** (tons/yr) **0.13** (tons/yr/ft)	Curve used: **Fig 3-9**	Remarks:	
Sediment Capacity (POWERSED)	☐ Sufficient capacity ☐ Insufficient capacity ☐ Excess capacity			Remarks:	
Entrainment/ Competence	Largest particle from bar sample (mm): **0**	$\tau =$ **0**	$\tau^* =$ **#####**	Existing $depth_{bkf}$: Required $depth_{bkf}$:	Existing $slope_{bkf}$: Required $slope_{bkf}$:
Successional Stage Shift	→ → → → →		Existing stream state (type): **E6**	Potential stream state (type): **E6**	
Lateral Stability	☐ Stable ☑ Mod. unstable ☐ Unstable ☐ Highly unstable			Remarks/causes: **None**	
Vertical Stability (Aggradation)	☑ No deposition ☐ Mod. deposition ☐ Ex. deposition ☐ Aggradation			Remarks/causes: **None**	
Vertical Stability (Degradation)	☐ Not incised ☑ Slightly incised ☐ Mod. incised ☐ Degradation			Remarks/causes: **None**	
Channel Enlargement	☐ No increase ☑ Slight increase ☐ Mod. increase ☐ Extensive			Remarks/causes: **None**	
Sediment Supply (Channel Source)	☐ Low ☑ Moderate ☐ High ☐ Very high			Remarks/causes: **None**	

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Sheyenne River**		Location: **Sheyenne River - 7 - 43.27**	
Observers: **KD, JB**	Reference reach [ ]	Disturbed (impacted reach) [X]	Date: **11/20/2010**
Existing species composition: **trees, small shrubs, cocklebur bushes, grass**		Potential species composition: **trees, small shrubs, cocklebur bushes, grass**	

	Riparian cover categories	Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**5% without leaves, 70% with leaves**	**1%**	**trees**	**100%**
					100%
2. Understory	Shrub layer		**5%**	**small shrubs**	**95%**
				cocklebur	**5%**
					100%
3. Ground level	Herbaceous		**2%**	**grass**	**100%**
					100%
	Leaf or needle litter		**1%**		
	Bare ground		**91%**		
			Column total = 100%		

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

Remarks:
Condition, vigor and/or usage of existing reach:
None

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Sheyenne River**				Location: **Sheyenne River - 7 - 43.27**				
Observers: **KD, JB**						Date: **11/20/2010**		
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P7**	**P9**				

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order

Stream:	**Sheyenne River**
Location:	**Sheyenne River - 7 - 43.27**
Observers:	**KD, JB**
Date:	**11/20/2010**

Stream Size Category and Order ☞	**S-7**

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).

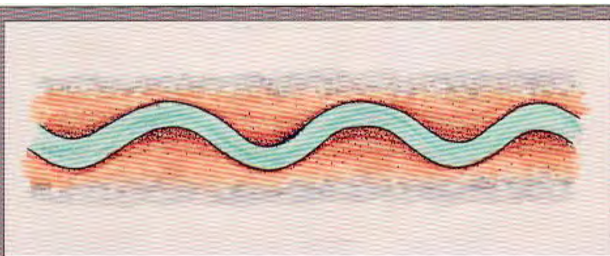
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Sheyenne River**	Reach:	**Sheyenne River - 7 - 43.27**
Observers:	**KD, JB**	Date:	**11/20/2010**

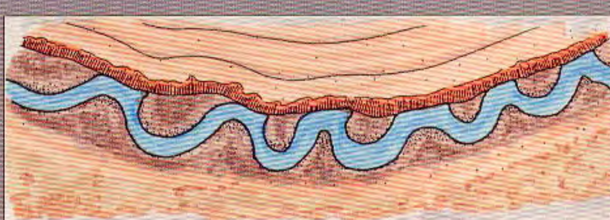
List ALL CATEGORIES that APPLY ☞	M2				

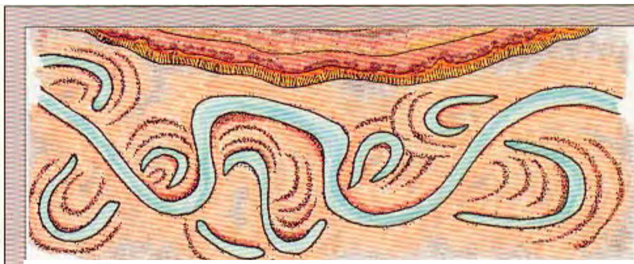
Various Meander Pattern variables modified from Galay et al. (1973)

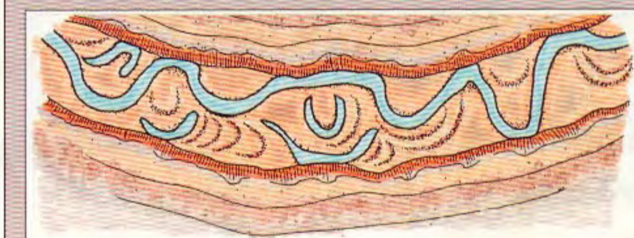

M1 REGULAR MEANDERS

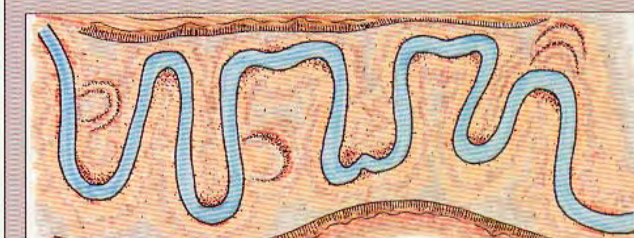

M2 TORTUOUS MEANDERS


M3 IRREGULAR MEANDERS


M4 TRUNCATED MEANDERS


M5 UNCONFINED MEANDER SCROLLS


M6 CONFINED MEANDER SCROLLS

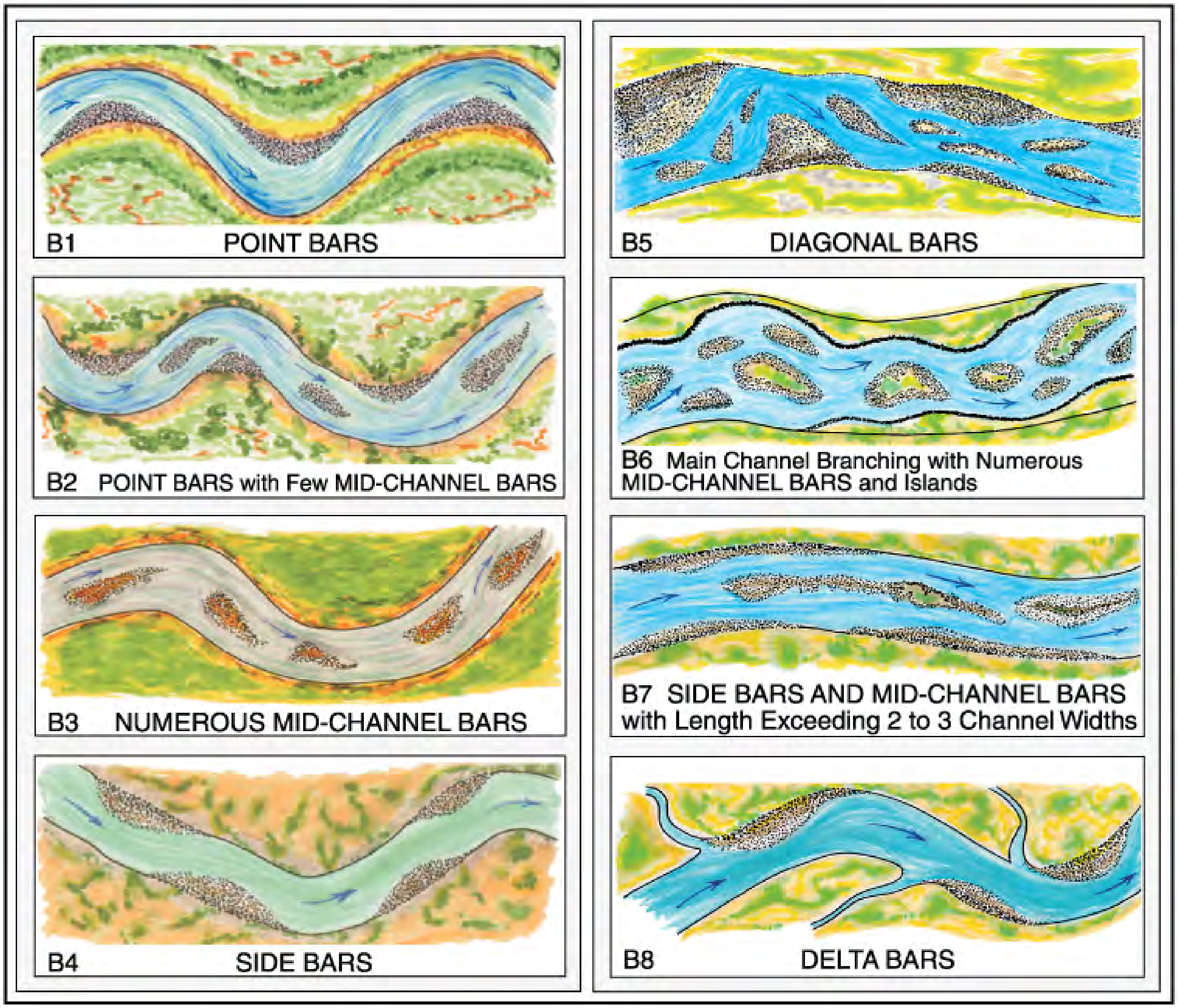

M7 DISTORTED MEANDER LOOPS


M8 IRREGULAR MEANDERS with oxbows and

Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns						
Stream: **Sheyenne River**			Reach: **Sheyenne River - 7 - 43.27**			
Observers: **KD, JB**			Date: **11/20/2010**			
List ALL CATEGORIES that APPLY ☞	**NONE**					

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



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Sheyenne River**		Location: **Sheyenne River - 7 - 43.27**	
Observers: **KD, JB**		Date: **11/20/2010**	
Description/extent		**Materials that 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.	☐

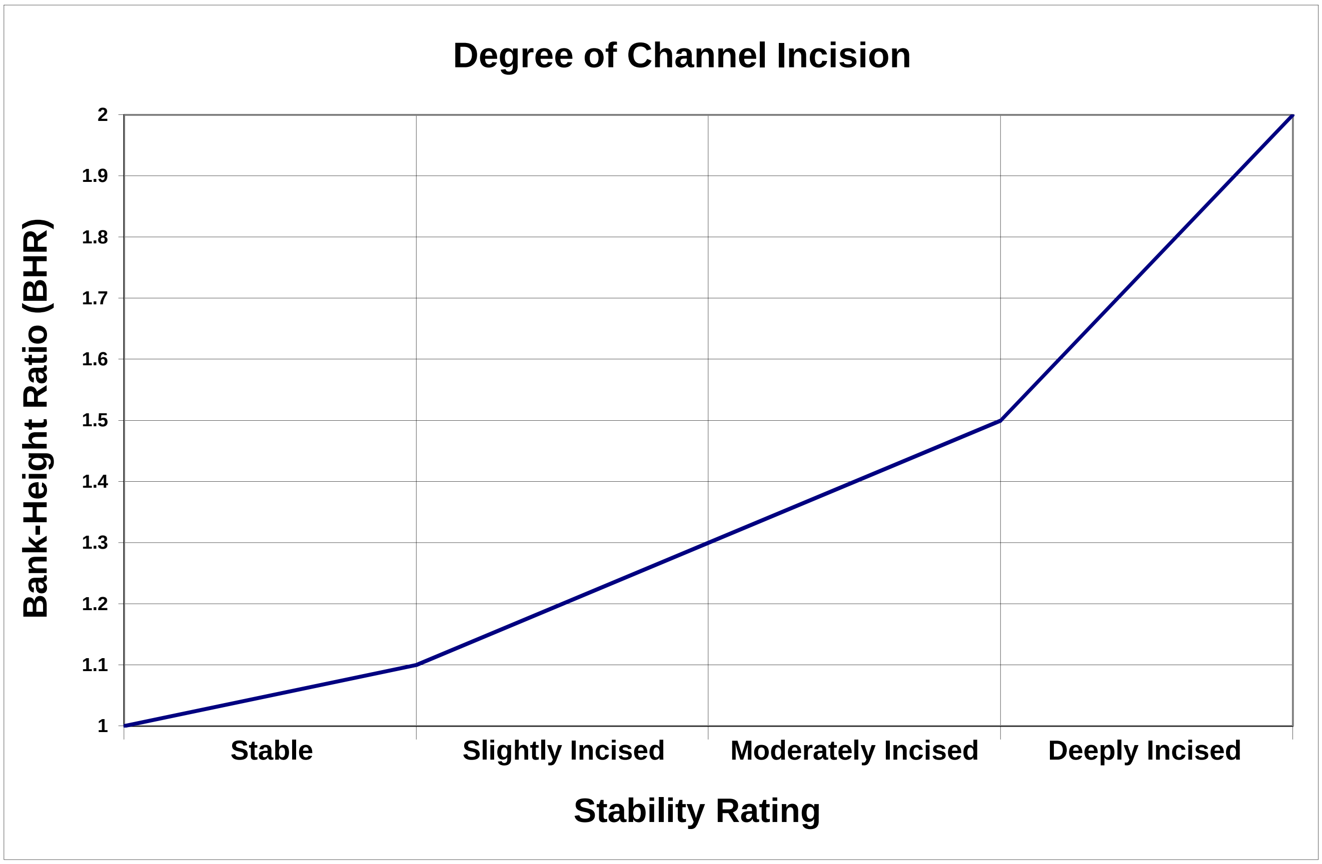
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision

Low Bank Height:	**23**
Max Bankfull Depth:	**14.79**

Bank-Height Ratio:	**1.6**

Degree of Channel Incision Stability Rating ☞	**Deeply Incised**

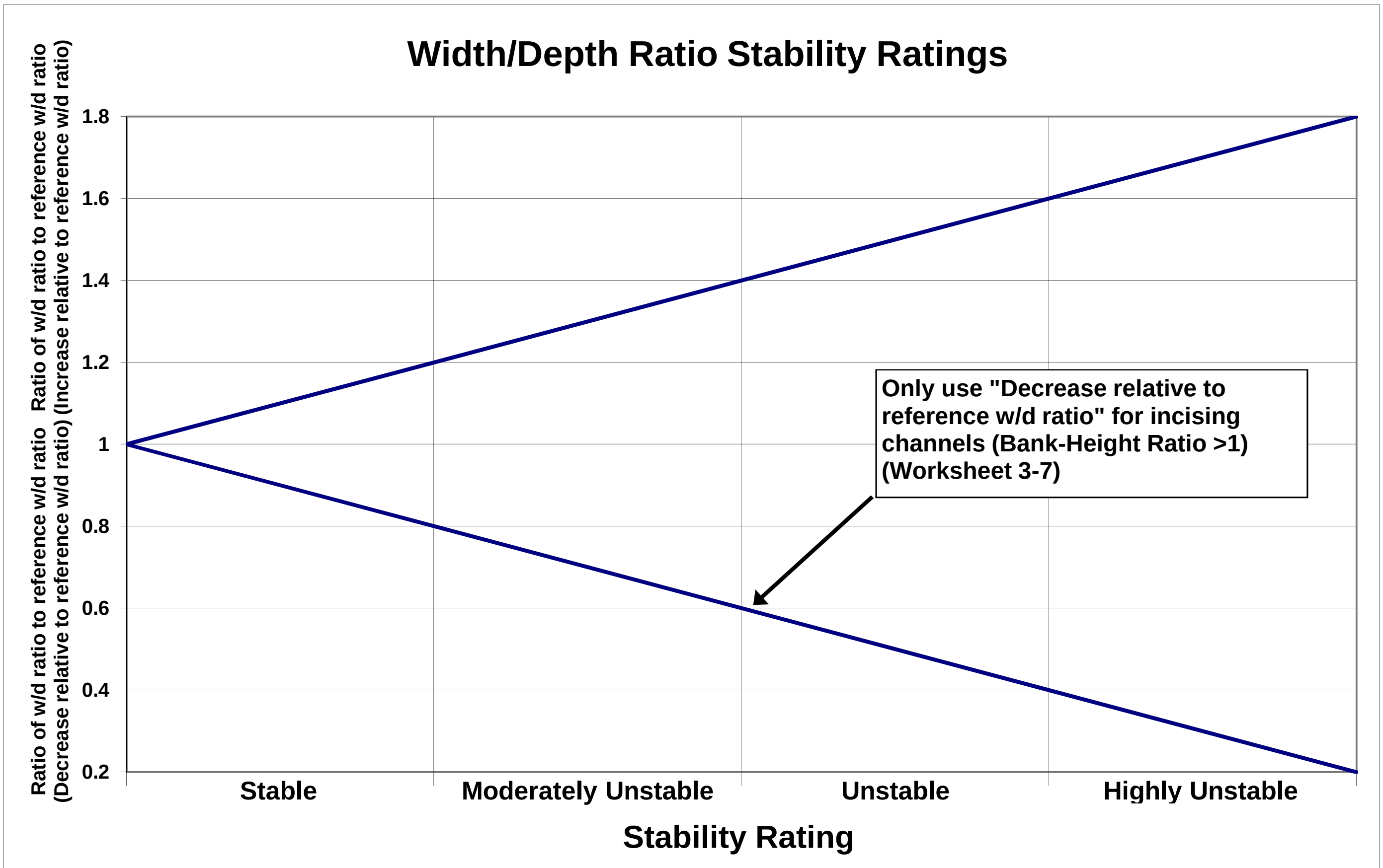


Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State

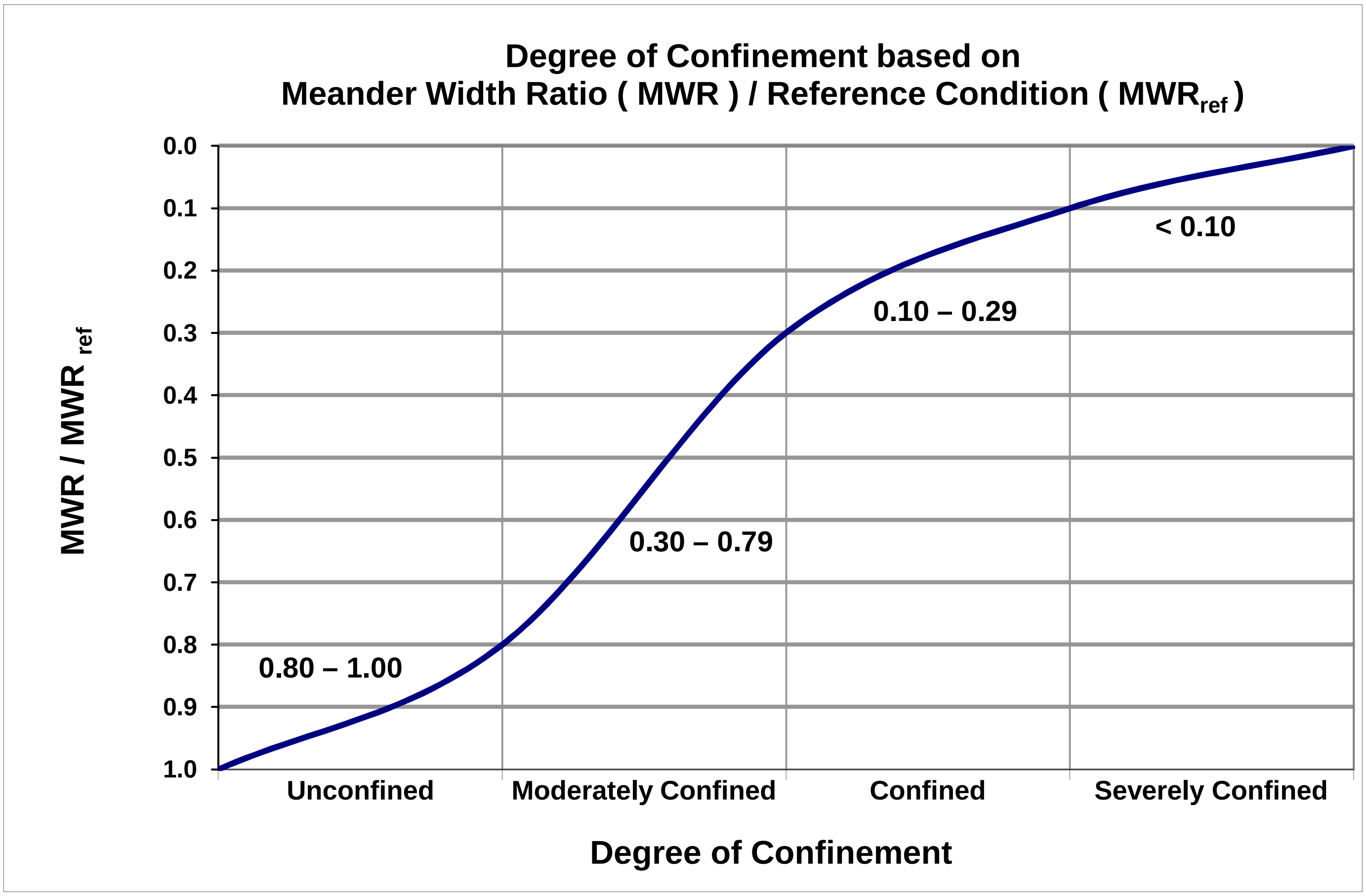
Existing Width/Depth Ratio:	**8.0**	Ratio of existing W/d to reference W/d:	**0.93**
Reference Width/Depth Ratio:	**8.6**		

Width/Depth Ratio State Stability Rating ☞ **Stable**



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	12.7	Ratio of MWR to MWR_{ref}:	1.029
Reference Meander Width Ratio (MWR_{ref}):	12.4		
Degree of Confinement Stability Rating ☞		**Unconfined**	



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Sheyenne River **Location:** Sheyenne River - 7 - 4 **Valley Type:** X **Observers:** KD, JB **Date:** 11/20/2010

Location	Key	Category	Excellent Description	Rating	Good Description	Rating	Fair Description	Rating	Poor Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	**6**	Bank slope gradient > 60%.	8
	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	**9**	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	**4**	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	**6**	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	**8**
	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	**4**	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	**12**	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	19	Good total =	14	Fair total =	27	Poor total =	12

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	72
Existing stream type =	E6
*Potential stream type =	E6
Modified channel stability rating =	Fair

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream: **Sheyenne River**		Location: **Sheyenne River - 7 - 43.27**	
Station:		Observers: **KD, JB**	
Date: **11/20/2010**	Stream Type: **E6**	Valley Type: **X**	

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	23.3 (A)	Bankfull Height (ft) =	14 (B)	(A) / (B) =	1.7 (C)	**7**

Root Depth / Study Bank Height (E)

Root Depth (ft) =	1 (D)	Study Bank Height (ft) =	23.3 (A)	(D) / (A) =	0.0 (E)	**10**

Weighted Root Density (G)

Root Density as % =	20% (F)	(F) x (E) =	1% (G)	**10**

Bank Angle (H)

Bank Angle as *Degrees* =	33 (H)	**2**

Surface Protection (I)

Surface Protection as % =	1% (I)	**10**

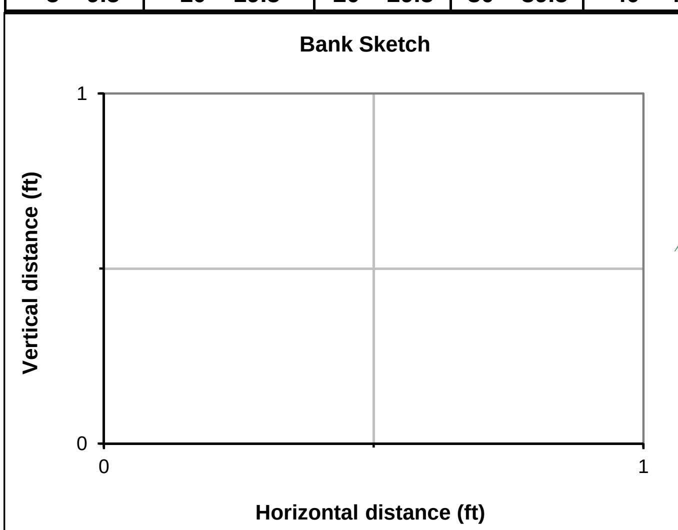
Bank Material Adjustment:

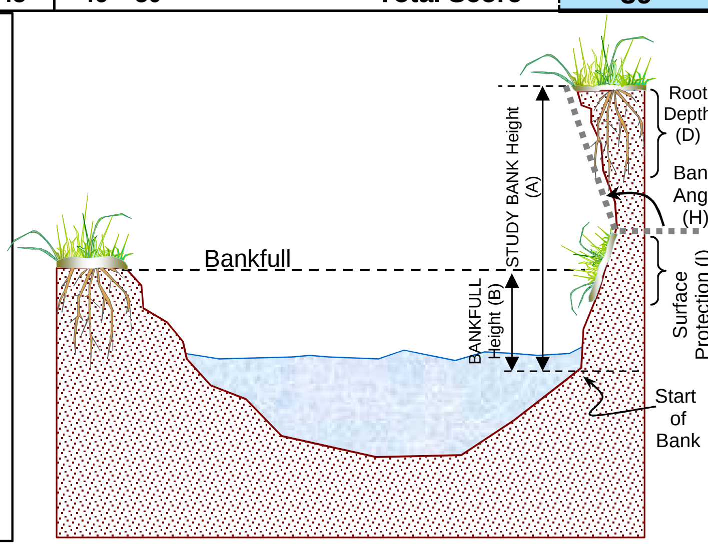
Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

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	**High**
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50	and Total Score	**39**





Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Sheyenne River**	Location: **Sheyenne River - 7 - 43.27**	
Station: **0**	Stream Type: **E6**	Valley Type: **X**
Observers: **KD, JB**		Date: **11/20/10**

Methods for Estimating Near-Bank Stress (NBS)

(1)	Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2)	Ratio of radius of curvature to bankfull width (R_c / W_{bkf})...	Level II	General prediction
(3)	Ratio of pool slope to average water surface slope (S_p / S)......................................	Level II	General prediction
(4)	Ratio of pool slope to riffle slope (S_p / S_{rif})..	Level II	General prediction
(5)	Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6)	Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})............................	Level III	Detailed prediction
(7)	Velocity profiles / Isovels / Velocity gradient..	Level IV	Validation

Level I

(1)
- Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
- Extensive deposition (continuous, cross-channel).. ....NBS = Extreme
- Chute cutoffs, down-valley meander migration, converging flow...NBS = Extreme

Level II

(2)	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)

(3)	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)

(4)	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)

Dominant Near-Bank Stress
Very Low

Level III

(5)	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)

(6)	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)

Level IV

(7)	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
		Very Low

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating	**Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Sheyenne River**			Location:	**Sheyenne River - 7 - 43.27**		
Graph Used:	**Fig 3-9**	Total Bank Length (ft):	**7463**			Date:	**11/20/2010**
Observers:	**KD, JB**		Valley Type:	**X**		Stream Type:	**E6**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**7463**	**23.3**	**28692**	**0.2**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**28692**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**1063**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**1381**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.2**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Sheyenne River**		Stream Type:	**E6**
Location:	**Sheyenne River - 7 - 43.27**		Valley Type:	**X**
Observers:	**KD, JB**		Date:	**11/20/2010**

Enter Required Information for Existing Condition

	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	**#DIV/0!**

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	**d**	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)
		Check: ☐ Stable ☐ Aggrading ☐ Degrading		

Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	**S**	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)
		Check: ☐ Stable ☐ Aggrading ☐ Degrading		

Sediment Competence Using Dimensional Shear Stress

0	Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope	
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**	
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**	
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope	$d = \dfrac{\tau}{\gamma S}$
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth	$S = \dfrac{\tau}{\gamma d}$

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis

Observers: **KD, JB**

Stream: **Sheyenne River** | Location: **Sheyenne River - 7 - 43.27** | Date: **11/20/2010**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		**100%**

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	**0**
Materials less than:	mm

Be sure to add separate material weights to grand total

GRAND TOTAL: **0**

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Sheyenne River**	Stream Type: **E6**
Location: **Sheyenne River - 7 - 43.27**	Valley Type: **X**
Observers: **KD, JB**	Date: **11/20/2010**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream:	**Sheyenne River**	Stream Type:	**E6**
Location:	**Sheyenne River - 7 - 43.27**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**11/20/2010**

Lateral stability criteria (choose one stability category for each criterion 1–5)	Lateral Stability Categories: Stable	Moderately unstable	Unstable	Highly unstable	Selected points (from each row)
1 W/d ratio state (Worksheet 3-8)	< 1.2 (2)	1.2 – 1.4 (4)	1.4 – 1.6 (6)	> 1.6 (8)	2
2 Depositional pattern (Worksheet 3-5)	B1, B2 (1)	B4, B8 (2)	B3 (3)	B5, B6, B7 (4)	1
3 Meander pattern (Worksheet 3-4)	M1, M3, M4 (1)		M2, M5, M6, M7, M8 (3)		3
4 Dominant BEHI / NBS (Worksheet 3-13)	L/VL, L/L, L/M, L/H, L/VH, M/VL (2)	M/L, M/M, M/H, L/Ex, H/L (4)	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL (6)	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex (8)	4
5 Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)	0.8 – 1.0 (1)	0.3 – 0.79 (2)	0.1 – 0.29 (3)	< 0.1 (4)	1
				Total points	**11**

Overall lateral stability category (use total points and check stability rating)	Lateral stability category point range: Stable 7 – 9 ☐	Moderately unstable 10 – 12 ☑	Unstable 13 – 21 ☐	Highly unstable > 21 ☐

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Sheyenne River**	Stream Type:	**E6**
Location:	**Sheyenne River - 7 - 43.27**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**11/20/2010**

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 3-14)**	Sufficient depth and/or slope to transport largest size available **(2)**	Trend toward insufficient depth and/or slope-slightly incompetent **(4)**	Cannot move D_{35} of bed material and/or D_{100} of bar material **(6)**	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size **(8)**	**2**
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load **(2)**	Trend toward insufficient sediment capacity **(4)**	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand **(6)**	Reduction over 25% of annual sediment yield for bedload and/or suspended sand **(8)**	**2**
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	>1.6 **(8)**	**2**
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation **(2)**	(E→C) **(4)**	(C→High W/d C), (B→High W/d B), (C→F) **(6)**	(C→D), (F→D) **(8)**	**2**
5 **Depositional patterns (Worksheet 3-5)**	B1 **(1)**	B2, B4 **(2)**	B3, B5 **(3)**	B6, B7, B8 **(4)**	**1**
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 **(1)**	D4, D7 **(2)**	D5, D8 **(3)**	D6, D9, D10 **(4)**	**1**
				Total points	**10**

Vertical stability for excess deposition / aggradation (use total points and check stability rating)	**Vertical stability category point range for excess deposition / aggradation**			
	No deposition 10 – 14 ☑	**Moderate deposition 15 – 20** ☐	**Excess deposition 21 – 30** ☐	**Aggradation > 30** ☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream: **Sheyenne River**			Stream Type:	**E6**	
Location: **Sheyenne River - 7 - 43.27**			Valley Type:	**X**	
Observers: **KD, JB**			Date:	**11/20/2010**	
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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	**2**
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	**2**
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	**8**
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	**4**
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	**1**
				Total points	**17**
	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** ☐	

Worksheet 3-20. Channel enlargement prediction summary.

Stream: **Sheyenne River**				Stream Type: **E6**	
Location: **Sheyenne River - 7 - 43.27**				Valley Type: **X**	
Observers: **KD, JB**				Date: **11/20/2010**	
Channel enlargement prediction criteria **(choose one stability category for each criterion 1–4)**	**Channel Enlargement Prediction Categories**				**Selected points (from each row)**
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) (2)	(C→High W/d C), (E→C) (4)	(G→F), (F→D) (6)	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) (8)	**2**
2 **Lateral stability (Worksheet 3-17)**	Stable (2)	Moderately unstable (4)	Unstable (6)	Highly unstable (8)	**4**
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition (2)	Moderate deposition (4)	Excess deposition (6)	Aggradation (8)	**2**
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised (2)	Slightly incised (4)	Moderately incised (6)	Degradation (8)	**4**
				Total points	**12**
	Category point range				
Channel enlargement prediction (use total points and check stability rating)	**No increase 8 – 10** ☐	**Slight increase 11 – 16** ☑	**Moderate increase 17 – 24** ☐	**Extensive > 24** ☐	

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream: **Sheyenne River**		Stream Type:	**E6**
Location: **Sheyenne River - 7 - 43.27**		Valley Type:	**X**
Observers: **KD, JB**		Date:	**11/20/2010**

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	**Stability Rating**	**Points**	**Selected Points**
1 Lateral stability (Worksheet 3-17)	Stable	1	2
	Mod. unstable	2	
	Unstable	3	
	Highly unstable	4	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition	1	1
	Mod. deposition	2	
	Excess deposition	3	
	Aggradation	4	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	2
	Slightly incised	2	
	Mod. Incised	3	
	Degradation	4	
4 Channel enlargement prediction (Worksheet 3-20)	No increase	1	2
	Slight increase	2	
	Mod. increase	3	
	Extensive	4	
5 Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	2
	Fair: mod unstable	2	
	Poor: unstable	4	
		Total Points	**9**

	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 ☐

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Sheyenne River**	Location:	**Sheyenne River - 7 - 43.27**
Observers:	**KD, JB**	Date: **11/20/2010**	Stream Type: **E6** Valley Type: **X**

Channel Dimension

Mean bankfull depth (ft): **10.1**	Mean bankfull width (ft): **80.81**	Cross-section area (ft^2): **819.7**	Width of flood-prone area (ft): **903.6667**	Entrenchment ratio: **11.2**

Channel Pattern

Mean: Range:	MWR: **12.7**	Lm/W_{bkf}: **12.7**	Rc/W_{bkf}: **2.7**	Sinuosity: **1.82**

River Profile and Bed Features

Check: ☐ Riffle/pool ☐ Step/pool ☑ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed

Max bankfull depth (ft):	Riffle	Pool	Depth ratio (max/mean):	Riffle	Pool	Pool to pool spacing:	Ratio	Slope	
	14.8			**1.5**				Valley:	Average bankfull: **0.00015**

Level III Stream Stability Indices

Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:

Flow regime: **P1, 2, 7, 9**	Stream size and order: **S-7**	Meander pattern(s): **M2**	Depositional pattern(s): **NONE**	Debris/channel blockage(s): **D2**

Degree of incision (Bank-Height Ratio): **1.6**	Degree of incision stability rating: **Deeply Incised**	Modified Pfankuch stability rating (numeric and adjective rating): **Fair**

Width/depth ratio (W/d): **8.0**	Reference W/d ratio (W/d_{ref}): **8.6**	Width/depth ratio state $(W/d) / (W/d_{ref})$: **0.9**	W/d ratio state stability rating: **Stable**
Meander Width Ratio (MWR): **12.7**	Reference MWR_{ref}: **12.4**	Degree of confinement (MWR / MWR_{ref}): **1.0**	MWR / MWR_{ref} stability rating: **Unconfined**

Bank Erosion Summary

Length of reach studied (ft):	Annual streambank erosion rate:		Curve used:	Remarks:
7463	**1381** (tons/yr)	**0.19** (tons/yr/ft)	**Fig 3-9**	

Sediment Capacity (POWERSED)

☑ Sufficient capacity ☐ Insufficient capacity ☐ Excess capacity | Remarks:

Entrainment/ Competence

Largest particle from bar sample (mm):	$\tau =$	$\tau^* =$	Existing $depth_{bkf}$:	Required $depth_{bkf}$:	Existing $slope_{bkf}$:	Required $slope_{bkf}$:

Successional Stage Shift

→ → → → → | Existing stream state (type): **E6** | Potential stream state (type): **E6**

Lateral Stability	☐ Stable	☑ Mod. unstable	☐ Unstable	☐ Highly unstable	Remarks/causes: **None**
Vertical Stability (Aggradation)	☑ No deposition	☐ Mod. deposition	☐ Ex. deposition	☐ Aggradation	Remarks/causes: **None**
Vertical Stability (Degradation)	☐ Not incised	☑ Slightly incised	☐ Mod. incised	☐ Degradation	Remarks/causes: **None**
Channel Enlargement	☐ No increase	☑ Slight increase	☐ Mod. increase	☐ Extensive	Remarks/causes: **None**
Sediment Supply (Channel Source)	☐ Low	☑ Moderate	☐ High	☐ Very high	Remarks/causes: **None**

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Sheyenne River**

Location: **Sheyenne River-8-55.75**

Observers: **KP, AL**

Reference reach: [ ]

Disturbed (impacted reach): **X**

Date: **10/2/2011**

Existing species composition:

Potential species composition:

	Riparian cover categories	Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**25%**	**3%**		100%
2. Understory	Shrub layer		**38%**		100%
3. Ground level	Herbaceous		**7%**		100%
3. Ground level	Leaf or needle litter		**2%**		
3. Ground level	Bare ground		**50%**		
			Column total = 100%		

*Based on crown closure.

**Based on basal area to surface area.

Remarks:
Condition, vigor and/or usage of existing reach:

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Sheyenne River**			Location: **Sheyenne River-8-55.75**					
Observers: **KP, AL**						Date: **10/2/2011**		
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P7**	**P9**				

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order			
Stream:	**Sheyenne River**		
Location:	**Sheyenne River-8-55.75**		
Observers:	**KP, AL**		
Date:	**10/2/2011**		
Stream Size Category and Order ☞			**S-6**
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).			

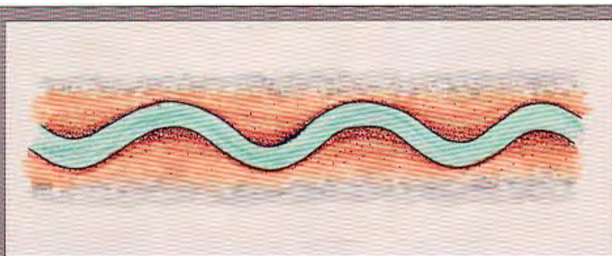
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Sheyenne River**	Reach:	**Sheyenne River-8-55.75**
Observers:	**KP, AL**	Date:	**10/2/2011**

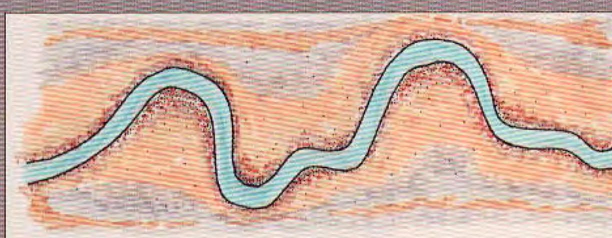
List ALL CATEGORIES that APPLY ☞	**M2**				

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

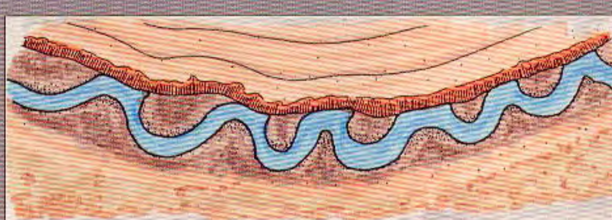


M1 REGULAR MEANDERS

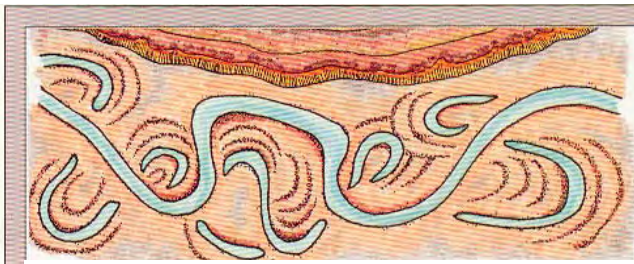
M2 TORTUOUS MEANDERS



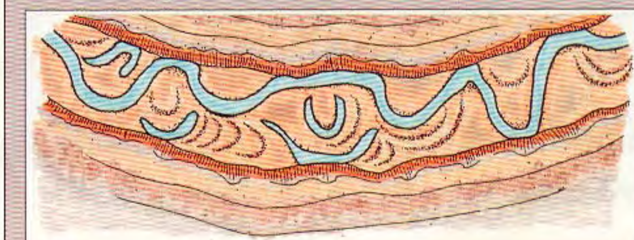
M3 IRREGULAR MEANDERS



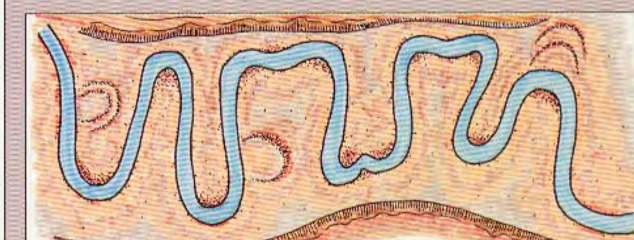
M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS



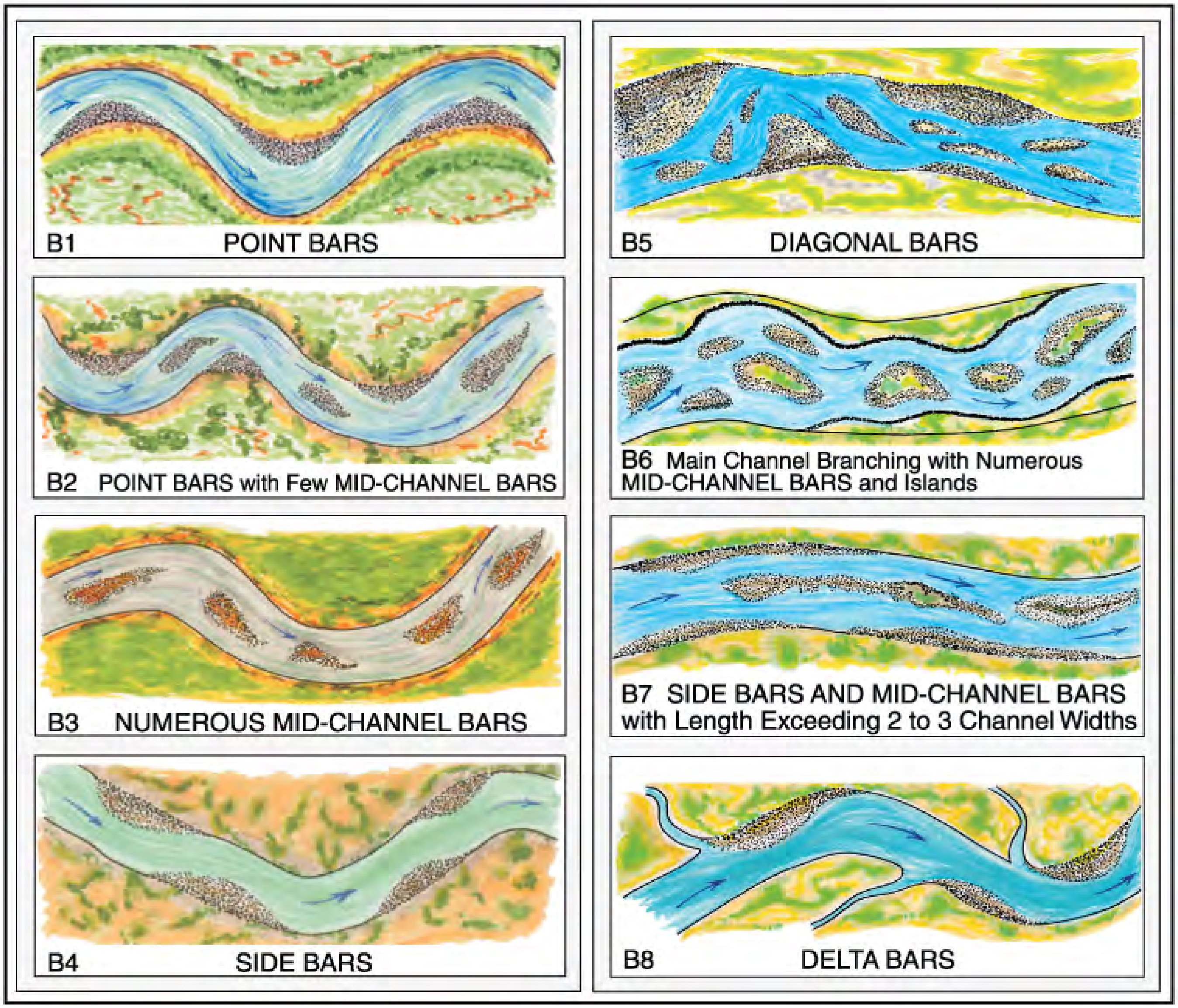
M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns					
Stream: **Sheyenne River**			Reach: **Sheyenne River-8-55.75**		
Observers: **KP, AL**			Date: **10/2/2011**		
List ALL CATEGORIES that APPLY ☞	**N/A**				

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

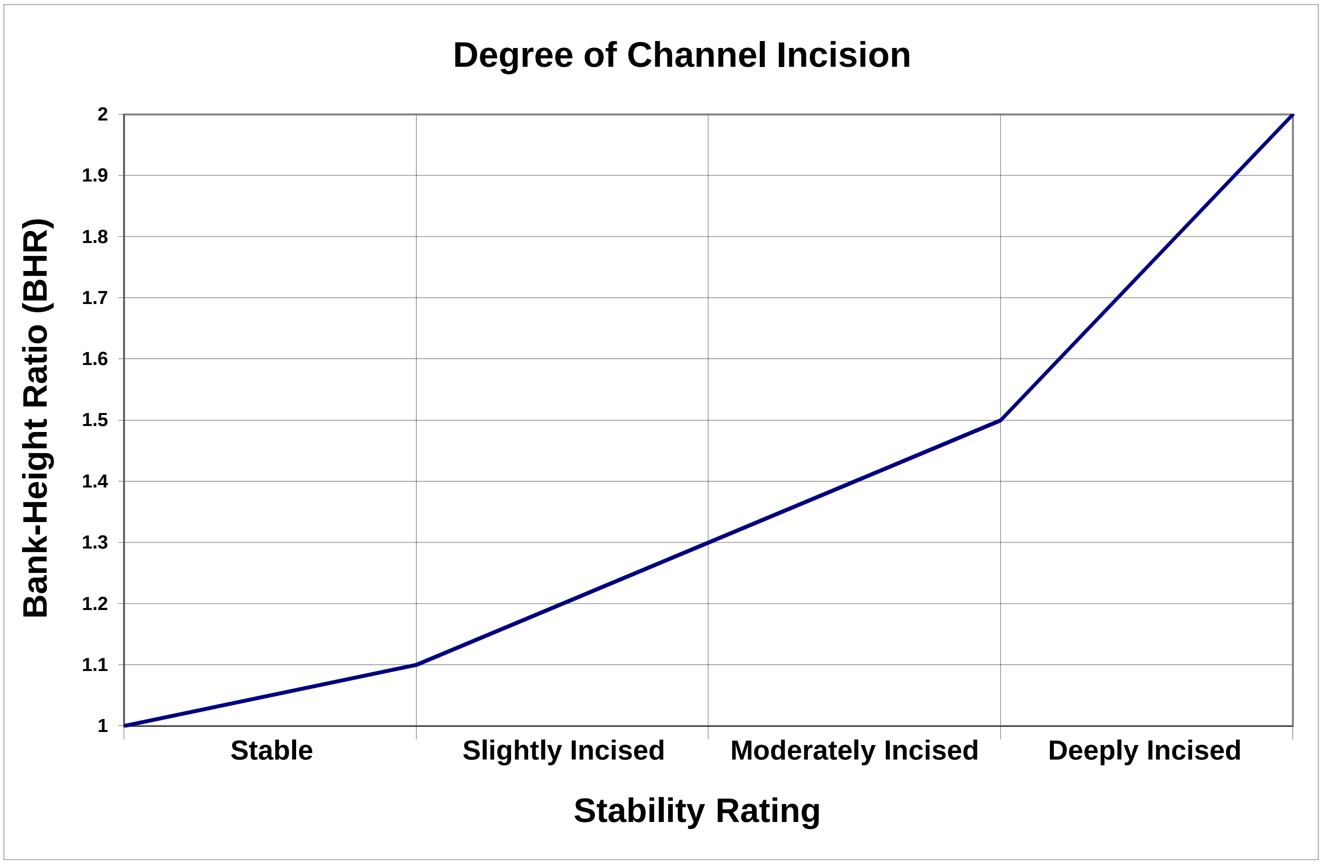


Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Sheyenne River**		Location: **Sheyenne River-8-55.75**	
Observers: **KP, AL**		Date: **10/2/2011**	
Description/extent		**Materials that 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.	☐

Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

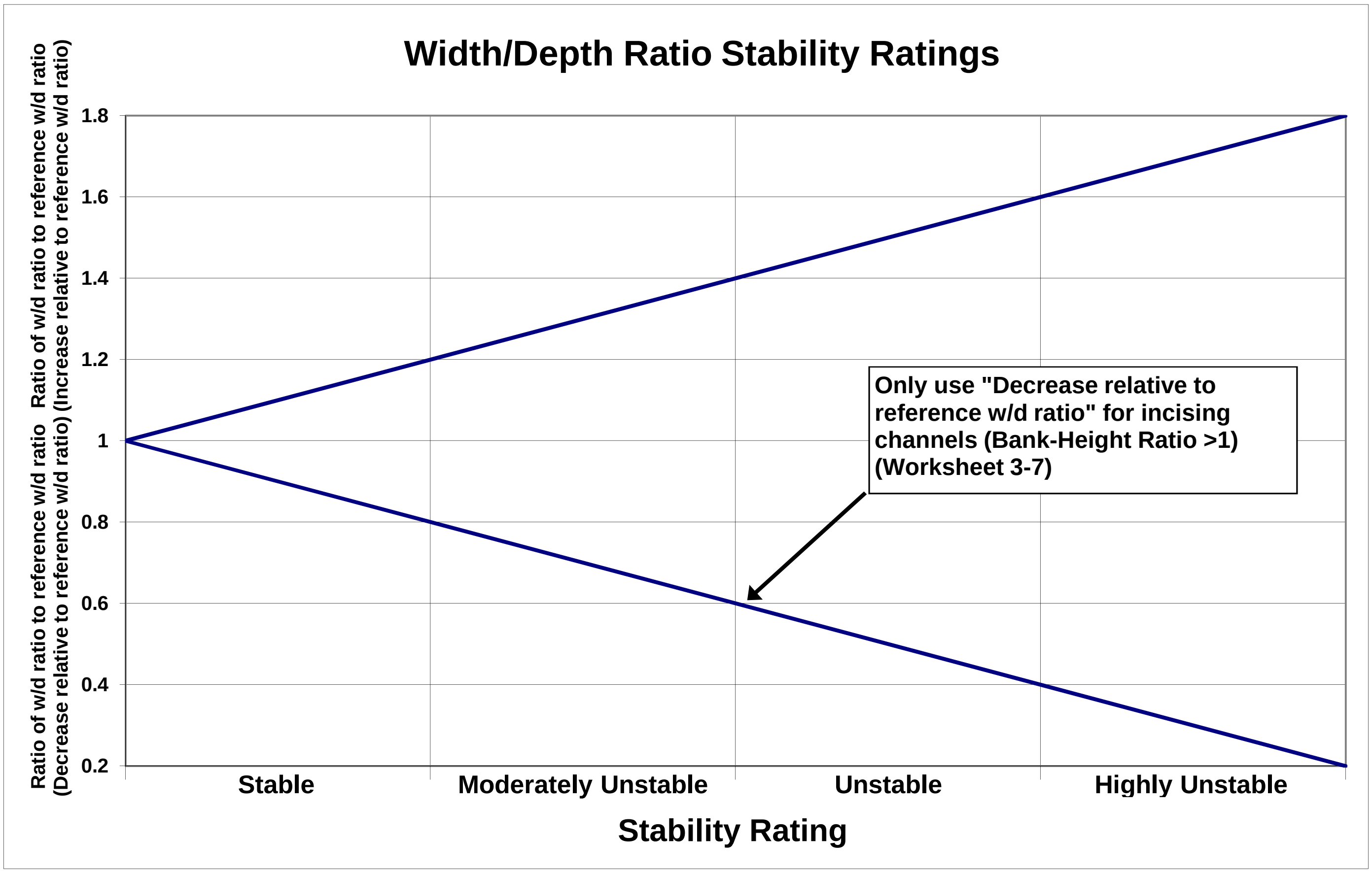
Degree of Channel Incision			
Low Bank Height:	21.2	Bank-Height Ratio:	1.6
Max Bankfull Depth:	13.08		
Degree of Channel Incision Stability Rating ☞			Deeply Incised



Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State			
Existing Width/Depth Ratio:	9.0	Ratio of existing W/d to reference W/d:	1
Reference Width/Depth Ratio:	9.0		

Width/Depth Ratio State Stability Rating ☞	Stable

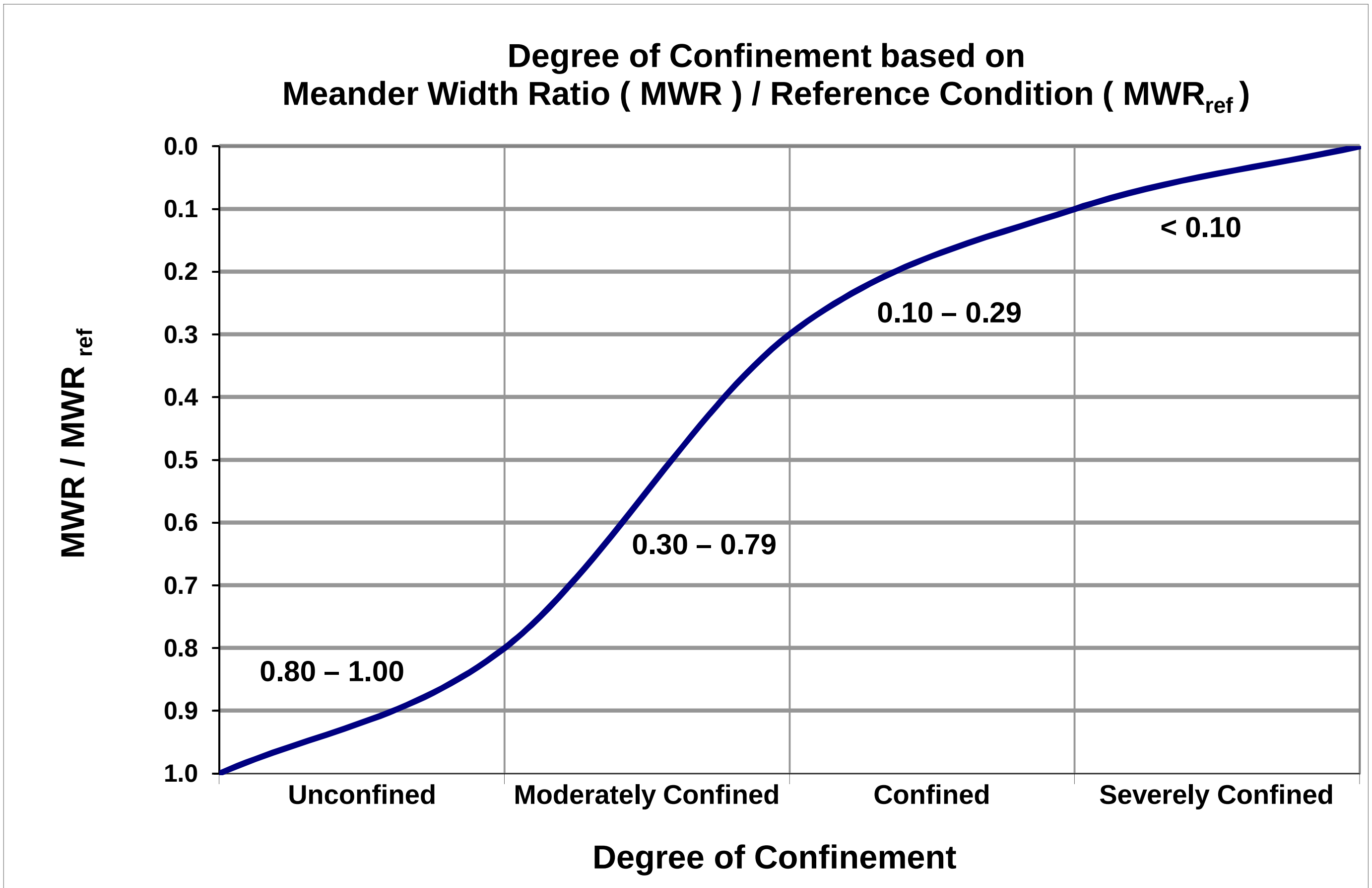


Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement

Existing Meander Width Ratio (MWR):	**16.9**	Ratio of MWR to MWR_{ref}:	**1**
Reference Meander Width Ratio (MWR_{ref}):	**16.9**		

Degree of Confinement Stability Rating ☞ **Unconfined**



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Sheyenne River **Location:** Sheyenne River-8-55.7 **Valley Type:** X **Observers:** KP, AL **Date:** 10/2/2011

Location	Key	Category	Excellent – Description	Rating	Good – Description	Rating	Fair – Description	Rating	Poor – Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	**6**	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	**12**
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	**6**	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	**12**
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	**8**
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	**4**	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	**16**
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	19	Good total =	8	Fair total =	12	Poor total =	52

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	91
Existing stream type =	E5
*Potential stream type =	E5
Modified channel stability rating =	Fair

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream: **Sheyenne River**		Location: **Sheyenne River-8-55.75**	
Station:		Observers: **KP, AL**	
Date: **10/2/2011**	Stream Type: **E5**	Valley Type: **X**	

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	21.4 (A)	**Bankfull Height** (ft) =	11.7 (B)	(A) / (B) =	1.8 (C)	7

Root Depth / Study Bank Height (E)

Root Depth (ft) =	1.5 (D)	**Study Bank Height** (ft) =	21.4 (A)	(D) / (A) =	0.1 (E)	8

Weighted Root Density (G)

Root Density as **%** =	10% (F)	(F) x (E) =	1% (G)	10

Bank Angle (H)

Bank Angle as *Degrees* =	29 (H)	2

Surface Protection (I)

Surface Protection as **%** =	5% (I)	10

Bank Material Adjustment:

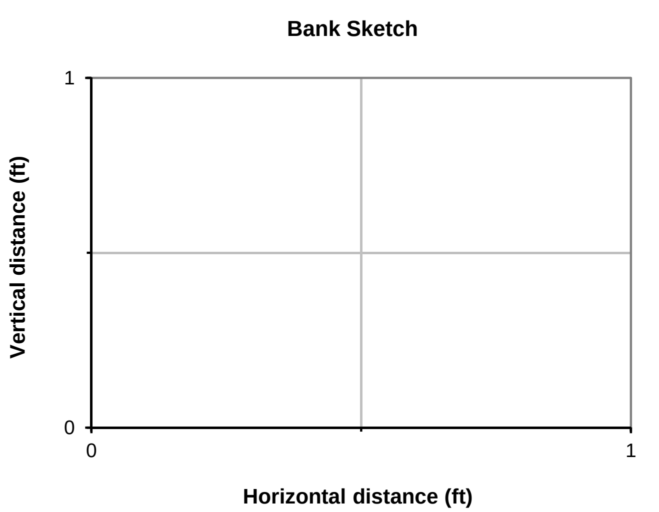
Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

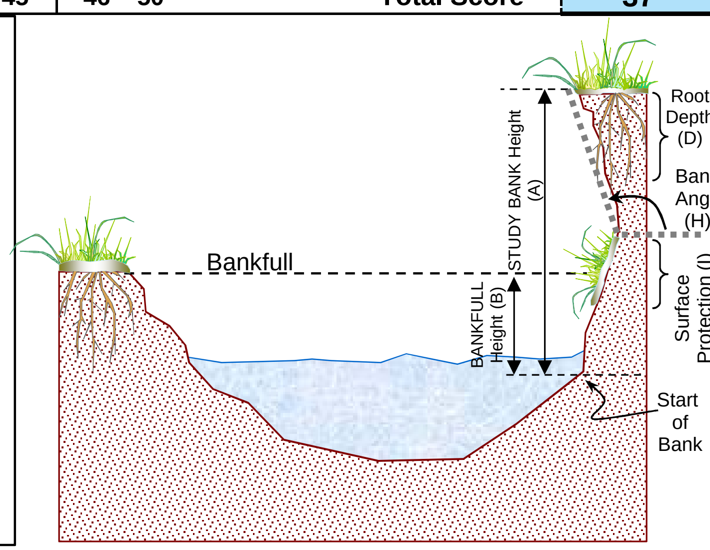
Bank Material Adjustment: 0

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**: **High** / **37**





Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Sheyenne River** Location: **Sheyenne River-8-55.75**

Station: **0** Stream Type: **E5** Valley Type: **X**

Observers: **KP, AL** Date: **10/2/11**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})..	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S)..	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})..	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})............................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient..	Level IV	Validation

Level I

(1)
- Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
- Extensive deposition (continuous, cross-channel)... ....NBS = Extreme
- Chute cutoffs, down-valley meander migration, converging flow..NBS = Extreme

Level II

	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)
(2)				

	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)
(3)				

	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)
(4)				

Dominant Near-Bank Stress
Very Low

Level III

	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)
(5)				

	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)
(6)								

Level IV

	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
(7)		**Very Low**

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating	Very Low

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Sheyenne River**			Location:	**Sheyenne River-8-55.75**		
Graph Used:	**Fig 3-9**	Total Bank Length (ft):	**12261.3**			Date:	**10/2/2011**
Observers:	**KP, AL**	Valley Type:	**X**			Stream Type:	**E5**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**12261.3**	**21.4**	**43295**	**0.17**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**43295**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**1604**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**2085**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.17**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Sheyenne River**		Stream Type:	**E5**
Location:	**Sheyenne River-8-55.75**		Valley Type:	**X**
Observers:	**KP, AL**		Date:	**10/2/2011**

Enter Required Information for Existing Condition

	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
0	D_{max}	Largest particle from bar sample (ft)		(mm)	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	#DIV/0!

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	d	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	S	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Sediment Competence Using Dimensional Shear Stress

0	Bankfull shear stress $\tau = \gamma d S$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope	
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**	
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**	
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope	$d = \dfrac{\tau}{\gamma S}$
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth	$S = \dfrac{\tau}{\gamma d}$

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis

Observers: **KP, AL**

Stream: **Sheyenne River** | Location: **Sheyenne River-8-55.75** | Date: **10/2/2011**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		**100%**

SURFACE MATERIALS DATA (Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	**0**
Materials less than:	mm

Be sure to add separate material weights to grand total

0

GRAND TOTAL

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Sheyenne River**	Stream Type: **E5**
Location: **Sheyenne River-8-55.75**	Valley Type: **X**
Observers: **KP, AL**	Date: **10/2/2011**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream:	**Sheyenne River**		Stream Type:	**E5**	
Location:	**Sheyenne River-8-55.75**		Valley Type:	**X**	
Observers:	**KP, AL**		Date:	**10/2/2011**	

Lateral stability criteria (choose one stability category for each criterion 1–5)	**Lateral Stability Categories: Stable**	**Moderately unstable**	**Unstable**	**Highly unstable**	**Selected points (from each row)**
1 **W/d ratio state (Worksheet 3-8)**	< 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	> 1.6 **(8)**	**2**
2 **Depositional pattern (Worksheet 3-5)**	B1, B2 **(1)**	B4, B8 **(2)**	B3 **(3)**	B5, B6, B7 **(4)**	**1**
3 **Meander pattern (Worksheet 3-4)**	M1, M3, M4 **(1)**		M2, M5, M6, M7, M8 **(3)**		**3**
4 **Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL **(2)**	M/L, M/M, M/H, L/Ex, H/L **(4)**	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL **(6)**	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex **(8)**	**4**
5 **Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.8 – 1.0 **(1)**	0.3 – 0.79 **(2)**	0.1 – 0.29 **(3)**	< 0.1 **(4)**	**1**
				Total points	**11**

Overall lateral stability category (use total points and check stability rating)	**Lateral stability category point range: Stable 7 – 9**	**Moderately unstable 10 – 12**	**Unstable 13 – 21**	**Highly unstable > 21**
	☐	☑	☐	☐

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Sheyenne River**	Stream Type:	**E5**
Location:	**Sheyenne River-8-55.75**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**10/2/2011**

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 3-14)**	Sufficient depth and/or slope to transport largest size available **(2)**	Trend toward insufficient depth and/or slope-slightly incompetent **(4)**	Cannot move D_{35} of bed material and/or D_{100} of bar material **(6)**	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size **(8)**	**2**
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load **(2)**	Trend toward insufficient sediment capacity **(4)**	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand **(6)**	Reduction over 25% of annual sediment yield for bedload and/or suspended sand **(8)**	**2**
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	>1.6 **(8)**	**2**
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation **(2)**	(E→C) **(4)**	(C→High W/d C), (B→High W/d B), (C→F) **(6)**	(C→D), (F→D) **(8)**	**2**
5 **Depositional patterns (Worksheet 3-5)**	B1 **(1)**	B2, B4 **(2)**	B3, B5 **(3)**	B6, B7, B8 **(4)**	**1**
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 **(1)**	D4, D7 **(2)**	D5, D8 **(3)**	D6, D9, D10 **(4)**	**1**
				Total points	**10**

Vertical stability for excess deposition / aggradation (use total points and check stability rating)	**Vertical stability category point range for excess deposition / aggradation**			
	No deposition 10 – 14 ☑	**Moderate deposition 15 – 20** ☐	**Excess deposition 21 – 30** ☐	**Aggradation > 30** ☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream: **Sheyenne River**		Stream Type:	**E5**
Location: **Sheyenne River-8-55.75**		Valley Type:	**X**
Observers: **KP, AL**		Date:	**10/2/2011**

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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	2
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	2
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	8
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	4
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	1
				Total points	**17**

	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** ☐

Worksheet 3-20. Channel enlargement prediction summary.

Stream: **Sheyenne River**			Stream Type: **E5**		
Location: **Sheyenne River-8-55.75**			Valley Type: **X**		
Observers: **KP, AL**			Date: **10/2/2011**		
Channel enlargement prediction criteria (choose one stability category for each criterion 1–4)	**Channel Enlargement Prediction Categories**				**Selected points (from each row)**
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) **(2)**	(C→High W/d C), (E→C) **(4)**	(G→F), (F→D) **(6)**	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) **(8)**	**2**
2 **Lateral stability (Worksheet 3-17)**	Stable **(2)**	Moderately unstable **(4)**	Unstable **(6)**	Highly unstable **(8)**	**4**
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition **(2)**	Moderate deposition **(4)**	Excess deposition **(6)**	Aggradation **(8)**	**2**
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised **(2)**	Slightly incised **(4)**	Moderately incised **(6)**	Degradation **(8)**	**4**
				Total points	**12**
	Category point range				
Channel enlargement prediction (use total points and check stability rating)	**No increase 8 – 10** ☐	**Slight increase 11 – 16** ☑	**Moderate increase 17 – 24** ☐	**Extensive > 24** ☐	

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream: **Sheyenne River**		Stream Type:	**E5**
Location: **Sheyenne River-8-55.75**		Valley Type:	**X**
Observers: **KP, AL**		Date:	**10/2/2011**

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	Stability Rating	Points	Selected Points
1 Lateral stability (Worksheet 3-17)	Stable	1	2
	Mod. unstable	**2**	
	Unstable	3	
	Highly unstable	4	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	**No deposition**	**1**	1
	Mod. deposition	2	
	Excess deposition	3	
	Aggradation	4	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	2
	Slightly incised	**2**	
	Mod. Incised	3	
	Degradation	4	
4 Channel enlargement prediction (Worksheet 3-20)	No increase	1	2
	Slight increase	**2**	
	Mod. increase	3	
	Extensive	4	
5 Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	2
	Fair: mod unstable	**2**	
	Poor: unstable	4	
		Total Points	9

	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 ☐

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Sheyenne River**	Location:	**Sheyenne River-8-55.75**
Observers:	**KP, AL**	Date: **10/2/2011**	Stream Type: **E5** Valley Type: **X**

Section					
Channel Dimension	Mean bankfull depth (ft): **8.26**	Mean bankfull width (ft): **74.7**	Cross-section area (ft^2): **616.4**	Width of flood-prone area (ft): **898.5**	Entrenchment ratio: **12.0**
Channel Pattern	Mean: / Range: MWR: **16.9**	Lm/W_{bkf}: **16.9**	Rc/W_{bkf}: **2.8**	Sinuosity: **3.97**	
River Profile and Bed Features	Check: ☐ Riffle/pool ☐ Step/pool ☐ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed				
	Max bankfull depth (ft): Riffle **13.1**, Pool	Depth ratio (max/mean): Riffle **1.6**, Pool	Pool to pool spacing: Ratio	Slope: Valley:	Average bankfull: **0.0001**
Level III Stream Stability Indices	Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:	
	Flow regime: **P1, 2, 7, 9**	Stream size and order: **S-6**	Meander pattern(s): **M2**	Depositional pattern(s): **NONE**	Debris/channel blockage(s): **D3**
	Degree of incision (Bank-Height Ratio): **1.6**	Degree of incision stability rating: **Deeply Incised**	Modified Pfankuch stability rating (numeric and adjective rating): **Fair**		
	Width/depth ratio (W/d): **9.0**	Reference W/d ratio (W/d_{ref}): **9.0**	Width/depth ratio state $(W/d) / (W/d_{ref})$: **1.0**	W/d ratio state stability rating: **Stable**	
	Meander Width Ratio (MWR): **16.9**	Reference MWR_{ref}: **16.9**	Degree of confinement (MWR / MWR_{ref}): **1.0**	MWR / MWR_{ref} stability rating: **Unconfined**	
Bank Erosion Summary	Length of reach studied (ft): **####**	Annual streambank erosion rate: **2085** (tons/yr) **0.17** (tons/yr/ft)	Curve used: **Fig 3-9**	Remarks:	
Sediment Capacity (POWERSED)	☑ Sufficient capacity ☐ Insufficient capacity ☐ Excess capacity			Remarks:	
Entrainment/ Competence	Largest particle from bar sample (mm):	$\tau =$	$\tau^* =$	Existing $depth_{bkf}$: / Required $depth_{bkf}$:	Existing $slope_{bkf}$: / Required $slope_{bkf}$:
Successional Stage Shift	→ → → → →			Existing stream state (type): **E5**	Potential stream state (type): **E5**
Lateral Stability	☐ Stable ☑ Mod. unstable ☐ Unstable ☐ Highly unstable			Remarks/causes:	
Vertical Stability (Aggradation)	☑ No deposition ☐ Mod. deposition ☐ Ex. deposition ☐ Aggradation			Remarks/causes:	
Vertical Stability (Degradation)	☐ Not incised ☑ Slightly incised ☐ Mod. incised ☐ Degradation			Remarks/causes:	
Channel Enlargement	☐ No increase ☑ Slight increase ☐ Mod. increase ☐ Extensive			Remarks/causes:	
Sediment Supply (Channel Source)	☐ Low ☑ Moderate ☐ High ☐ Very high			Remarks/causes:	

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Wild Rice River**

Location: **Wild Rice River-1-3.01**

Observers: **KP, AL**

Reference reach: [ ]

Disturbed (impacted reach): **X**

Date: **10/4/2011**

Existing species composition:

Potential species composition:

	Riparian cover categories	Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**60%**	**3%**		
					100%
2. Understory	Shrub layer		**3%**		
					100%
3. Ground level	Herbaceous		**5%**		
					100%
	Leaf or needle litter		**10%**		
	Bare ground		**79%**		
			Column total = 100%		

Remarks:
Condition, vigor and/or usage of existing reach:

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

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Wild Rice River**		Location: **Wild Rice River-1-3.01**						
Observers: **KP, AL**						Date: **10/4/2011**		
List ALL COMBINATIONS that APPLY...............☞	**P1**	**P2**	**P9**					

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order

Stream:	**Wild Rice River**
Location:	**Wild Rice River-1-3.01**
Observers:	**KP, AL**
Date:	**10/4/2011**
Stream Size Category and Order ☞	**S-7**

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).

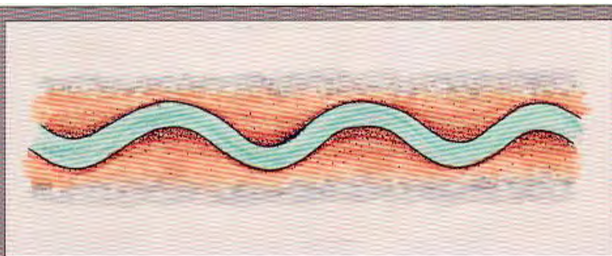
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Wild Rice River**	Reach:	**Wild Rice River-1-3.01**
Observers:	**KP, AL**	Date:	**10/4/2011**

List ALL CATEGORIES that APPLY ☞	**M2**				

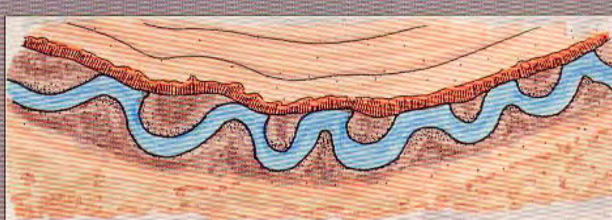
Various Meander Pattern variables modified from Galay et al. (1973)



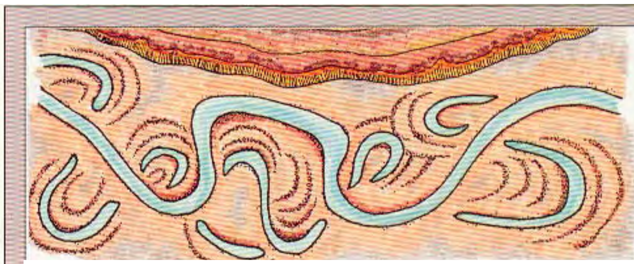
M1 REGULAR MEANDERS

M2 TORTUOUS MEANDERS

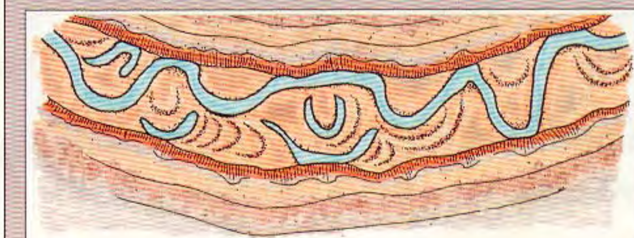
M3 IRREGULAR MEANDERS



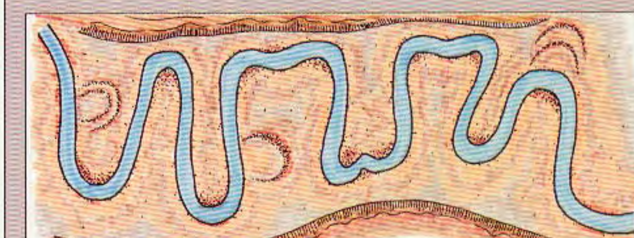
M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS



M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

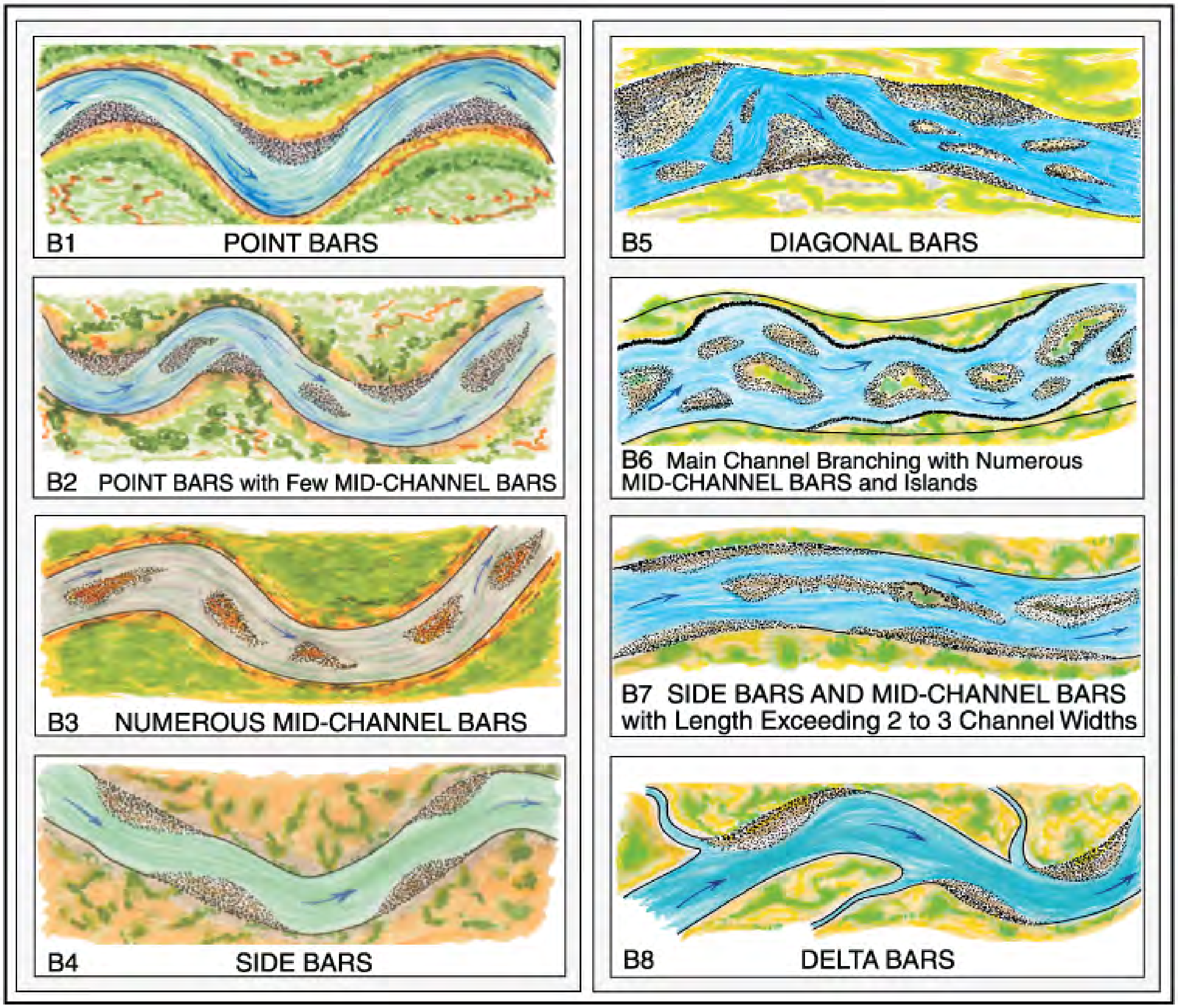
Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns

Stream:	**Wild Rice River**	Reach:	**Wild Rice River-1-3.01**
Observers:	**KP, AL**	Date:	**10/4/2011**

List ALL CATEGORIES that APPLY ☞	N/A				

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



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

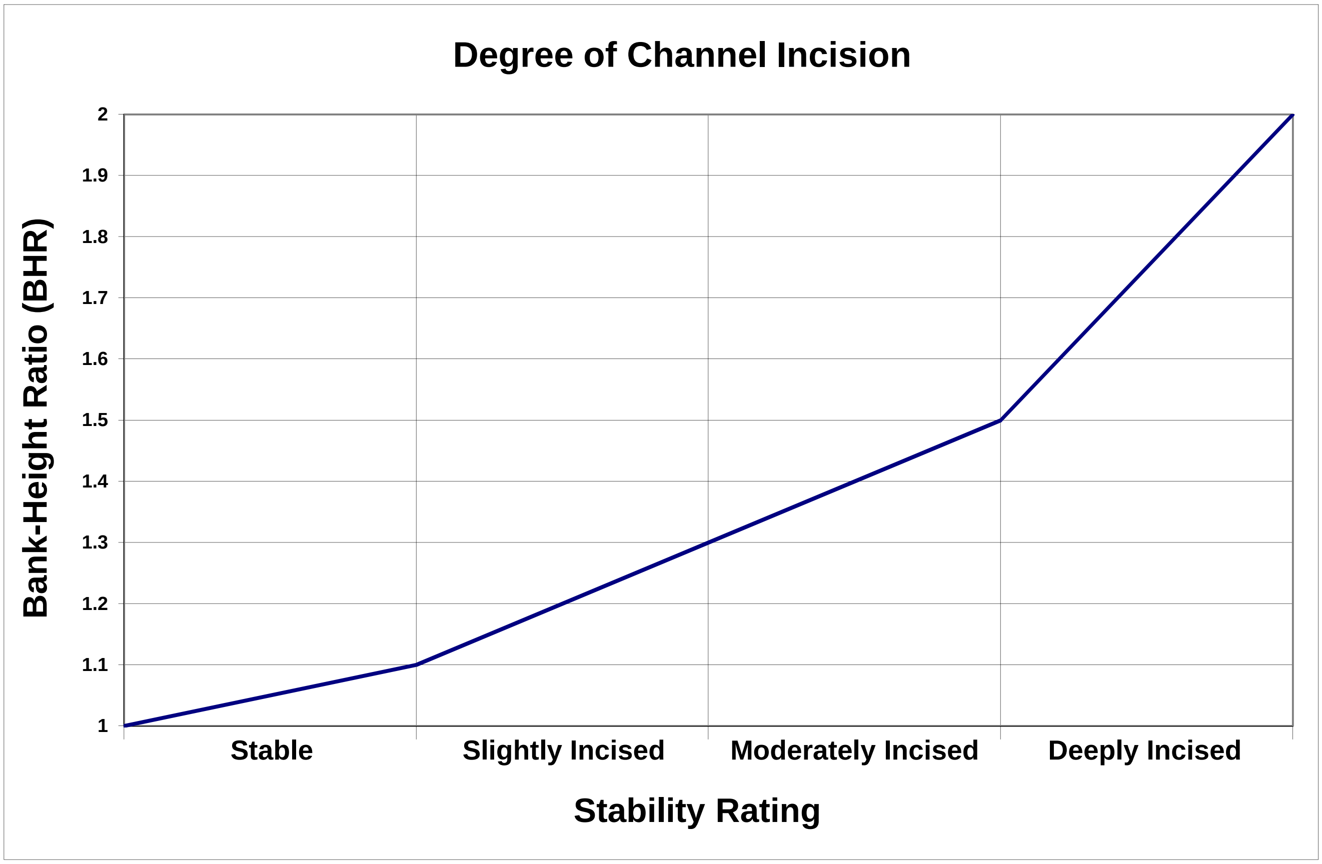
Channel Blockages			
Stream: **Wild Rice River**		Location: **Wild Rice River-1-3.01**	
Observers: **KP, AL**		Date: **10/4/2011**	
Description/extent		**Materials that upon placement into the active channel or flood-prone area may cause adjustments in channel dimensions or conditions due to influences 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.	☐

Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision

Low Bank Height:	**8.8**		Bank-Height Ratio:	**0.9**
Max Bankfull Depth:	**10.18**			

Degree of Channel Incision Stability Rating ☞	**Stable**

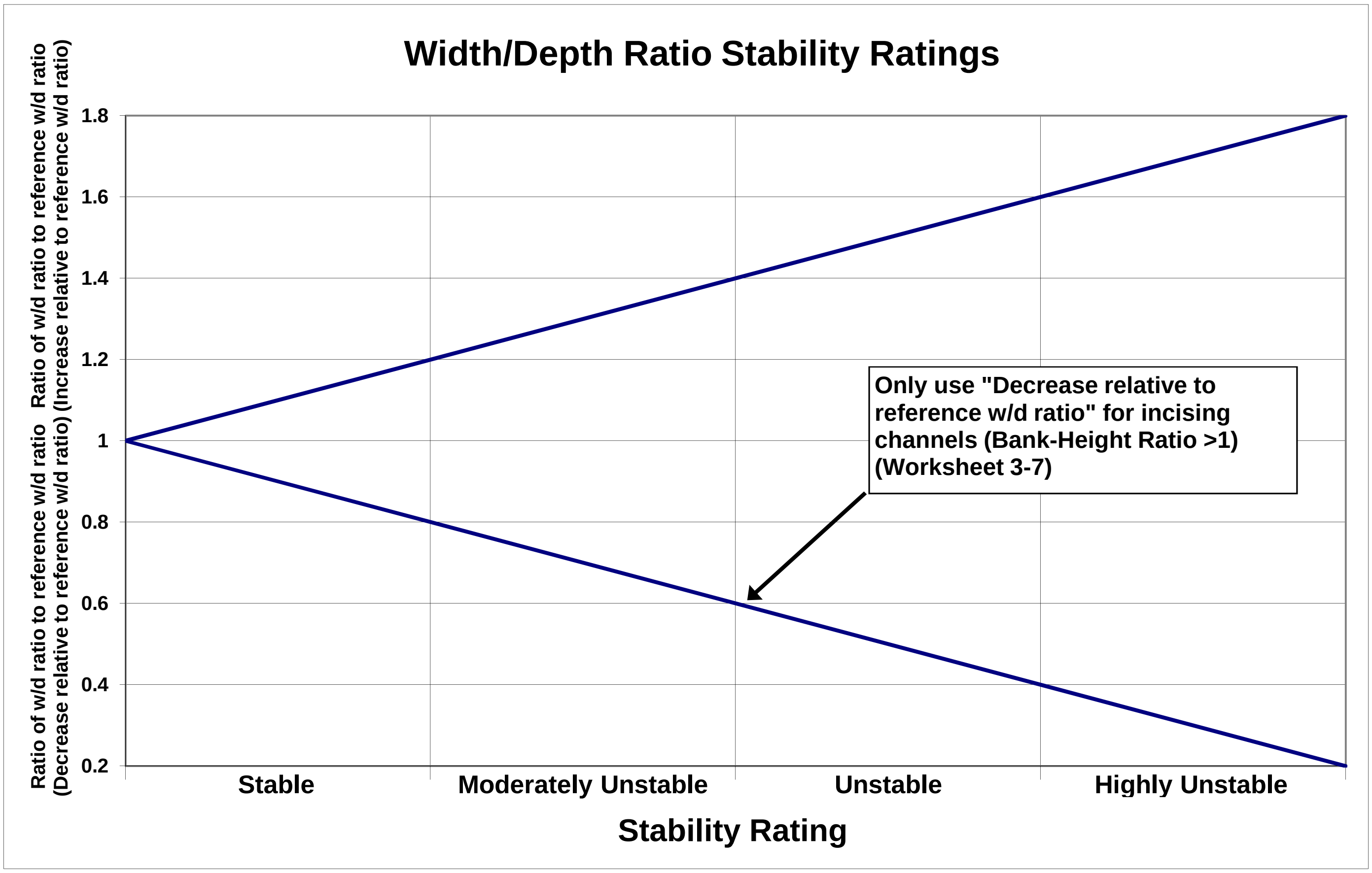


Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State

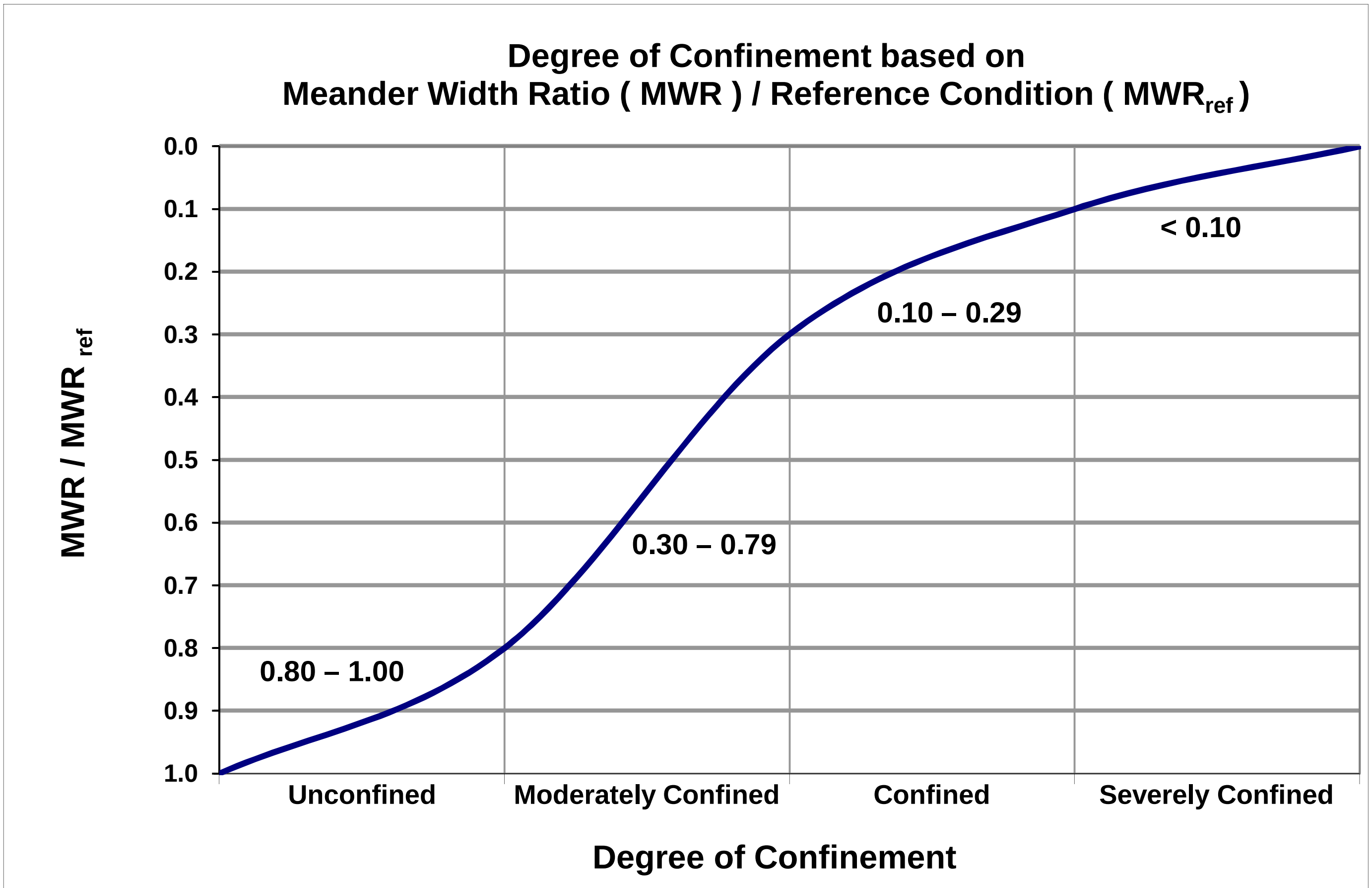
Existing Width/Depth Ratio:	11.3	Ratio of existing W/d to reference W/d:	1
Reference Width/Depth Ratio:	11.3		

Width/Depth Ratio State Stability Rating ☞ **Stable**



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	11.5	Ratio of MWR to MWR_{ref}:	1
Reference Meander Width Ratio (MWR_{ref}):	11.5		
Degree of Confinement Stability Rating ☞		**Unconfined**	



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Wild Rice River **Location:** Wild Rice River-1-3.01 **Valley Type:** X **Observers:** KP, AL **Date:** 10/4/2011

Location	Key	Category	Excellent Description	Rating	Good Description	Rating	Fair Description	Rating	Poor Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	**4**	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	**9**	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	**6**	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	**12**
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	**2**	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	**6**	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	**6**	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	21	Good total =	10	Fair total =	21	Poor total =	16

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	68
Existing stream type =	E6
*Potential stream type =	E6
Modified channel stability rating =	Fair

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream: **Wild Rice River**	Location: **Wild Rice River-1-3.01**
Station:	Observers: **KP, AL**
Date: **10/4/2011** Stream Type: **E6**	Valley Type: **X**

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	9.3 (A)	**Bankfull Height** (ft) =	8.1 (B)	(A) / (B) =	1.1 (C)	BEHI Score	2

Root Depth / Study Bank Height (E)

Root Depth (ft) =	2 (D)	**Study Bank Height** (ft) =	9.3 (A)	(D) / (A) =	0.2 (E)	BEHI Score	7

Weighted Root Density (G)

Root Density as **%** =	15% (F)	(F) x (E) =	3% (G)	BEHI Score	10

Bank Angle (H)

Bank Angle as *Degrees* =	27 (H)	BEHI Score	2

Surface Protection (I)

Surface Protection as **%** =	5% (I)	BEHI Score	10

Bank Material Adjustment:

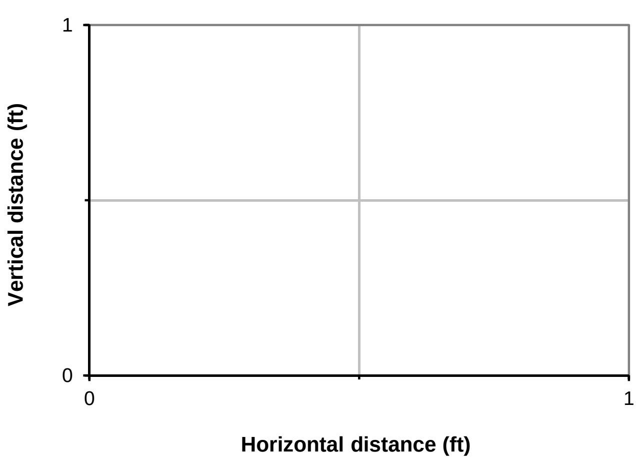
Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

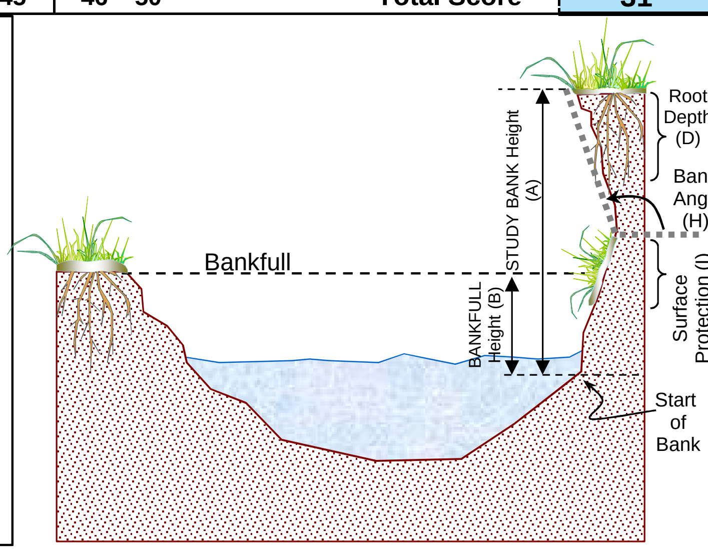
Bank Material Adjustment: 0

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** 31

Bank Sketch





Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Wild Rice River** Location: **Wild Rice River-1-3.01**

Station: **0** Stream Type: **E6** Valley Type: **X**

Observers: **KP, AL** Date: **10/4/11**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})...	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S)......................................	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})..	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})............................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient..	Level IV	Validation

Level I

(1)
- Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
- Extensive deposition (continuous, cross-channel)...................................... ....NBS = Extreme
- Chute cutoffs, down-valley meander migration, converging flow.....................................NBS = Extreme

Level II

	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)
(2)				

	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)
(3)				

	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)
(4)				

Dominant Near-Bank Stress
Very Low

Level III

	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)
(5)				

	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)
(6)								

Level IV

	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
(7)		**Very Low**

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating **Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Wild Rice River**				Location: **Wild Rice River-1-3.01**		
Graph Used:	**Fig 3-9**	Total Bank Length (ft): **4850.3**				Date: **10/4/2011**	
Observers:	**KP, AL**		Valley Type: **X**			Stream Type: **E6**	
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**4850.3**	**9.3**	**7443**	**0.07**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**7443**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**276**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**358**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.07**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Wild Rice River**	Stream Type:	**E6**
Location:	**Wild Rice River-1-3.01**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**10/4/2011**

Enter Required Information for Existing Condition

	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
0	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	**#DIV/0!**

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	d	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	S	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Sediment Competence Using Dimensional Shear Stress

0	Bankfull shear stress $\tau = \gamma d S$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) $d = \dfrac{\tau}{\gamma S}$ τ = predicted shear stress, γ = 62.4, S = existing slope
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) $S = \dfrac{\tau}{\gamma d}$ τ = predicted shear stress, γ = 62.4, d = existing depth

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis		Observers: **KP, AL**
Stream: **Wild Rice River**	Location: **Wild Rice River-1-3.01**	Date: **10/4/2011**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		**100%**

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	**0**
Materials less than:	mm

Be sure to add separate material weights to grand total

0

GRAND TOTAL

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Wild Rice River**	Stream Type: **E6**
Location: **Wild Rice River-1-3.01**	Valley Type: **X**
Observers: **KP, AL**	Date: **10/4/2011**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream:	**Wild Rice River**	Stream Type:	**E6**
Location:	**Wild Rice River-1-3.01**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**10/4/2011**

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 3-8)**	< 1.2 (2)	1.2 – 1.4 (4)	1.4 – 1.6 (6)	> 1.6 (8)	**2**
2 **Depositional pattern (Worksheet 3-5)**	B1, B2 (1)	B4, B8 (2)	B3 (3)	B5, B6, B7 (4)	**1**
3 **Meander pattern (Worksheet 3-4)**	M1, M3, M4 (1)		M2, M5, M6, M7, M8 (3)		**3**
4 **Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL (2)	M/L, M/M, M/H, L/Ex, H/L (4)	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL (6)	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex (8)	**4**
5 **Degree of confinement (MWR / MWR$_{ref}$) (Worksheet 3-9)**	0.8 – 1.0 (1)	0.3 – 0.79 (2)	0.1 – 0.29 (3)	< 0.1 (4)	**1**
				Total points	**11**

	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** ☐

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Wild Rice River**	Stream Type:	**E6**
Location:	**Wild Rice River-1-3.01**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**10/4/2011**

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 3-14)**	Sufficient depth and/or slope to transport largest size available **(2)**	Trend toward insufficient depth and/or slope-slightly incompetent **(4)**	Cannot move D_{35} of bed material and/or D_{100} of bar material **(6)**	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size **(8)**	**2**
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load **(2)**	Trend toward insufficient sediment capacity **(4)**	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand **(6)**	Reduction over 25% of annual sediment yield for bedload and/or suspended sand **(8)**	**2**
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	>1.6 **(8)**	**2**
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation **(2)**	(E→C) **(4)**	(C→High W/d C), (B→High W/d B), (C→F) **(6)**	(C→D), (F→D) **(8)**	**2**
5 **Depositional patterns (Worksheet 3-5)**	B1 **(1)**	B2, B4 **(2)**	B3, B5 **(3)**	B6, B7, B8 **(4)**	**1**
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 **(1)**	D4, D7 **(2)**	D5, D8 **(3)**	D6, D9, D10 **(4)**	**2**
				Total points	**11**

	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** ☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream: **Wild Rice River**			Stream Type: **E6**		
Location: **Wild Rice River-1-3.01**			Valley Type: **X**		
Observers: **KP, AL**			Date: **10/4/2011**		
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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	2
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	2
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	2
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	2
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	1
				Total points	9
	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** ☐	

Worksheet 3-20. Channel enlargement prediction summary.

Stream:	**Wild Rice River**			Stream Type:	**E6**
Location:	**Wild Rice River-1-3.01**			Valley Type:	**X**
Observers:	**KP, AL**			Date:	**10/4/2011**

Channel enlargement prediction criteria (choose one stability category for each criterion 1–4)	**Channel Enlargement Prediction Categories**				**Selected points** (from each row)
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) (2)	(C→High W/d C), (E→C) (4)	(G→F), (F→D) (6)	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) (8)	**2**
2 **Lateral stability (Worksheet 3-17)**	Stable (2)	Moderately unstable (4)	Unstable (6)	Highly unstable (8)	**4**
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition (2)	Moderate deposition (4)	Excess deposition (6)	Aggradation (8)	**2**
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised (2)	Slightly incised (4)	Moderately incised (6)	Degradation (8)	**2**
				Total points	**10**
	Category point range				
Channel enlargement prediction (use total points and check stability rating)	**No increase 8 – 10** ☑	**Slight increase 11 – 16** ☐	**Moderate increase 17 – 24** ☐	**Extensive > 24** ☐	

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream:	**Wild Rice River**	Stream Type:	**E6**
Location:	**Wild Rice River-1-3.01**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**10/4/2011**

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	Stability Rating	Points	Selected Points
1 Lateral stability (Worksheet 3-17)	Stable	1	2
	Mod. unstable	**2**	
	Unstable	3	
	Highly unstable	4	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	**No deposition**	**1**	1
	Mod. deposition	2	
	Excess deposition	3	
	Aggradation	4	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	**Not incised**	**1**	1
	Slightly incised	2	
	Mod. Incised	3	
	Degradation	4	
4 Channel enlargement prediction (Worksheet 3-20)	**No increase**	**1**	1
	Slight increase	2	
	Mod. increase	3	
	Extensive	4	
5 Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	2
	Fair: mod unstable	**2**	
	Poor: unstable	4	
		Total Points	7

	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 ☐

Worksheet 3-22. Summary of stability condition categories.

Stream: **Wild Rice River**	Location: **Wild Rice River-1-3.01**
Observers: **KP, AL**	Date: **10/4/2011** Stream Type: **E6** Valley Type: **X**
Channel Dimension	Mean bankfull depth (ft): **7.01** ; Mean bankfull width (ft): **79.16** ; Cross-section area (ft^2): **556.2** ; Width of flood-prone area (ft): **333** ; Entrenchment ratio: **4.2**
Channel Pattern	Mean: Range: ; MWR: **11.5** ; Lm/W_{bkf}: **11.5** ; Rc/W_{bkf}: **1.7** ; Sinuosity: **3.9**
River Profile and Bed Features	Check: ☐ Riffle/pool ☐ Step/pool ☐ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed
	Max bankfull depth (ft): Riffle **10.2**, Pool — ; Depth ratio (max/mean): Riffle **1.5**, Pool — ; Pool to pool spacing: Ratio — ; Slope: Valley: — ; Average bankfull: **0.0001**
Level III Stream Stability Indices	Riparian vegetation: Current composition/density: ; Potential composition/density: ; Remarks: Condition, vigor and/or usage of existing reach:
	Flow regime: **P1, 2, 9** ; Stream size and order: **S-7** ; Meander pattern(s): **M2** ; Depositional pattern(s): **NONE** ; Debris/channel blockage(s): **D3, 4**
	Degree of incision (Bank-Height Ratio): **0.9** ; Degree of incision stability rating: **Stable** ; Modified Pfankuch stability rating (numeric and adjective rating): **Fair**
	Width/depth ratio (W/d): **11.3** ; Reference W/d ratio (W/d_{ref}): **11.3** ; Width/depth ratio state $(W/d) / (W/d_{ref})$: **1.0** ; W/d ratio state stability rating: **Stable**
	Meander Width Ratio (MWR): **11.5** ; Reference MWR_{ref}: **11.5** ; Degree of confinement (MWR / MWR_{ref}): **1.0** ; MWR / MWR_{ref} stability rating: **Unconfined**
Bank Erosion Summary	Length of reach studied (ft): **4850** ; Annual streambank erosion rate: **358** (tons/yr) **0.07** (tons/yr/ft) ; Curve used: **Fig 3-9** ; Remarks:
Sediment Capacity (POWERSED)	☑ Sufficient capacity ☐ Insufficient capacity ☐ Excess capacity ; Remarks:
Entrainment/ Competence	Largest particle from bar sample (mm): — ; $\tau =$ — ; $\tau^* =$ — ; Existing $depth_{bkf}$: — ; Required $depth_{bkf}$: — ; Existing $slope_{bkf}$: — ; Required $slope_{bkf}$: —
Successional Stage Shift	→ → → → → ; Existing stream state (type): **E6** ; Potential stream state (type): **E6**
Lateral Stability	☐ Stable ☑ Mod. unstable ☐ Unstable ☐ Highly unstable ; Remarks/causes:
Vertical Stability (Aggradation)	☑ No deposition ☐ Mod. deposition ☐ Ex. deposition ☐ Aggradation ; Remarks/causes:
Vertical Stability (Degradation)	☑ Not incised ☐ Slightly incised ☐ Mod. incised ☐ Degradation ; Remarks/causes:
Channel Enlargement	☑ No increase ☐ Slight increase ☐ Mod. increase ☐ Extensive ; Remarks/causes:
Sediment Supply (Channel Source)	☐ Low ☑ Moderate ☐ High ☐ Very high ; Remarks/causes:

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Wild Rice River**			Location: **Wild Rice River-2-4.23**		
Observers: **KP, AL**	Reference reach		Disturbed (impacted reach)	**X**	Date: **10/4/2011**
Existing species composition:			Potential species composition:		

Riparian cover categories		Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**75%**	**5%**		
					100%
2. Understory	Shrub layer		**10%**		
					100%
3. Ground level	Herbaceous		**10%**		
					100%
	Leaf or needle litter		**5%**	**Remarks:** Condition, vigor and/or usage of existing reach:	
	Bare ground		**70%**		
			Column total = 100%		

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

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Wild Rice River**			Location: **Wild Rice River-2-4.23**					
Observers: **KP, AL**						Date: **10/4/2011**		
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P9**					

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order			
Stream:	**Wild Rice River**		
Location:	**Wild Rice River-2-4.23**		
Observers:	**KP, AL**		
Date:	**10/4/2011**		
Stream Size Category and Order ☞			**S-7**
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).			

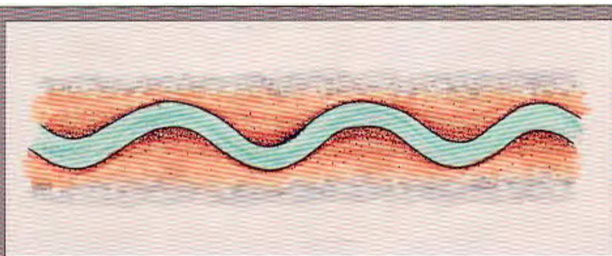
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Wild Rice River**	Reach:	**Wild Rice River-2-4.23**
Observers:	**KP, AL**	Date:	**10/4/2011**

List ALL CATEGORIES that APPLY ☞	M2				

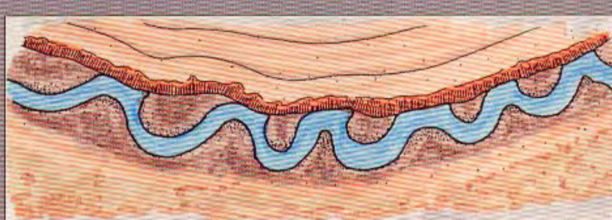
Various Meander Pattern variables modified from Galay et al. (1973)



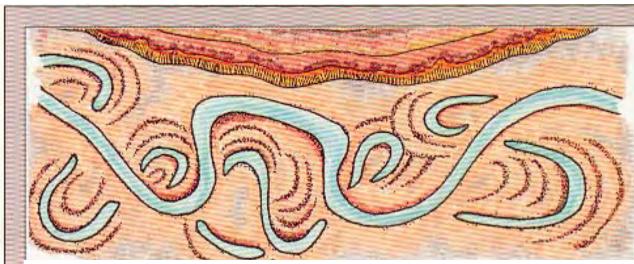
M1 REGULAR MEANDERS

M2 TORTUOUS MEANDERS

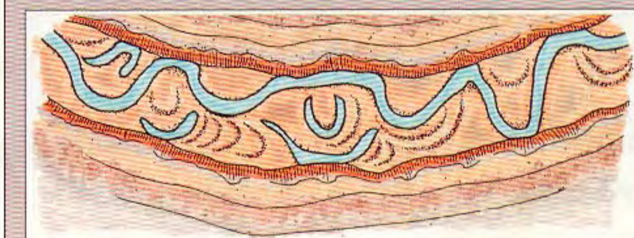
M3 IRREGULAR MEANDERS



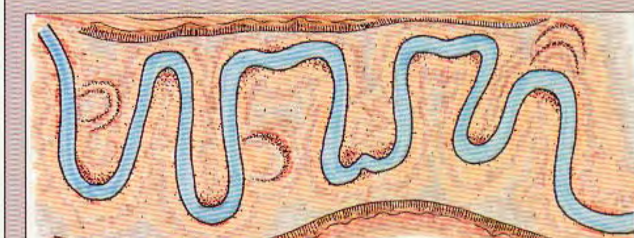
M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS



M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

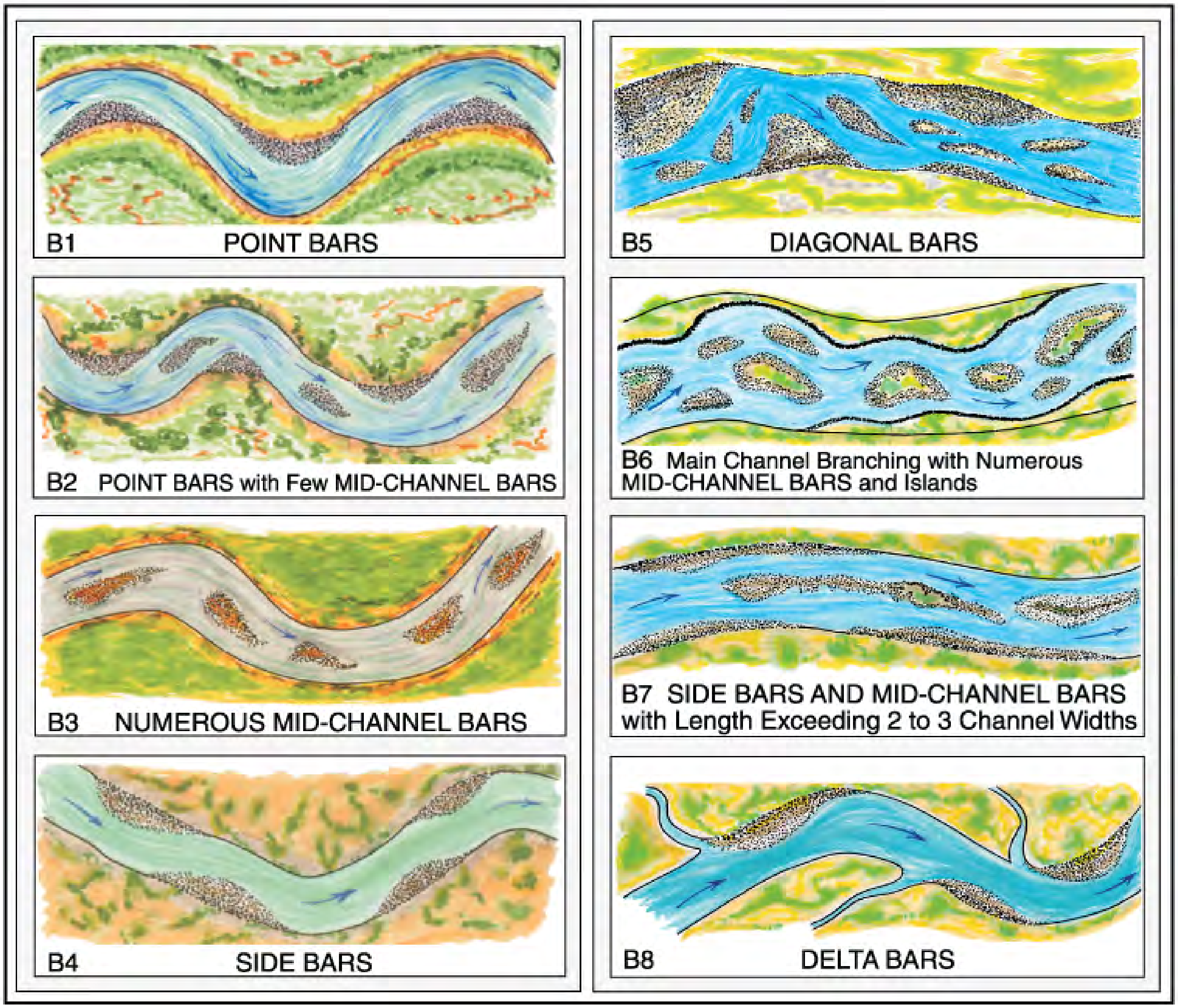
Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns

Stream:	**Wild Rice River**	Reach:	**Wild Rice River-2-4.23**
Observers:	**KP, AL**	Date:	**10/4/2011**

List ALL CATEGORIES that APPLY ☞	**N/A**				

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

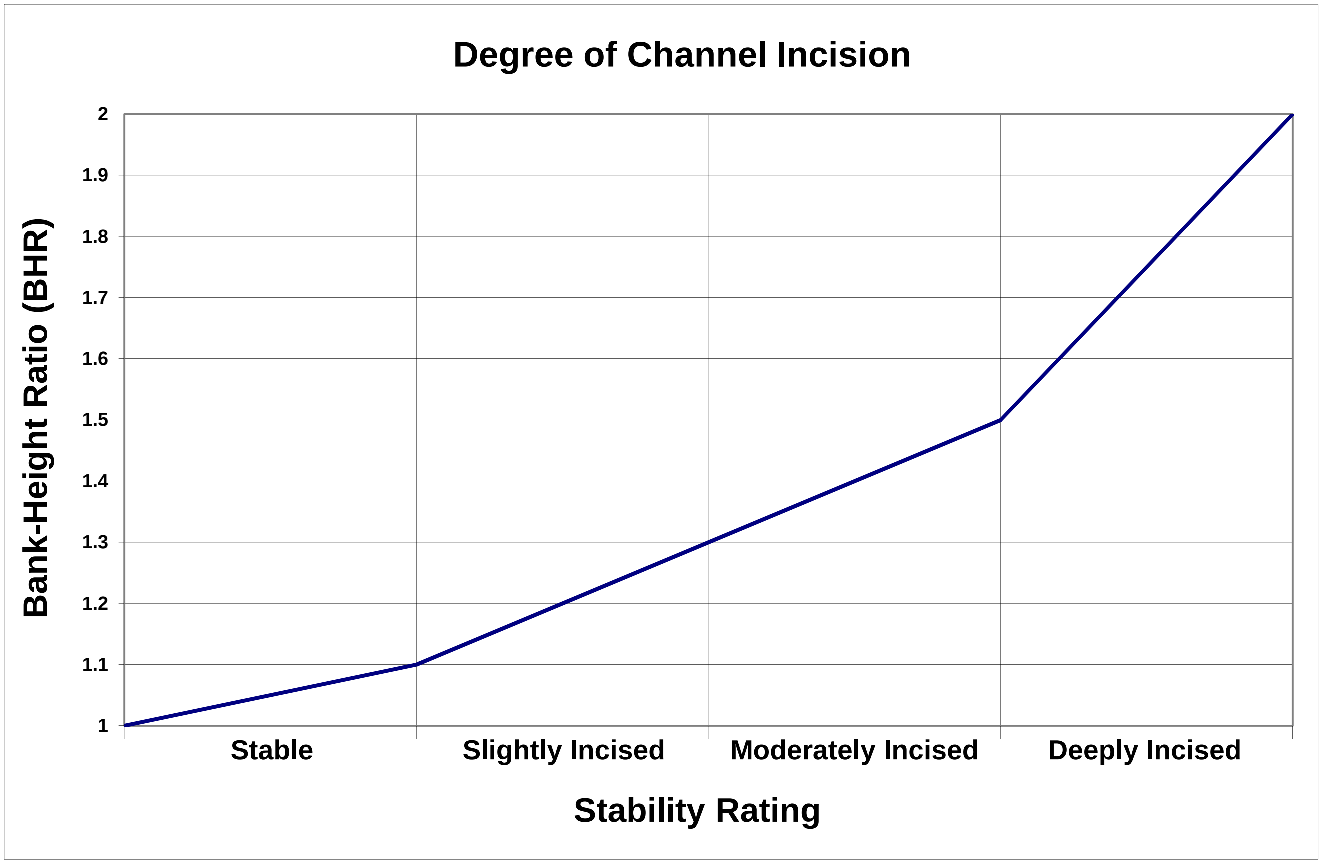


Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Wild Rice River**		Location: **Wild Rice River-2-4.23**	
Observers: **KP, AL**		Date: **10/4/2011**	
Description/extent		**Materials that 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.	☐

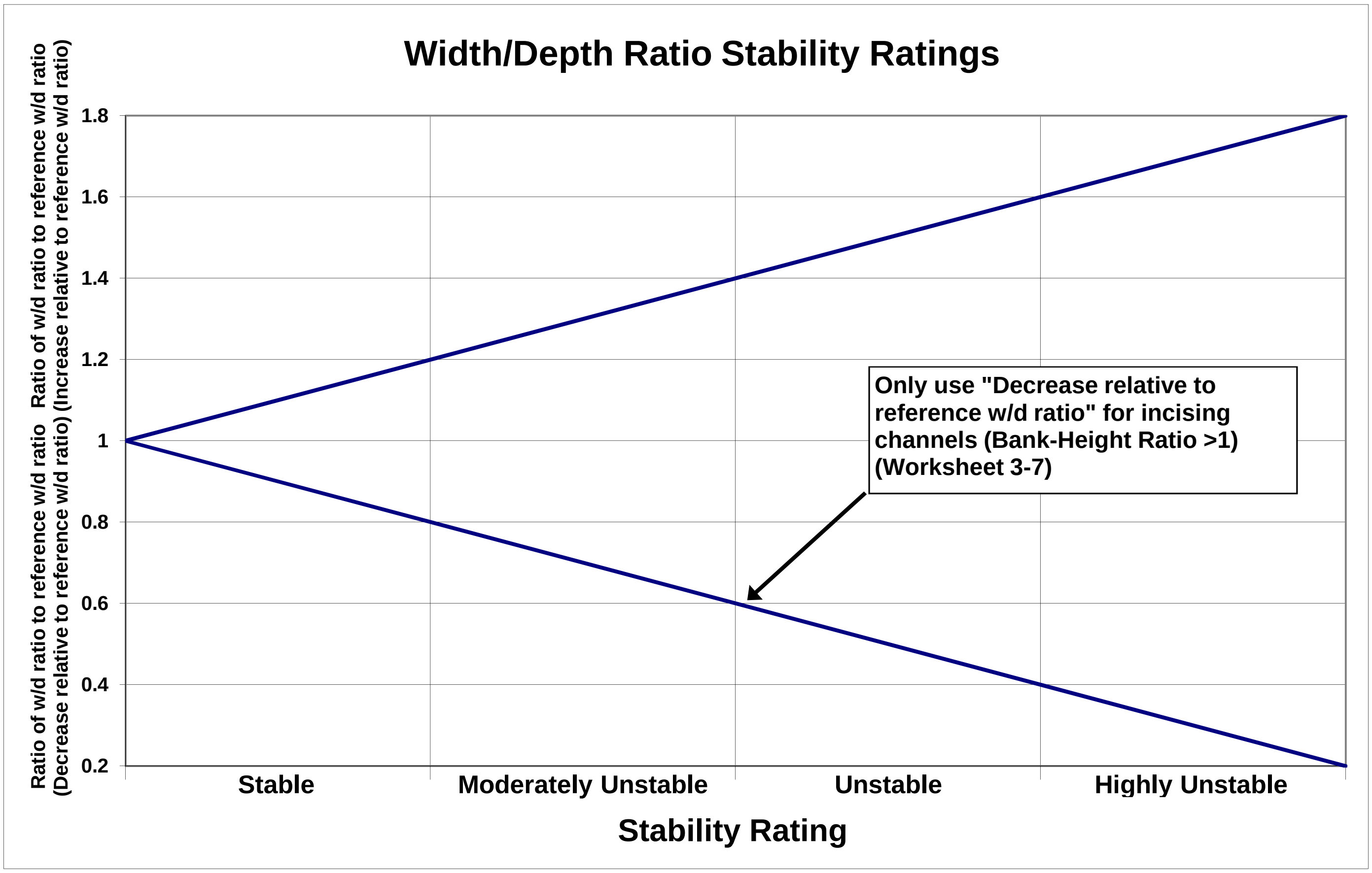
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision			
Low Bank Height:	9.8	Bank-Height Ratio:	1.2
Max Bankfull Depth:	8.467		
Degree of Channel Incision Stability Rating ☞		Slightly Incised	



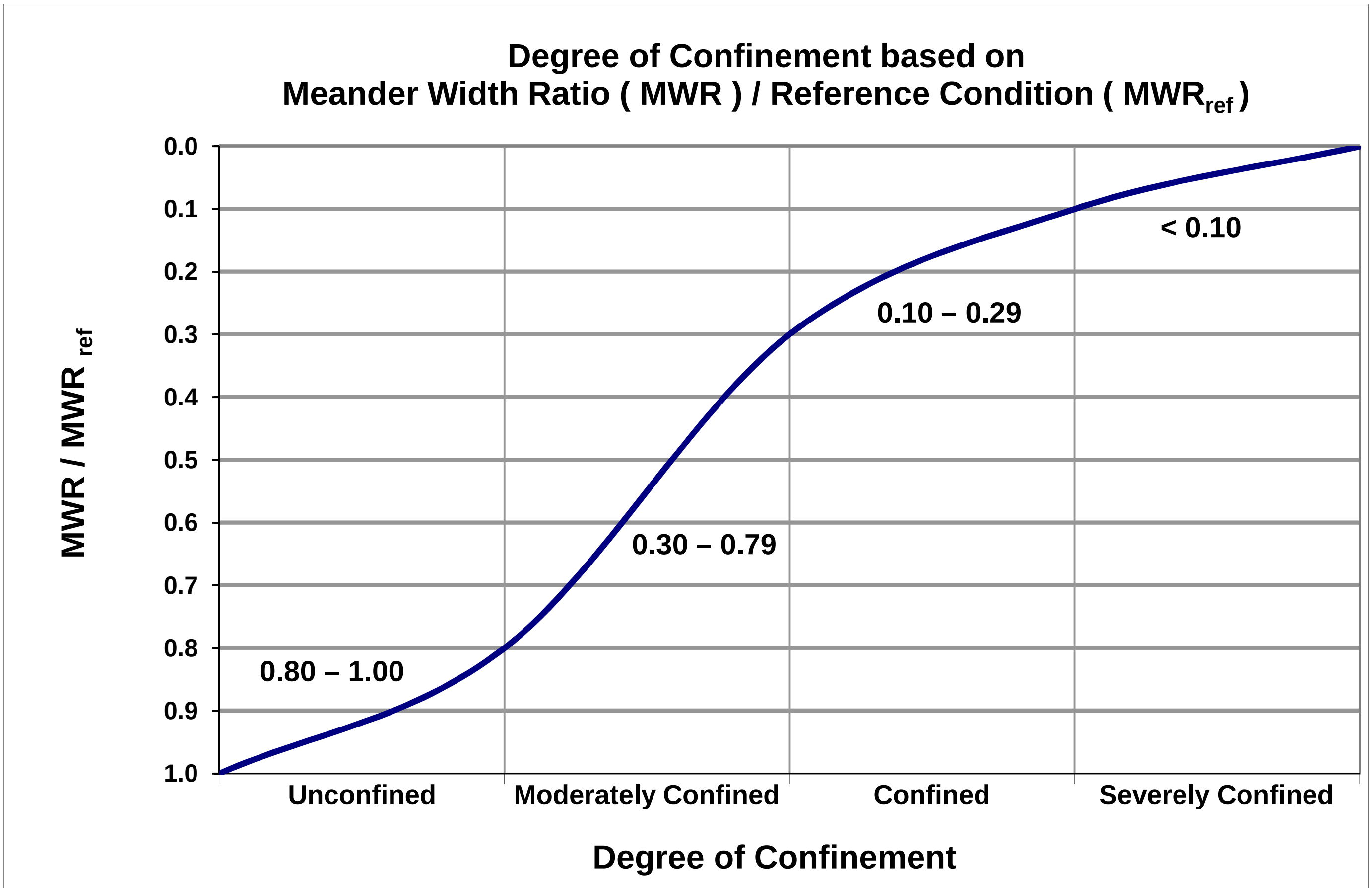
Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State			
Existing Width/Depth Ratio:	**13.5**	Ratio of existing W/d to reference W/d:	**1**
Reference Width/Depth Ratio:	**13.5**		
Width/Depth Ratio State Stability Rating ☞		**Stable**	



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	8.8	Ratio of MWR to MWR_{ref}:	1
Reference Meander Width Ratio (MWR_{ref}):	8.8		
Degree of Confinement Stability Rating ☞		**Unconfined**	



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Wild Rice River **Location:** Wild Rice River-2-4.23 **Valley Type:** X **Observers:** KP, AL **Date:** 10/4/2011

Location	Key	Category	Excellent Description	Excellent Rating	Good Description	Good Rating	Fair Description	Fair Rating	Poor Description	Poor Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	**2**	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	**9**	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	**4**	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	**12**
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	**2**	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	**2**	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	**12**	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	25	Good total =	4	Fair total =	21	Poor total =	16

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	66
Existing stream type =	E6
*Potential stream type =	E6
Modified channel stability rating =	Fair

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream: **Wild Rice River** Location: **Wild Rice River-2-4.23**

Station: Observers: **KP, AL**

Date: **10/4/2011** Stream Type: **E6** Valley Type: **X**

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	9.9 **(A)**	**Bankfull Height** (ft) =	8 **(B)**	(A) / (B) =	1.2 **(C)**	4

Root Depth / Study Bank Height (E)

Root Depth (ft) =	1.5 **(D)**	**Study Bank Height** (ft) =	9.9 **(A)**	(D) / (A) =	0.2 **(E)**	7

Weighted Root Density (G)

Root Density as **%** =	20% **(F)**	(F) x (E) =	3% **(G)**	10

Bank Angle (H)

Bank Angle as *Degrees* =	22 **(H)**	2

Surface Protection (I)

Surface Protection as **%** =	5% **(I)**	10

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)

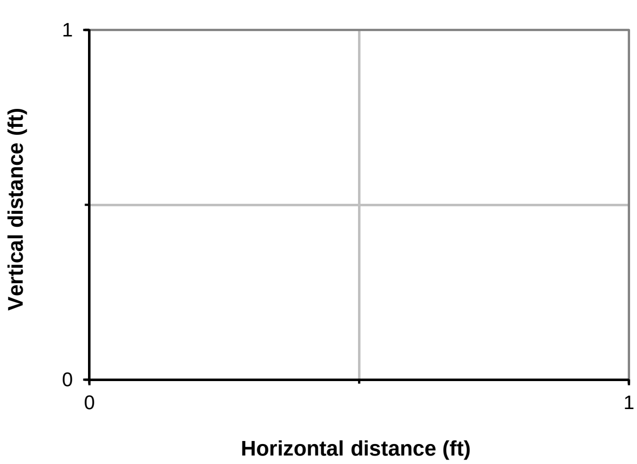
Bank Material Adjustment: 0

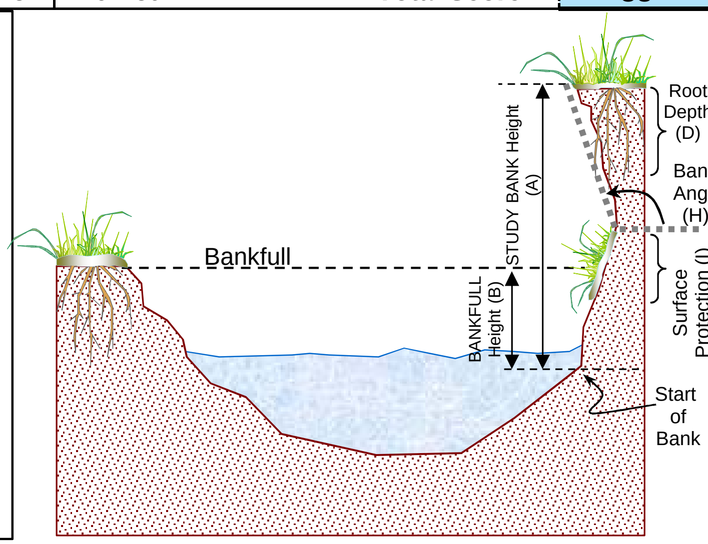
Stratification Adjustment
Add 5–10 points, depending on position of unstable layers in relation to bankfull stage: 0

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**: **High** 33

Bank Sketch





Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Wild Rice River**	Location: **Wild Rice River-2-4.23**	
Station: **0**	Stream Type: **E6**	Valley Type: **X**
Observers: **KP, AL**		Date: **10/4/11**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})...	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S).......................................	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})..	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})...........................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient...	Level IV	Validation

Level I

(1)
- Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
- Extensive deposition (continuous, cross-channel).................................... ....NBS = Extreme
- Chute cutoffs, down-valley meander migration, converging flow..NBS = Extreme

Level II

(2)	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)

(3)	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)

(4)	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)

Dominant Near-Bank Stress
Very Low

Level III

(5)	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)

(6)	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)

Level IV

(7)	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
		Very Low

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating	**Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Wild Rice River**			Location:	**Wild Rice River-2-4.23**		
Graph Used:	**Fig 3-9**	Total Bank Length (ft):	**3730.5**			Date:	**10/4/2011**
Observers:	**KP, AL**	Valley Type:	**X**			Stream Type:	**E6**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**3730.5**	**9.9**	**6094**	**0.08**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**6094**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**226**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**293**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.08**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Wild Rice River**		Stream Type: **E6**		
Location:	**Wild Rice River-2-4.23**		Valley Type: **X**		
Observers:	**KP, AL**		Date: **10/4/2011**		
Enter Required Information for Existing Condition					
	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
0	**D_{max}**	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			
Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress					
#DIV/0!	**$D_{50}/\hat{D}_{50}$**	Range: 3 – 7	Use EQUATION 1: $\tau^* = 0.0834\ (D_{50}/\hat{D}_{50})^{-0.872}$		
#DIV/0!	**D_{max}/D_{50}**	Range: 1.3 – 3.0	Use EQUATION 2: $\tau^* = 0.0384\ (D_{max}/D_{50})^{-0.887}$		
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:		**#DIV/0!**
Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample					
#DIV/0!	**d**	Required bankfull mean depth (ft) $d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)		
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample					
#DIV/0!	**S**	Required bankfull water surface slope (ft/ft) $S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)		
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Sediment Competence Using Dimensional Shear Stress					
0	Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope				
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**				
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**				
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) $\mathbf{d} = \dfrac{\tau}{\gamma \mathbf{S}}$ τ = predicted shear stress, γ = 62.4, S = existing slope				
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) $\mathbf{S} = \dfrac{\tau}{\gamma \mathbf{d}}$ τ = predicted shear stress, γ = 62.4, d = existing depth				

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis	Observers: **KP, AL**	
Stream: **Wild Rice River**	Location: **Wild Rice River-2-4.23**	Date: **10/4/2011**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		**100%**

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	**0**
Materials less than:	mm

Be sure to add separate material weights to grand total

GRAND TOTAL **0**

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Wild Rice River**	Stream Type: **E6**
Location: **Wild Rice River-2-4.23**	Valley Type: **X**
Observers: **KP, AL**	Date: **10/4/2011**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream: **Wild Rice River**				Stream Type:	**E6**
Location: **Wild Rice River-2-4.23**				Valley Type:	**X**
Observers: **KP, AL**				Date:	**10/4/2011**

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 3-8)**	< 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	> 1.6 **(8)**	**2**
2 **Depositional pattern (Worksheet 3-5)**	B1, B2 **(1)**	B4, B8 **(2)**	B3 **(3)**	B5, B6, B7 **(4)**	**1**
3 **Meander pattern (Worksheet 3-4)**	M1, M3, M4 **(1)**		M2, M5, M6, M7, M8 **(3)**		**3**
4 **Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL **(2)**	M/L, M/M, M/H, L/Ex, H/L **(4)**	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL **(6)**	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex **(8)**	**4**
5 **Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.8 – 1.0 **(1)**	0.3 – 0.79 **(2)**	0.1 – 0.29 **(3)**	< 0.1 **(4)**	**1**
				Total points	**11**

	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** ☐

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Wild Rice River**	Stream Type:	**E6**
Location:	**Wild Rice River-2-4.23**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**10/4/2011**

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 3-14)**	Sufficient depth and/or slope to transport largest size available (2)	Trend toward insufficient depth and/or slope-slightly incompetent (4)	Cannot move D_{35} of bed material and/or D_{100} of bar material (6)	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size (8)	**2**
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load (2)	Trend toward insufficient sediment capacity (4)	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand (6)	Reduction over 25% of annual sediment yield for bedload and/or suspended sand (8)	**2**
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 (2)	1.2 – 1.4 (4)	1.4 – 1.6 (6)	>1.6 (8)	**2**
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation (2)	(E→C) (4)	(C→High W/d C), (B→High W/d B), (C→F) (6)	(C→D), (F→D) (8)	**2**
5 **Depositional patterns (Worksheet 3-5)**	B1 (1)	B2, B4 (2)	B3, B5 (3)	B6, B7, B8 (4)	**1**
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 (1)	D4, D7 (2)	D5, D8 (3)	D6, D9, D10 (4)	**1**
				Total points	**10**

Vertical stability for excess deposition / aggradation (use total points and check stability rating)	Vertical stability category point range for excess deposition / aggradation			
	No deposition 10 – 14 ☑	**Moderate deposition 15 – 20** ☐	**Excess deposition 21 – 30** ☐	**Aggradation > 30** ☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream: **Wild Rice River**				Stream Type:	**E6**	
Location: **Wild Rice River-2-4.23**				Valley Type:	**X**	
Observers: **KP, AL**				Date:	**10/4/2011**	
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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	**2**	
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	**2**	
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	**4**	
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	**4**	
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	**1**	
				Total points	**13**	
	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** ☐		

Worksheet 3-20. Channel enlargement prediction summary.

Stream: **Wild Rice River**			Stream Type:	**E6**	
Location: **Wild Rice River-2-4.23**			Valley Type:	**X**	
Observers: **KP, AL**			Date:	**10/4/2011**	
Channel enlargement prediction criteria **(choose one stability category for each criterion 1–4)**	**Channel Enlargement Prediction Categories**				**Selected points (from each row)**
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) **(2)**	(C→High W/d C), (E→C) **(4)**	(G→F), (F→D) **(6)**	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) **(8)**	**2**
2 **Lateral stability (Worksheet 3-17)**	Stable **(2)**	Moderately unstable **(4)**	Unstable **(6)**	Highly unstable **(8)**	**4**
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition **(2)**	Moderate deposition **(4)**	Excess deposition **(6)**	Aggradation **(8)**	**2**
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised **(2)**	Slightly incised **(4)**	Moderately incised **(6)**	Degradation **(8)**	**4**
				Total points	**12**
	Category point range				
Channel enlargement prediction (use total points and check stability rating)	**No increase** **8 – 10** ☐	**Slight increase** **11 – 16** ☑	**Moderate increase** **17 – 24** ☐	**Extensive** **> 24** ☐	

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream:	**Wild Rice River**	Stream Type:	**E6**
Location:	**Wild Rice River-2-4.23**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**10/4/2011**

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	**Stability Rating**	**Points**	**Selected Points**
1 Lateral stability (Worksheet 3-17)	Stable	1	2
	Mod. unstable	2	
	Unstable	3	
	Highly unstable	4	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition	1	1
	Mod. deposition	2	
	Excess deposition	3	
	Aggradation	4	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	2
	Slightly incised	2	
	Mod. Incised	3	
	Degradation	4	
4 Channel enlargement prediction (Worksheet 3-20)	No increase	1	2
	Slight increase	2	
	Mod. increase	3	
	Extensive	4	
5 Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	2
	Fair: mod unstable	2	
	Poor: unstable	4	
		Total Points	**9**

	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 ☐

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Wild Rice River**		Location: **Wild Rice River-2-4.23**		
Observers:	**KP, AL**	Date: **10/4/2011**	Stream Type: **E6**	Valley Type: **X**	
Channel Dimension	Mean bankfull depth (ft): **6.23**	Mean bankfull width (ft): **84.31**	Cross-section area (ft^2): **525.3**	Width of flood-prone area (ft): **283.6667**	Entrenchment ratio: **3.4**
Channel Pattern	Mean: Range:	MWR: **8.8**	Lm/W_{bkf}: **8.8**	Rc/W_{bkf}: **1.8**	Sinuosity: **2.26**
River Profile and Bed Features	Check: [ ] Riffle/pool [ ] Step/pool [ ] Plane bed [ ] Convergence/divergence [x] Dunes/antidunes/smooth bed				
	Max bankfull depth (ft): Riffle **8.5**, Pool	Depth ratio (max/mean): Riffle **1.4**, Pool	Pool to pool spacing:	Ratio	Slope: Valley: ; Average bankfull: **8.8E-05**
Level III Stream Stability Indices	Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:	
	Flow regime: **P1, 2, 9**	Stream size and order: **S-7**	Meander pattern(s): **M2**	Depositional pattern(s): **NONE**	Debris/channel blockage(s): **D3**
	Degree of incision (Bank-Height Ratio): **1.2**	Degree of incision stability rating: **Slightly Incised**	Modified Pfankuch stability rating (numeric and adjective rating): **Fair**		
	Width/depth ratio (W/d): **13.5**	Reference W/d ratio (W/d_{ref}): **13.5**	Width/depth ratio state $(W/d) / (W/d_{ref})$: **1.0**	W/d ratio state stability rating: **Stable**	
	Meander Width Ratio (MWR): **8.8**	Reference MWR_{ref}: **8.8**	Degree of confinement (MWR / MWR_{ref}): **1.0**	MWR / MWR_{ref} stability rating: **Unconfined**	
Bank Erosion Summary	Length of reach studied (ft): **3731**	Annual streambank erosion rate: **293** (tons/yr) **0.08** (tons/yr/ft)	Curve used: **Fig 3-9**	Remarks:	
Sediment Capacity (POWERSED)	[x] Sufficient capacity [ ] Insufficient capacity [ ] Excess capacity			Remarks:	
Entrainment/ Competence	Largest particle from bar sample (mm):	$\tau =$	$\tau^* =$	Existing $depth_{bkf}$: ; Required $depth_{bkf}$:	Existing $slope_{bkf}$: ; Required $slope_{bkf}$:
Successional Stage Shift	→ → → → →		Existing stream state (type): **E6**	Potential stream state (type): **E6**	
Lateral Stability	[ ] Stable [x] Mod. unstable [ ] Unstable [ ] Highly unstable			Remarks/causes:	
Vertical Stability (Aggradation)	[x] No deposition [ ] Mod. deposition [ ] Ex. deposition [ ] Aggradation			Remarks/causes:	
Vertical Stability (Degradation)	[ ] Not incised [x] Slightly incised [ ] Mod. incised [ ] Degradation			Remarks/causes:	
Channel Enlargement	[ ] No increase [x] Slight increase [ ] Mod. increase [ ] Extensive			Remarks/causes:	
Sediment Supply (Channel Source)	[ ] Low [x] Moderate [ ] High [ ] Very high			Remarks/causes:	

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Wild Rice River**

Location: **Wild Rice River-3-17.52**

Observers: **KD, JB**

Reference reach: [ ]

Disturbed (impacted reach): **X**

Date: **10/4/2011**

Existing species composition:

Potential species composition:

	Riparian cover categories	Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**60%**	**2%**	**Trees**	**100%**
					100%
2. Understory	Shrub layer		**25%**	**Shrubs**	**100%**
					100%
3. Ground level	Herbaceous		**5%**	**Grass, weeds**	**100%**
					100%
	Leaf or needle litter		**5%**		
	Bare ground		**63%**		
			Column total = 100%		

Remarks:
Condition, vigor and/or usage of existing reach:

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

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Wild Rice River**			Location: **Wild Rice River-3-17.52**					
Observers: **KD, JB**						Date: **10/4/2011**		
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P9**					

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order

Stream:	**Wild Rice River**
Location:	**Wild Rice River-3-17.52**
Observers:	**KD, JB**
Date:	**10/4/2011**

Stream Size Category and Order ☞ **S-6**

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	☐

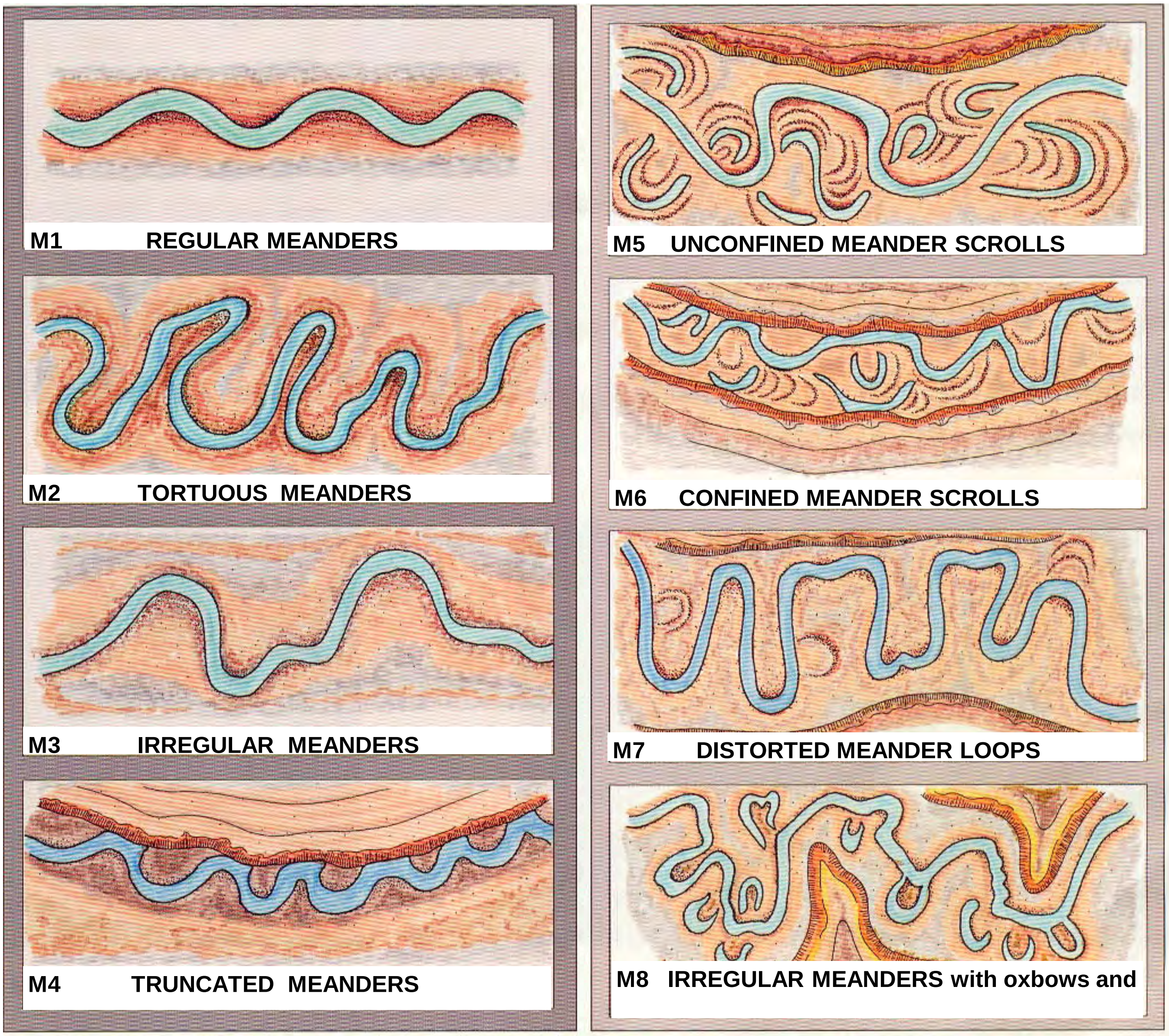
Stream Order

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).

Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns						
Stream:	**Wild Rice River**			Reach:	**Wild Rice River-3-17.52**	
Observers:	**KD, JB**			Date:	**10/4/2011**	
List ALL CATEGORIES that APPLY ☞	**M2**					

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



Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

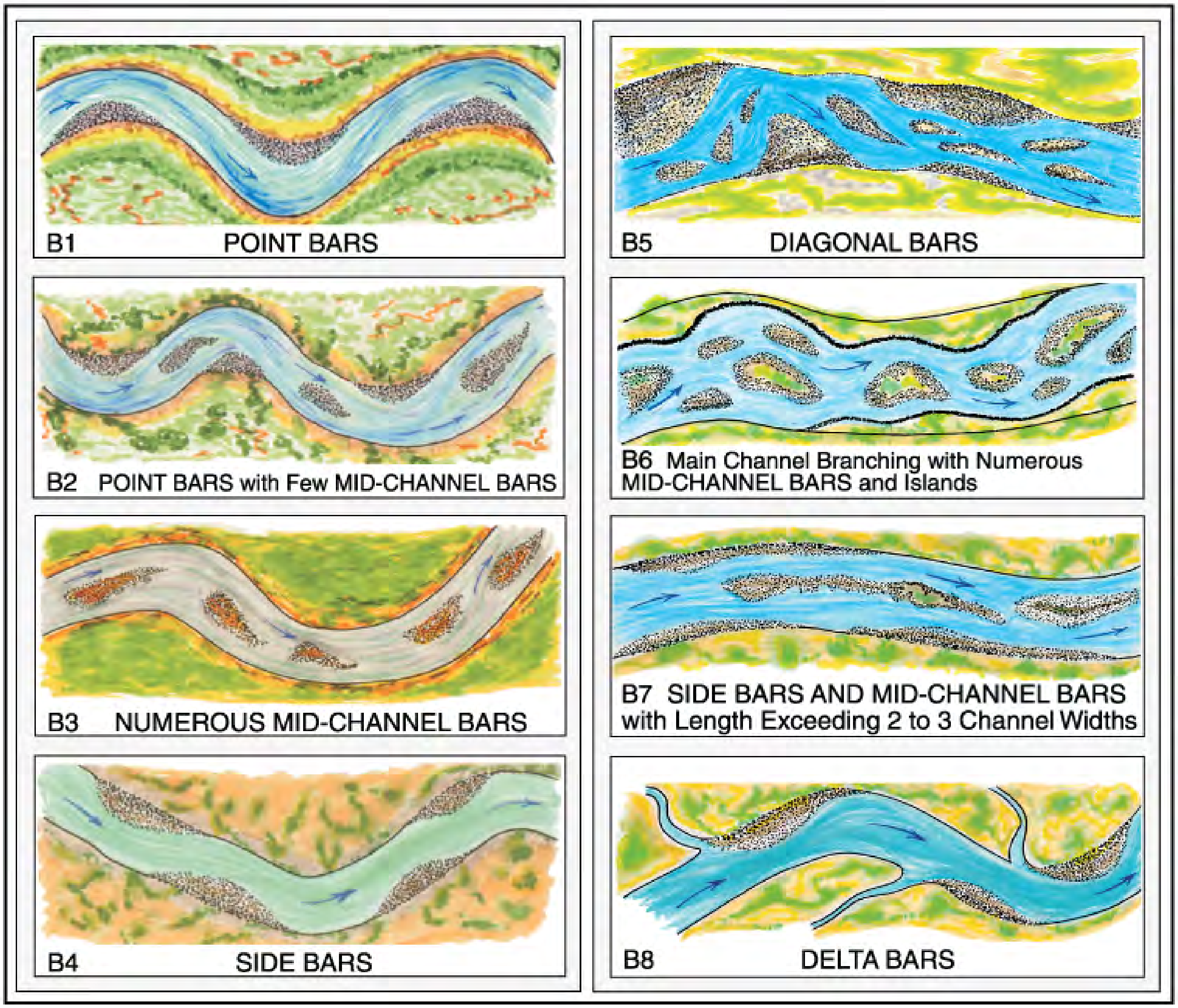
Depositional Patterns

Stream: **Wild Rice River** Reach: **Wild Rice River-3-17.52**

Observers: **KD, JB** Date: **10/4/2011**

List ALL CATEGORIES that APPLY ☞	None				

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



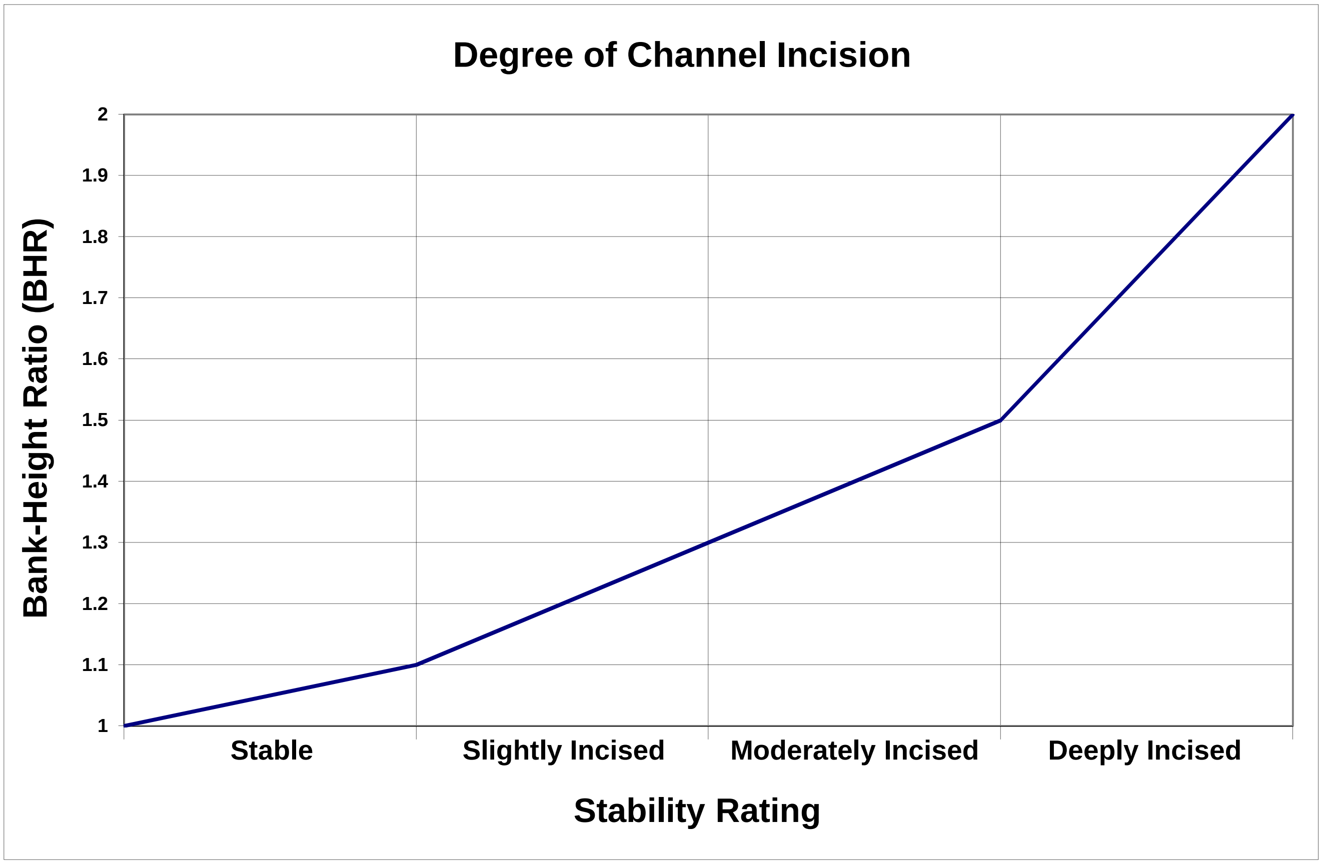
Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages				
Stream:	**Wild Rice River**	Location: **Wild Rice River-3-17.52**		
Observers:	**KD, JB**	Date: **10/4/2011**		
Description/extent		**Materials that 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.	☐	

Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

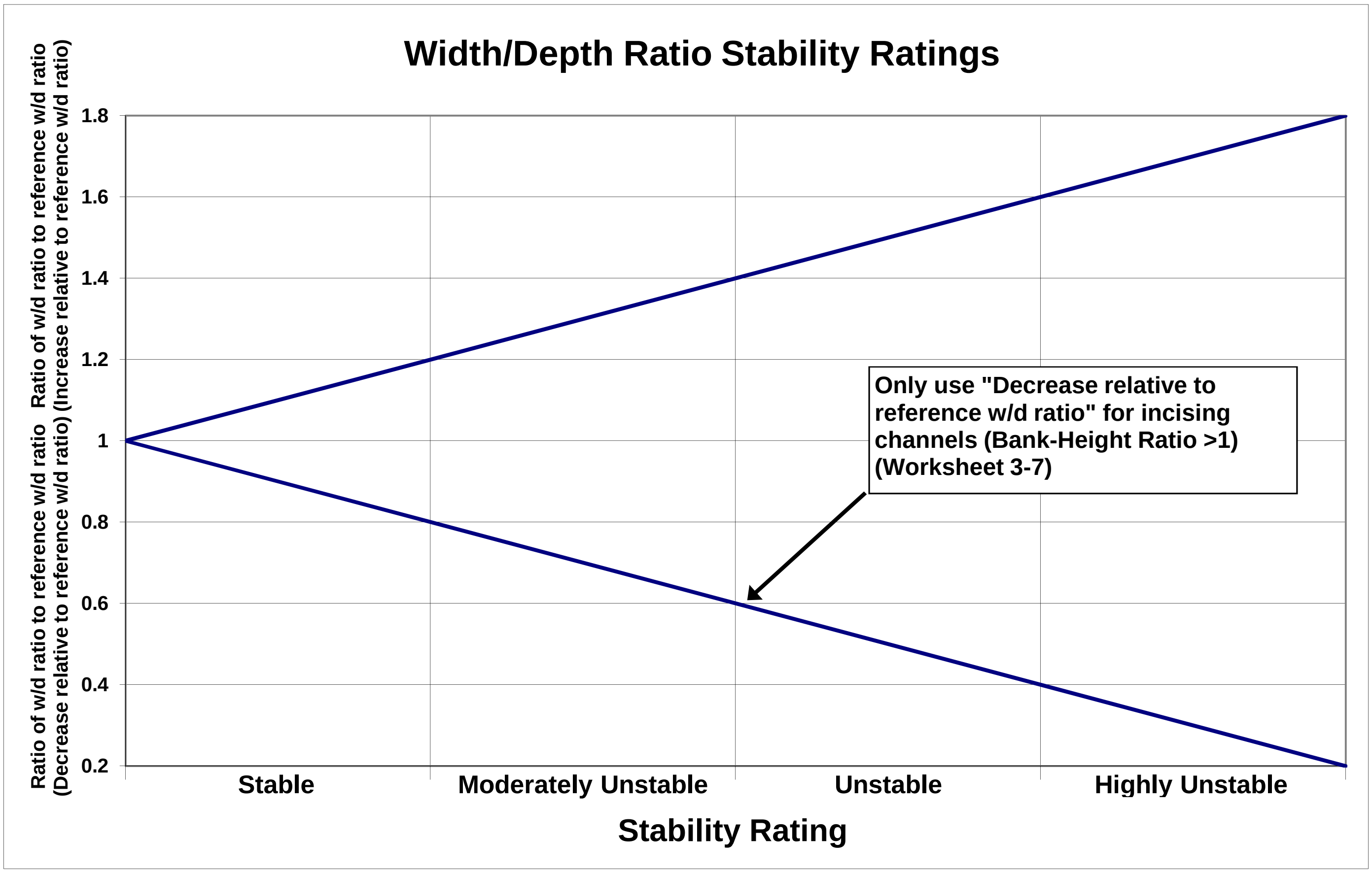
Degree of Channel Incision			
Low Bank Height:	19.8	Bank-Height Ratio:	2.3
Max Bankfull Depth:	8.667		

Degree of Channel Incision Stability Rating ☞	Deeply Incised



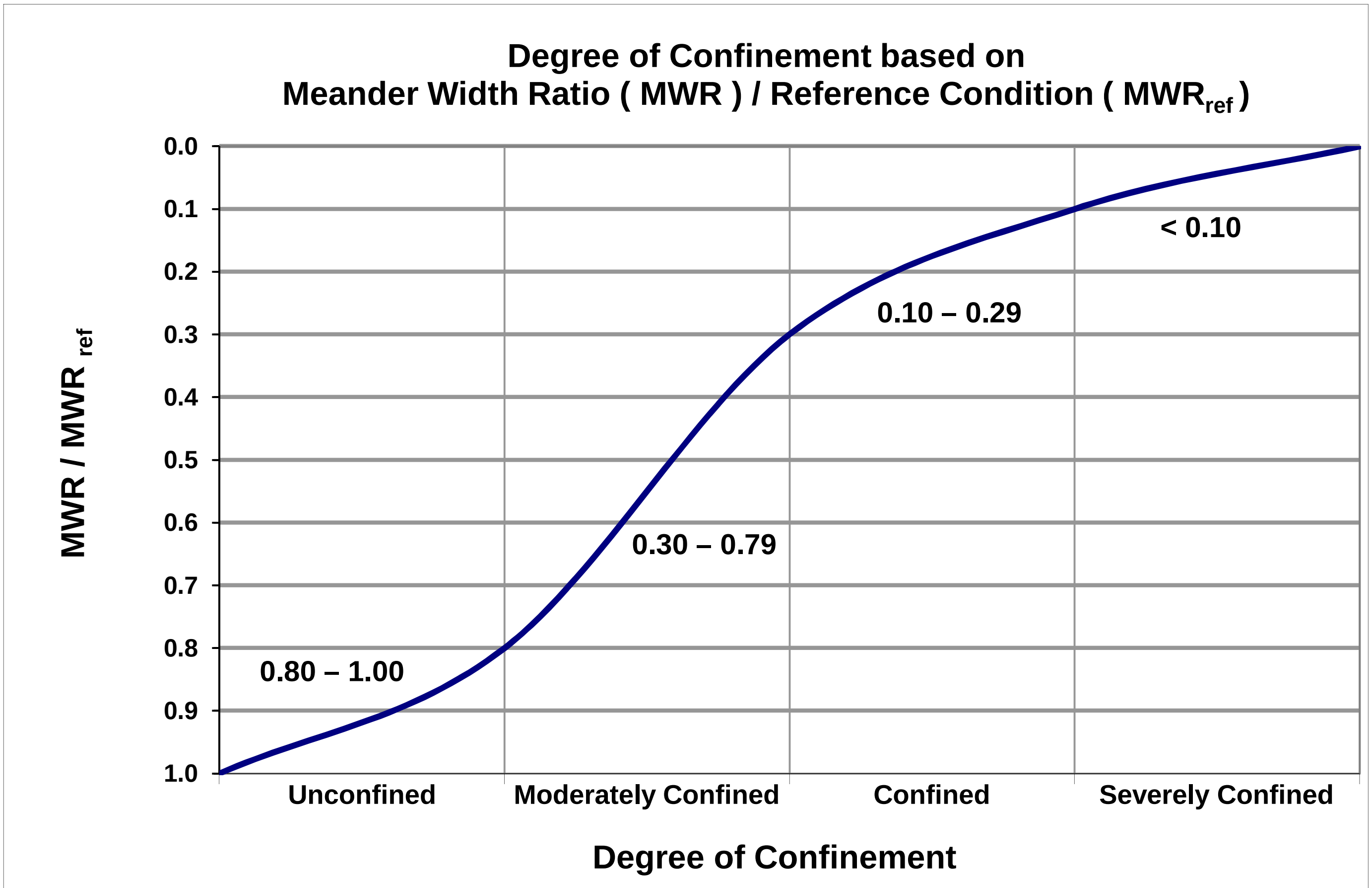
Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State			
Existing Width/Depth Ratio:	**12.1**	Ratio of existing W/d to reference W/d:	**1**
Reference Width/Depth Ratio:	**12.1**		
Width/Depth Ratio State Stability Rating ☞		**Stable**	



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	**18.2**	Ratio of MWR to MWR_{ref}:	**1**
Reference Meander Width Ratio (MWR_{ref}):	**18.2**		
Degree of Confinement Stability Rating ☞		**Unconfined**	



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Wild Rice River **Location:** Wild Rice River-3-17.5 **Valley Type:** X **Observers:** KD, JB **Date:** 10/4/2011

Location	Key	Category	Excellent Description	Excellent Rating	Good Description	Good Rating	Fair Description	Fair Rating	Poor Description	Poor Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	**2**	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	**12**
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	**6**	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	**12**
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	**2**	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	**6**	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	**16**
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	**23**	**Good total =**		**Fair total =**	**12**	**Poor total =**	**44**

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	**79**
Existing stream type =	**E6**
***Potential stream type =**	**E6**
Modified channel stability rating =	**Fair**

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream: **Wild Rice River**		Location: **Wild Rice River-3-17.52**	
Station:		Observers: **KD, JB**	
Date: **10/4/2011**	Stream Type: **E6**	Valley Type: **X**	

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	21.6 (A)	Bankfull Height (ft) =	7.3 (B)	(A) / (B) =	3.0 (C)	9

Root Depth / Study Bank Height (E)

Root Depth (ft) =	2 (D)	Study Bank Height (ft) =	21.6 (A)	(D) / (A) =	0.1 (E)	8

Weighted Root Density (G)

Root Density as % =	1% (F)	(F) x (E) =	0% (G)	10

Bank Angle (H)

Bank Angle as *Degrees* =	28 (H)	2

Surface Protection (I)

Surface Protection as % =	2% (I)	10

Bank Material Adjustment:

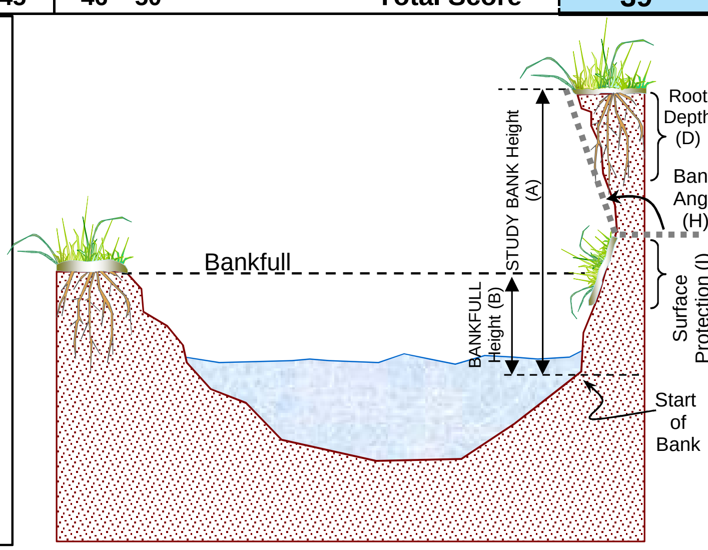
Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

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** 39

Bank Sketch



Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Wild Rice River**	Location: **Wild Rice River-3-17.52**	
Station: **0**	Stream Type: **E6**	Valley Type: **X**
Observers: **KD, JB**		Date: **10/4/11**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})...	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S)..	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})..	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})........................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient...	Level IV	Validation

Level I

(1)
- Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
- Extensive deposition (continuous, cross-channel)...................................... ....NBS = Extreme
- Chute cutoffs, down-valley meander migration, converging flow.......................................NBS = Extreme

Level II

	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)
(2)				

	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)
(3)				

	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)
(4)				

Dominant Near-Bank Stress
Very Low

Level III

	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)
(5)				

	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)
(6)								

Level IV

	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
(7)	**0**	**Very Low**

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating | **Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Wild Rice River**			Location: **Wild Rice River-3-17.52**			
Graph Used:	**Fig 3-9**		Total Bank Length (ft): **5215.2**			Date: **10/4/2011**	
Observers:	**KD, JB**		Valley Type: **X**			Stream Type: **E6**	
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**5215.2**	**21.6**	**18587**	**0.17**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**18587**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**688**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**895**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.17**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Wild Rice River**		Stream Type:	**E6**	
Location:	**Wild Rice River-3-17.52**		Valley Type:	**X**	
Observers:	**KD, JB**		Date:	**10/4/2011**	

Enter Required Information for Existing Condition

	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
0	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\ (D_{50}/\hat{D}_{50})^{-0.872}$
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\ (D_{max}/D_{50})^{-0.887}$
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	**#DIV/0!**

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	**d**	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)
	Check: ☐ Stable ☐ Aggrading ☐ Degrading			

Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	**S**	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)
	Check: ☐ Stable ☐ Aggrading ☐ Degrading			

Sediment Competence Using Dimensional Shear Stress

0	Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope	
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**	
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**	
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope	$d = \dfrac{\tau}{\gamma S}$
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth	$S = \dfrac{\tau}{\gamma d}$

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis

Observers: **KD, JB**

Stream: **Wild Rice River** | Location: **Wild Rice River-3-17.52** | Date: **10/4/2011**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		0		0		0		0		0		0		0		0		0
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		100%

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	0
Materials less than:	mm

Be sure to add separate material weights to grand total

GRAND TOTAL: 0

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Wild Rice River**	Stream Type: **E6**
Location: **Wild Rice River-3-17.52**	Valley Type: **X**
Observers: **KD, JB**	Date: **10/4/2011**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream:	**Wild Rice River**	Stream Type:	**E6**
Location:	**Wild Rice River-3-17.52**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**10/4/2011**

	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 3-8)**	< 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	> 1.6 **(8)**	**2**
2	**Depositional pattern (Worksheet 3-5)**	B1, B2 **(1)**	B4, B8 **(2)**	B3 **(3)**	B5, B6, B7 **(4)**	**1**
3	**Meander pattern (Worksheet 3-4)**	M1, M3, M4 **(1)**		M2, M5, M6, M7, M8 **(3)**		**3**
4	**Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL **(2)**	M/L, M/M, M/H, L/Ex, H/L **(4)**	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL **(6)**	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex **(8)**	**4**
5	**Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.8 – 1.0 **(1)**	0.3 – 0.79 **(2)**	0.1 – 0.29 **(3)**	< 0.1 **(4)**	**1**
					Total points	**11**

	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** ☐

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Wild Rice River**	Stream Type:	**E6**
Location:	**Wild Rice River-3-17.52**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**10/4/2011**

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 3-14)**	Sufficient depth and/or slope to transport largest size available **(2)**	Trend toward insufficient depth and/or slope-slightly incompetent **(4)**	Cannot move D_{35} of bed material and/or D_{100} of bar material **(6)**	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size **(8)**	2
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load **(2)**	Trend toward insufficient sediment capacity **(4)**	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand **(6)**	Reduction over 25% of annual sediment yield for bedload and/or suspended sand **(8)**	2
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	>1.6 **(8)**	2
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation **(2)**	(E→C) **(4)**	(C→High W/d C), (B→High W/d B), (C→F) **(6)**	(C→D), (F→D) **(8)**	2
5 **Depositional patterns (Worksheet 3-5)**	B1 **(1)**	B2, B4 **(2)**	B3, B5 **(3)**	B6, B7, B8 **(4)**	1
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 **(1)**	D4, D7 **(2)**	D5, D8 **(3)**	D6, D9, D10 **(4)**	2
				Total points	11

	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** ☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream:	**Wild Rice River**	Stream Type:	**E6**
Location:	**Wild Rice River-3-17.52**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**10/4/2011**

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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	2
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	2
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	8
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	4
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	1
				Total points	**17**

	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 ☐

Worksheet 3-20. Channel enlargement prediction summary.

Stream: **Wild Rice River**				Stream Type: **E6**	
Location: **Wild Rice River-3-17.52**				Valley Type: **X**	
Observers: **KD, JB**				Date: **10/4/2011**	
Channel enlargement prediction criteria (choose one stability category for each criterion 1–4)	**Channel Enlargement Prediction Categories**				**Selected points (from each row)**
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) **(2)**	(C→High W/d C), (E→C) **(4)**	(G→F), (F→D) **(6)**	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) **(8)**	**2**
2 **Lateral stability (Worksheet 3-17)**	Stable **(2)**	Moderately unstable **(4)**	Unstable **(6)**	Highly unstable **(8)**	**4**
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition **(2)**	Moderate deposition **(4)**	Excess deposition **(6)**	Aggradation **(8)**	**2**
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised **(2)**	Slightly incised **(4)**	Moderately incised **(6)**	Degradation **(8)**	**4**
				Total points	**12**
	Category point range				
Channel enlargement prediction (use total points and check stability rating)	**No increase 8 – 10** ☐	**Slight increase 11 – 16** ☑	**Moderate increase 17 – 24** ☐	**Extensive > 24** ☐	

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream:	**Wild Rice River**	Stream Type:	**E6**
Location:	**Wild Rice River-3-17.52**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**10/4/2011**

	Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	Stability Rating	Points	Selected Points
1	Lateral stability (Worksheet 3-17)	Stable	1	2
		Mod. unstable	2	
		Unstable	3	
		Highly unstable	4	
2	Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition	1	1
		Mod. deposition	2	
		Excess deposition	3	
		Aggradation	4	
3	Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	2
		Slightly incised	2	
		Mod. Incised	3	
		Degradation	4	
4	Channel enlargement prediction (Worksheet 3-20)	No increase	1	2
		Slight increase	2	
		Mod. increase	3	
		Extensive	4	
5	Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	2
		Fair: mod unstable	2	
		Poor: unstable	4	
			Total Points	9

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

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Wild Rice River**	Location: **Wild Rice River-3-17.52**	
Observers:	**KD, JB**	Date: **10/4/2011**	Stream Type: **E6** Valley Type: **X**

Category					
Channel Dimension	Mean bankfull depth (ft): **6.11**	Mean bankfull width (ft): **73.8**	Cross-section area (ft^2): **450.7**	Width of flood-prone area (ft): **150.6667**	Entrenchment ratio: **2.0**
Channel Pattern	Mean: Range: MWR: **18.2**	Lm/W_{bkf}: **18.2**	Rc/W_{bkf}: **3.8**		Sinuosity: **1.54**
River Profile and Bed Features	Check: ☐ Riffle/pool ☐ Step/pool ☐ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed				
	Max bankfull depth (ft): Riffle **8.7**; Pool	Depth ratio (max/mean): Riffle **1.4**; Pool	Pool to pool spacing: Ratio	Slope: Valley:	Average bankfull: **7.3E-05**
Level III Stream Stability Indices	Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:	
	Flow regime: **P1, 2, 9**	Stream size and order: **S-6**	Meander pattern(s): **M2**	Depositional pattern(s): **NONE**	Debris/channel blockage(s): **D1-4**
	Degree of incision (Bank-Height Ratio): **2.3**	Degree of incision stability rating: **Deeply Incised**	Modified Pfankuch stability rating (numeric and adjective rating): **Fair**		
	Width/depth ratio (W/d): **12.1**	Reference W/d ratio (W/d_{ref}): **12.1**	Width/depth ratio state $(W/d) / (W/d_{ref})$: **1.0**	W/d ratio state stability rating: **Stable**	
	Meander Width Ratio (MWR): **18.2**	Reference MWR_{ref}: **18.2**	Degree of confinement (MWR / MWR_{ref}): **1.0**	MWR / MWR_{ref} stability rating: **Unconfined**	
Bank Erosion Summary	Length of reach studied (ft): **5215**	Annual streambank erosion rate: **895** (tons/yr) **0.17** (tons/yr/ft)	Curve used: **Fig 3-9**	Remarks:	
Sediment Capacity (POWERSED)	☑ Sufficient capacity ☐ Insufficient capacity ☐ Excess capacity			Remarks:	
Entrainment/ Competence	Largest particle from bar sample (mm):	$\tau =$	$\tau^* =$	Existing $depth_{bkf}$: Required $depth_{bkf}$:	Existing $slope_{bkf}$: Required $slope_{bkf}$:
Successional Stage Shift	→ → → → →			Existing stream state (type): **E6**	Potential stream state (type): **E6**
Lateral Stability	☐ Stable ☑ Mod. unstable ☐ Unstable ☐ Highly unstable			Remarks/causes:	
Vertical Stability (Aggradation)	☑ No deposition ☐ Mod. deposition ☐ Ex. deposition ☐ Aggradation			Remarks/causes:	
Vertical Stability (Degradation)	☐ Not incised ☑ Slightly incised ☐ Mod. incised ☐ Degradation			Remarks/causes:	
Channel Enlargement	☐ No increase ☑ Slight increase ☐ Mod. increase ☐ Extensive			Remarks/causes:	
Sediment Supply (Channel Source)	☐ Low ☑ Moderate ☐ High ☐ Very high			Remarks/causes:	

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Wild Rice River**		Location: **Wild Rice River-4-22.94**	
Observers: **KD, JB**	Reference reach [ ]	Disturbed (impacted reach) **X**	Date: **10/3/2011**
Existing species composition:		Potential species composition:	

	Riparian cover categories	Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**75%**	**3%**	**Trees**	**100%**
					100%
2. Understory	Shrub layer		**5%**	**Shrubs**	**100%**
					100%
3. Ground level	Herbaceous		**15%**	**Weeds, grass**	**100%**
					100%
	Leaf or needle litter		**5%**		
	Bare ground		**72%**		
			Column total = 100%		

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

Remarks:
Condition, vigor and/or usage of existing reach:

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream:	**Wild Rice River**		Location: **Wild Rice River-4-22.94**						
Observers:	**KD, JB**						Date: **10/3/2011**		
List ALL COMBINATIONS that APPLY..............☞		**P1**	**P2**	**P9**					

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order

Stream:	**Wild Rice River**
Location:	**Wild Rice River-4-22.94**
Observers:	**KD, JB**
Date:	**10/3/2011**

Stream Size Category and Order ☞	**S-7**

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).

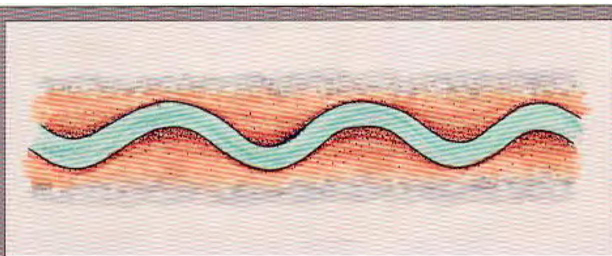
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Wild Rice River**	Reach:	**Wild Rice River-4-22.94**
Observers:	**KD, JB**	Date:	**10/3/2011**

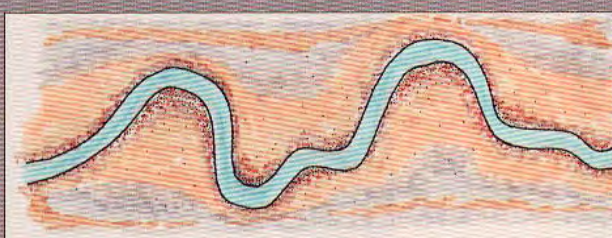
List ALL CATEGORIES that APPLY ☞	**M2**				

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

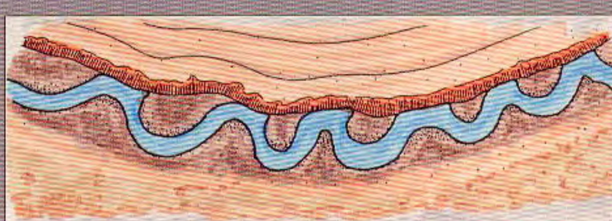


M1 REGULAR MEANDERS

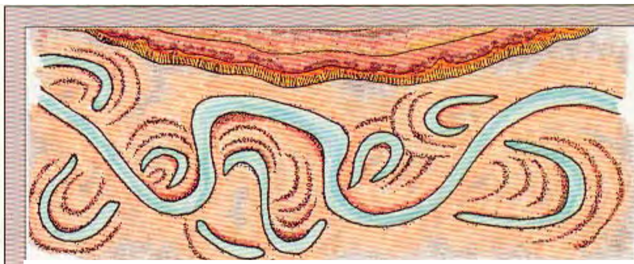
M2 TORTUOUS MEANDERS



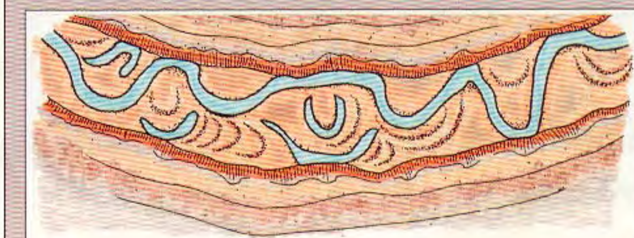
M3 IRREGULAR MEANDERS



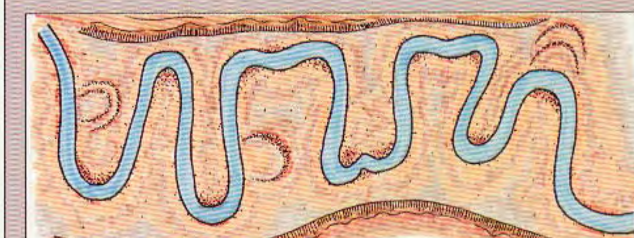
M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS



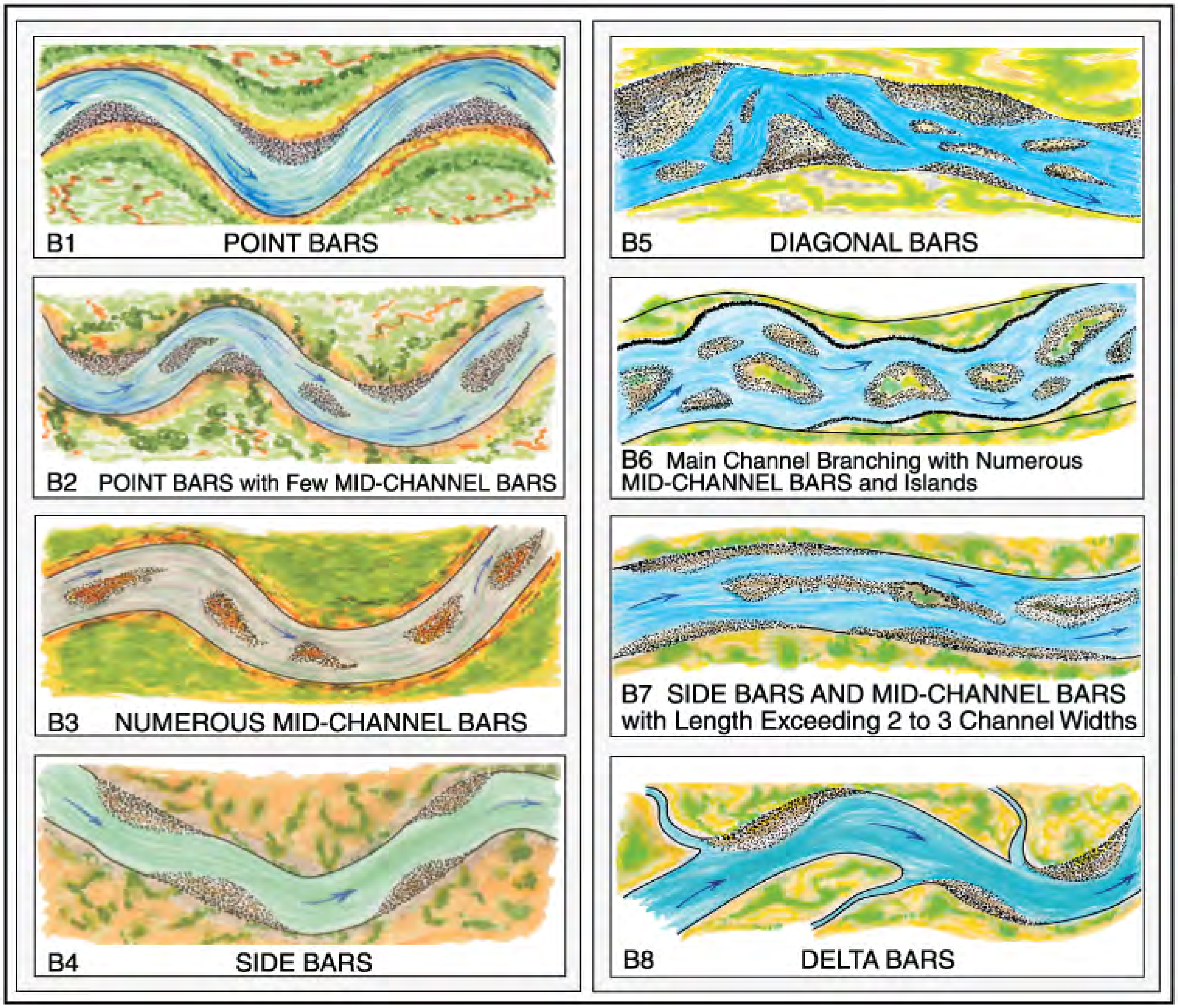
M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns					
Stream: **Wild Rice River**		Reach: **Wild Rice River-4-22.94**			
Observers: **KD, JB**		Date: **10/3/2011**			
List ALL CATEGORIES that APPLY ☞	**None**				

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



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

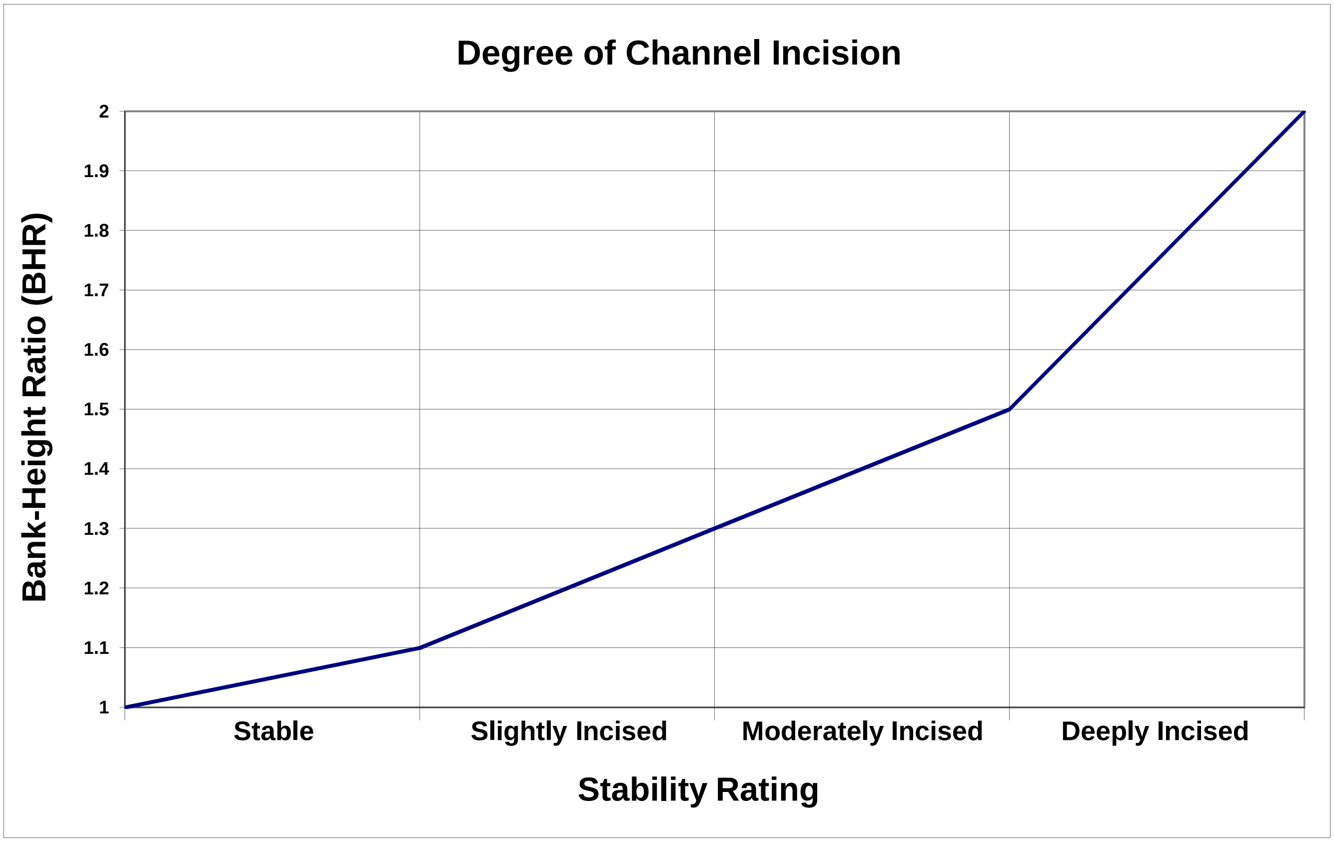
Channel Blockages			
Stream: **Wild Rice River**		Location: **Wild Rice River-4-22.94**	
Observers: **KD, JB**		Date: **10/3/2011**	
Description/extent		**Materials that upon placement into the active channel or flood-prone area may cause adjustments in channel dimensions or conditions due to influences 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.	☐

Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision

Low Bank Height:	**17.1**		Bank-Height Ratio:	**2.1**
Max Bankfull Depth:	**8.183333**			

Degree of Channel Incision Stability Rating ☞ **Deeply Incised**

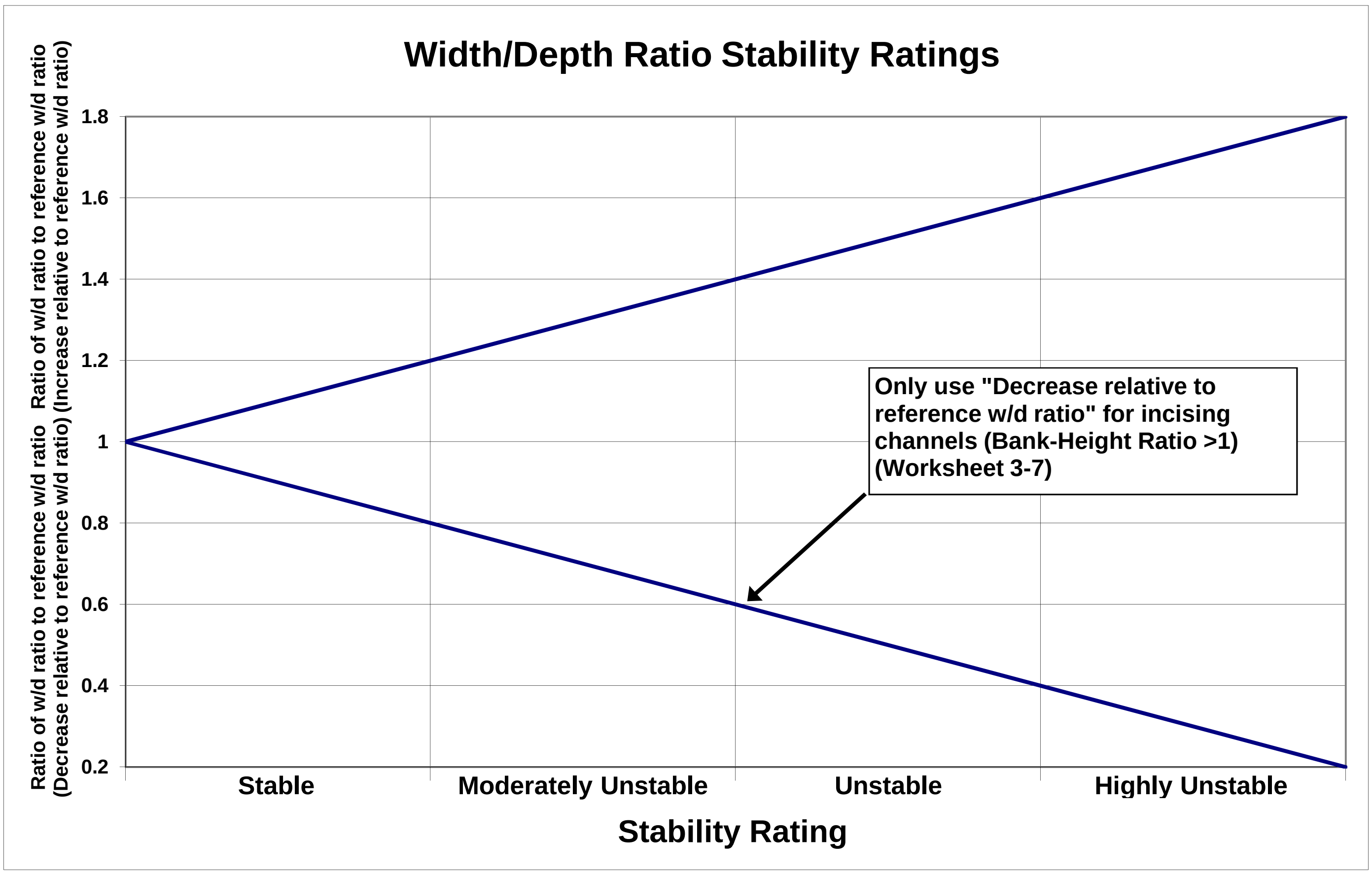


Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State

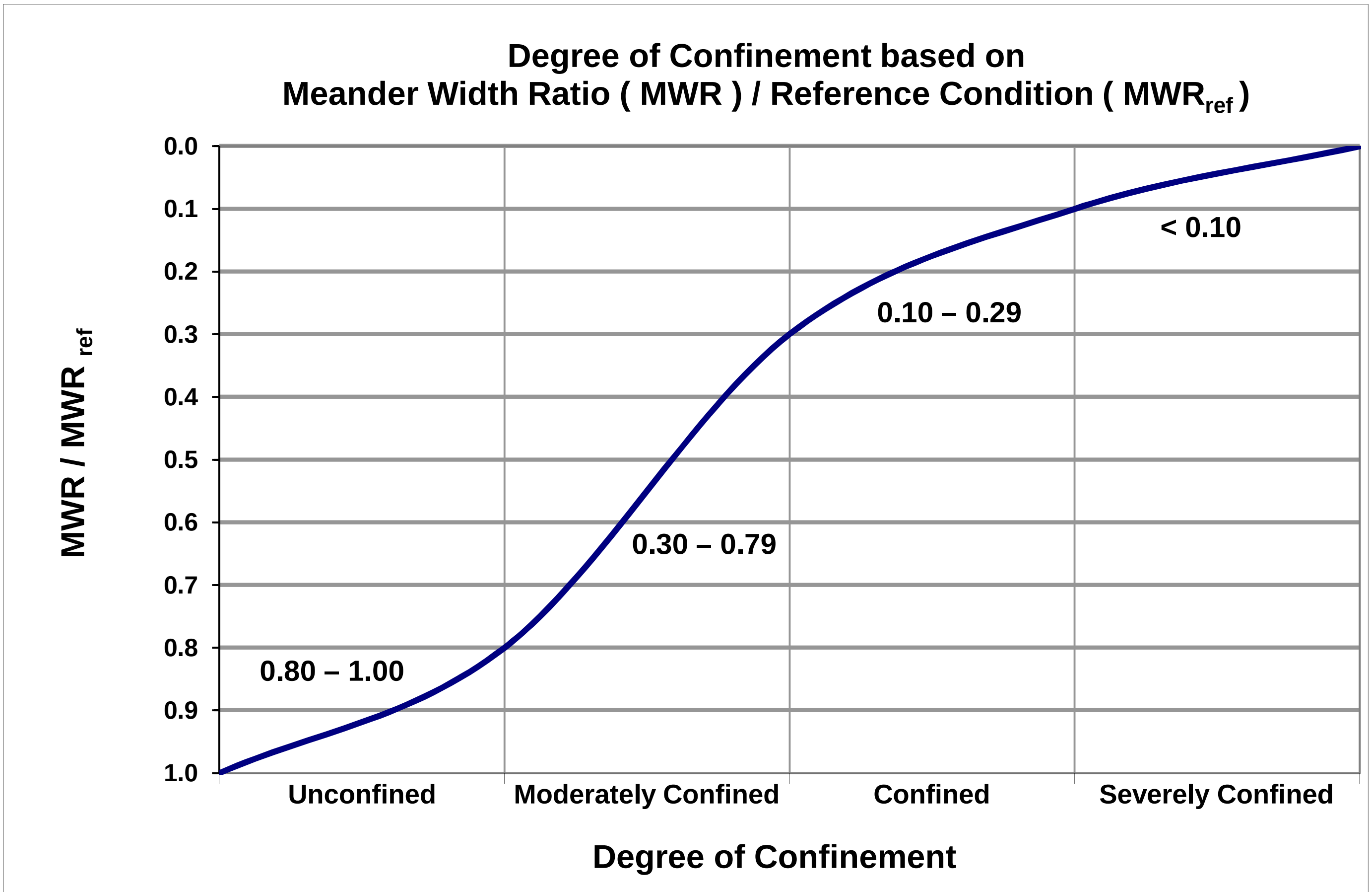
Existing Width/Depth Ratio:	**13.4**	Ratio of existing W/d to reference W/d:	**1**
Reference Width/Depth Ratio:	**13.4**		

Width/Depth Ratio State Stability Rating ☞	**Stable**



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	**20.1**	Ratio of MWR to MWR_{ref}:	**1**
Reference Meander Width Ratio (MWR_{ref}):	**20.1**		
Degree of Confinement Stability Rating ☞		**Unconfined**	



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Wild Rice River **Location:** Wild Rice River-4-22.9 **Valley Type:** X **Observers:** KD, JB **Date:** 10/3/2011

Location	Key	Category	Excellent Description	Excellent Rating	Good Description	Good Rating	Fair Description	Fair Rating	Poor Description	Poor Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	**2**	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	**12**
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	**4**	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	**12**
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	**2**	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	**4**	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	**16**
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	23	Good total =	8	Fair total =	0	Poor total =	44

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	75
Existing stream type =	B6c
*Potential stream type =	B6c
Modified channel stability rating =	Fair

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream:	**Wild Rice River**	Location:	**Wild Rice River-4-22.94**
Station:		Observers:	**KD, JB**
Date:	**10/3/2011**	Stream Type: **B6c**	Valley Type: **X**

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	20.7 (A)	**Bankfull Height** (ft) =	5.8 (B)	(A) / (B) =	3.6 (C)	10

Root Depth / Study Bank Height (E)

Root Depth (ft) =	2 (D)	**Study Bank Height** (ft) =	20.7 (A)	(D) / (A) =	0.1 (E)	8

Weighted Root Density (G)

Root Density as **%** =	2% (F)	(F) x (E) =	0% (G)	10

Bank Angle (H)

Bank Angle as *Degrees* =	28 (H)	2

Surface Protection (I)

Surface Protection as **%** =	10% (I)	9

Bank Material Adjustment:

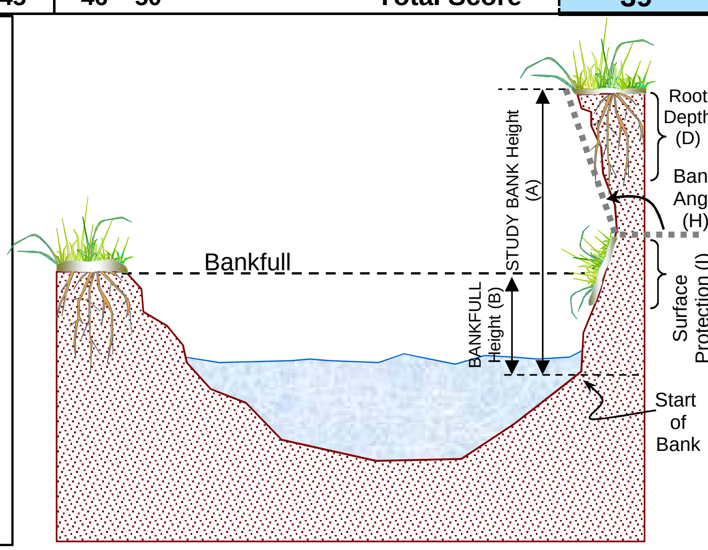
Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

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**	**High**
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50	**and Total Score**	**39**

Bank Sketch



Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Wild Rice River**	Location: **Wild Rice River-4-22.94**	
Station: **0**	Stream Type: **B6c**	Valley Type: **X**
Observers: **KD, JB**		Date: **10/3/11**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})...	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S)..	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})..	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})...........................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient..	Level IV	Validation

Level I

(1)
- Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
- Extensive deposition (continuous, cross-channel).. ....NBS = Extreme
- Chute cutoffs, down-valley meander migration, converging flow...NBS = Extreme

Level II

	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)
(2)				

	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)
(3)				

	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)
(4)				

Dominant Near-Bank Stress
Very Low

Level III

	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)
(5)				

	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)
(6)								

Level IV

	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
(7)	**0.01**	**Very Low**

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating	**Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Wild Rice River**			Location:	**Wild Rice River-4-22.94**		
Graph Used:	**Fig 3-9**	Total Bank Length (ft):	**9465.7**			Date:	**10/3/2011**
Observers:	**KD, JB**	Valley Type:	**X**			Stream Type:	**B6c**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**9465.7**	**20.7**	**32330**	**0.16**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**32330**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**1197**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**1557**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.16**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Wild Rice River**		Stream Type:	**B6c**	
Location:	**Wild Rice River-4-22.94**		Valley Type:	**X**	
Observers:	**KD, JB**		Date:	**10/3/2011**	

Enter Required Information for Existing Condition

	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
0	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	**#DIV/0!**

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	d	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	S	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Sediment Competence Using Dimensional Shear Stress

0	Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope	
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**	
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**	
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope	$d = \dfrac{\tau}{\gamma S}$
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth	$S = \dfrac{\tau}{\gamma d}$

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis | Observers: **KD, JB**

Stream: **Wild Rice River** | Location: **Wild Rice River-4-22.94** | Date: **10/3/2011**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		0		0		0		0		0		0		0		0		0
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		100%

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	0
Materials less than:	mm

Be sure to add separate material weights to grand total

GRAND TOTAL: 0

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Wild Rice River**	Stream Type: **B6c**
Location: **Wild Rice River-4-22.94**	Valley Type: **X**
Observers: **KD, JB**	Date: **10/3/2011**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream:	**Wild Rice River**	Stream Type:	**B6c**
Location:	**Wild Rice River-4-22.94**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**10/3/2011**

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 3-8)**	< 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	> 1.6 **(8)**	**2**
2 **Depositional pattern (Worksheet 3-5)**	B1, B2 **(1)**	B4, B8 **(2)**	B3 **(3)**	B5, B6, B7 **(4)**	**1**
3 **Meander pattern (Worksheet 3-4)**	M1, M3, M4 **(1)**		M2, M5, M6, M7, M8 **(3)**		**3**
4 **Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL **(2)**	M/L, M/M, M/H, L/Ex, H/L **(4)**	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL **(6)**	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex **(8)**	**4**
5 **Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.8 – 1.0 **(1)**	0.3 – 0.79 **(2)**	0.1 – 0.29 **(3)**	< 0.1 **(4)**	**1**
				Total points	**11**

Overall lateral stability category (use total points and check stability rating)	**Lateral stability category point range**			
	Stable 7 – 9 ☐	**Moderately unstable 10 – 12** ☑	**Unstable 13 – 21** ☐	**Highly unstable > 21** ☐

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream: **Wild Rice River**			Stream Type: **B6c**		
Location: **Wild Rice River-4-22.94**			Valley Type: **X**		
Observers: **KD, JB**			Date: **10/3/2011**		
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 3-14)**	Sufficient depth and/or slope to transport largest size available **(2)**	Trend toward insufficient depth and/or slope-slightly incompetent **(4)**	Cannot move D_{35} of bed material and/or D_{100} of bar material **(6)**	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size **(8)**	2
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load **(2)**	Trend toward insufficient sediment capacity **(4)**	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand **(6)**	Reduction over 25% of annual sediment yield for bedload and/or suspended sand **(8)**	2
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	>1.6 **(8)**	2
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation **(2)**	(E→C) **(4)**	(C→High W/d C), (B→High W/d B), (C→F) **(6)**	(C→D), (F→D) **(8)**	2
5 **Depositional patterns (Worksheet 3-5)**	B1 **(1)**	B2, B4 **(2)**	B3, B5 **(3)**	B6, B7, B8 **(4)**	1
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 **(1)**	D4, D7 **(2)**	D5, D8 **(3)**	D6, D9, D10 **(4)**	1
				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** ☐	

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream:	**Wild Rice River**	Stream Type:	**B6c**
Location:	**Wild Rice River-4-22.94**	Valley Type:	**X**
Observers:	**KD, JB**	Date:	**10/3/2011**

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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	2
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	2
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	8
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	4
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	1
				Total points	**17**

	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 ☐

Worksheet 3-20. Channel enlargement prediction summary.

Stream:	Wild Rice River			Stream Type:	B6c	
Location:	Wild Rice River-4-22.94			Valley Type:	X	
Observers:	KD, JB			Date:	10/3/2011	

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 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) (2)	(C→High W/d C), (E→C) (4)	(G→F), (F→D) (6)	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) (8)	2
2 **Lateral stability (Worksheet 3-17)**	Stable (2)	Moderately unstable (4)	Unstable (6)	Highly unstable (8)	4
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition (2)	Moderate deposition (4)	Excess deposition (6)	Aggradation (8)	2
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised (2)	Slightly incised (4)	Moderately incised (6)	Degradation (8)	4
				Total points	**12**

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

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream: **Wild Rice River**		Stream Type:	**B6c**
Location: **Wild Rice River-4-22.94**		Valley Type:	**X**
Observers: **KD, JB**		Date:	**10/3/2011**

	Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	Stability Rating	Points	Selected Points
1	Lateral stability (Worksheet 3-17)	Stable	1	2
		Mod. unstable	**2**	
		Unstable	3	
		Highly unstable	4	
2	Vertical stability excess deposition/ aggradation (Worksheet 3-18)	**No deposition**	**1**	1
		Mod. deposition	2	
		Excess deposition	3	
		Aggradation	4	
3	Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	2
		Slightly incised	**2**	
		Mod. Incised	3	
		Degradation	4	
4	Channel enlargement prediction (Worksheet 3-20)	No increase	1	2
		Slight increase	**2**	
		Mod. increase	3	
		Extensive	4	
5	Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	2
		Fair: mod unstable	**2**	
		Poor: unstable	4	
			Total Points	9

	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 ☐

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Wild Rice River**		Location: **Wild Rice River-4-22.94**	
Observers:	**KD, JB**	Date: **10/3/2011**	Stream Type: **B6c**	Valley Type: **X**

Channel Dimension	Mean bankfull depth (ft): **5.63**	Mean bankfull width (ft): **75.47**	Cross-section area (ft^2): **424.6**	Width of flood-prone area (ft): **144.3333**	Entrenchment ratio: **1.9**
Channel Pattern	Mean: Range: MWR: **20.1**	Lm/W_{bkf}: **20.1**	Rc/W_{bkf}: **8.1**	Sinuosity: **1.75**	
River Profile and Bed Features	Check: ☐ Riffle/pool ☐ Step/pool ☐ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed				
	Max bankfull depth (ft): Riffle **8.2**; Pool	Depth ratio (max/mean): Riffle **1.5**; Pool	Pool to pool spacing: Ratio	Slope: Valley:	Average bankfull: **0.00014**
Level III Stream Stability Indices	Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:	
	Flow regime: **P1, 2, 9**	Stream size and order: **S-7**	Meander pattern(s): **M2**	Depositional pattern(s): **NONE**	Debris/channel blockage(s): **D1-3**
	Degree of incision (Bank-Height Ratio): **2.1**	Degree of incision stability rating: **Deeply Incised**	Modified Pfankuch stability rating (numeric and adjective rating): **Fair**		
	Width/depth ratio (W/d): **13.4**	Reference W/d ratio (W/d_{ref}): **13.4**	Width/depth ratio state $(W/d) / (W/d_{ref})$: **1.0**	W/d ratio state stability rating: **Stable**	
	Meander Width Ratio (MWR): **20.1**	Reference MWR_{ref}: **20.1**	Degree of confinement (MWR / MWR_{ref}): **1.0**	MWR / MWR_{ref} stability rating: **Unconfined**	
Bank Erosion Summary	Length of reach studied (ft): **9466**	Annual streambank erosion rate: **1557** (tons/yr) **0.16** (tons/yr/ft)	Curve used: **Fig 3-9**	Remarks:	
Sediment Capacity (POWERSED)	☑ Sufficient capacity ☐ Insufficient capacity ☐ Excess capacity			Remarks:	
Entrainment/ Competence	Largest particle from bar sample (mm):	$\tau =$	$\tau^* =$	Existing $depth_{bkf}$: Required $depth_{bkf}$:	Existing $slope_{bkf}$: Required $slope_{bkf}$:
Successional Stage Shift	→ → → → →			Existing stream state (type): **B6c**	Potential stream state (type): **B6c**
Lateral Stability	☐ Stable ☑ Mod. unstable ☐ Unstable ☐ Highly unstable			Remarks/causes:	
Vertical Stability (Aggradation)	☑ No deposition ☐ Mod. deposition ☐ Ex. deposition ☐ Aggradation			Remarks/causes:	
Vertical Stability (Degradation)	☐ Not incised ☑ Slightly incised ☐ Mod. incised ☐ Degradation			Remarks/causes:	
Channel Enlargement	☐ No increase ☑ Slight increase ☐ Mod. increase ☐ Extensive			Remarks/causes:	
Sediment Supply (Channel Source)	☐ Low ☑ Moderate ☐ High ☐ Very high			Remarks/causes:	

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Wild Rice River**		Location: **Wild Rice River-5-**	
Observers: **KF, JB**	Reference reach: [ ]	Disturbed (impacted reach): **X**	Date: **10/2/2011**
Existing species composition:		Potential species composition:	

	Riparian cover categories	Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**70%**	**3%**	**Trees**	**100%**
					100%
2. Understory	Shrub layer		**10%**	**Shrubs**	**100%**
					100%
3. Ground level	Herbaceous		**5%**	**Grass, weeds**	**100%**
					100%
	Leaf or needle litter		**10%**		
	Bare ground		**72%**		
			Column total = 100%		

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

Remarks:
Condition, vigor and/or usage of existing reach:

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Wild Rice River**	Location: **Wild Rice River-5-**							
Observers: **KF, JB**	Date: **10/2/2011**							
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P9**					

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order			
Stream:	**Wild Rice River**		
Location:	**Wild Rice River-5-**		
Observers:	**KF, JB**		
Date:	**10/2/2011**		
Stream Size Category and Order ☞			**S-6**
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).			

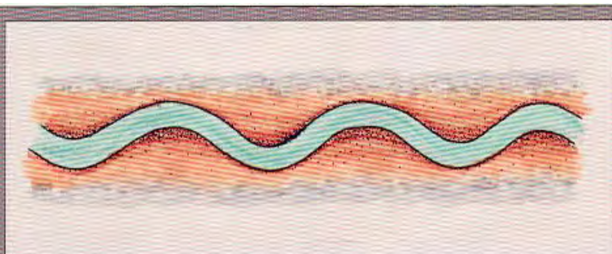
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Wild Rice River**	Reach:	**Wild Rice River-5-**
Observers:	**KF, JB**	Date:	**10/2/2011**

List ALL CATEGORIES that APPLY ☞	**M2**				

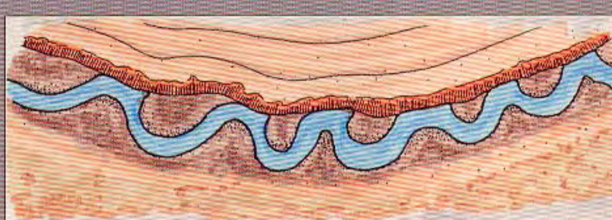
Various Meander Pattern variables modified from Galay et al. (1973)



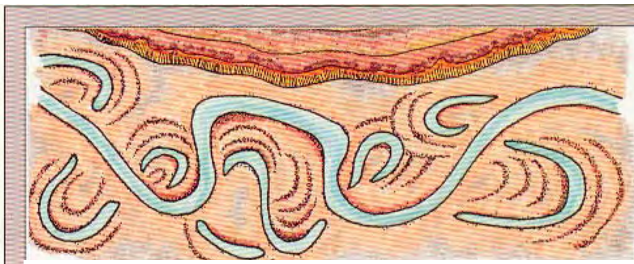
M1 REGULAR MEANDERS

M2 TORTUOUS MEANDERS

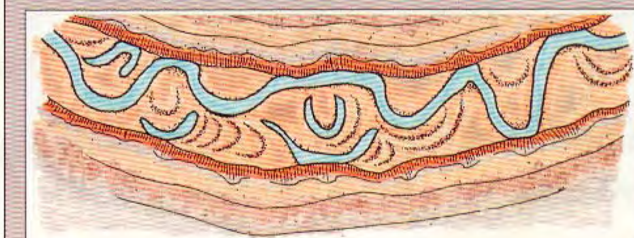
M3 IRREGULAR MEANDERS



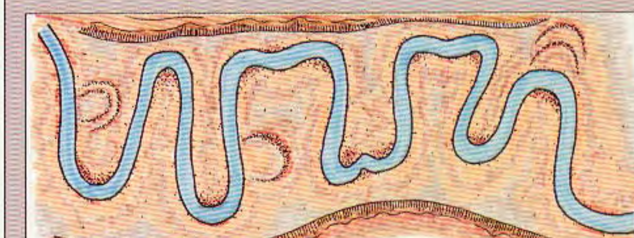
M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS



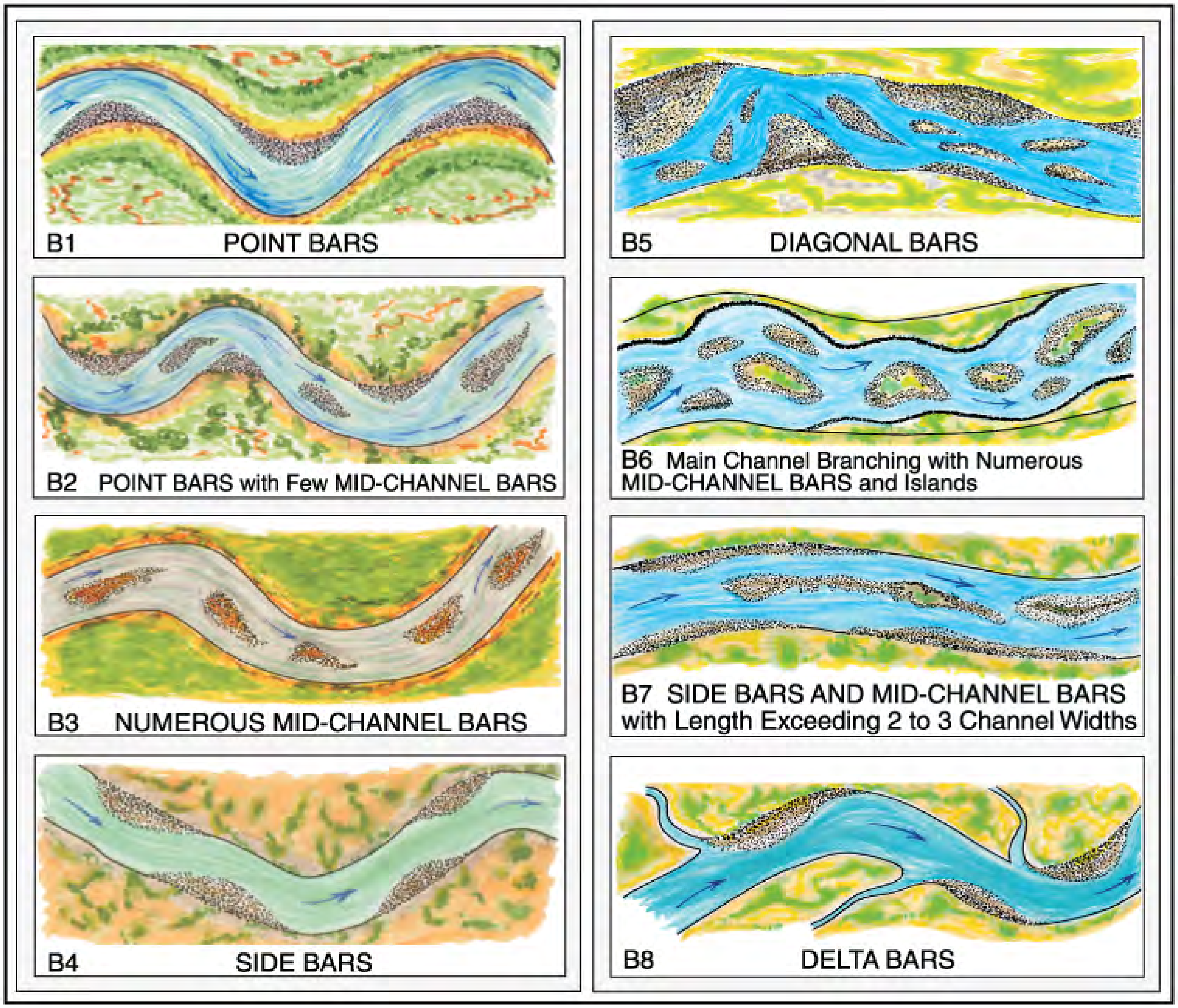
M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns					
Stream: **Wild Rice River**		Reach: **Wild Rice River-5-**			
Observers: **KF, JB**		Date: **10/2/2011**			
List ALL CATEGORIES that APPLY ☞	**None**				

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

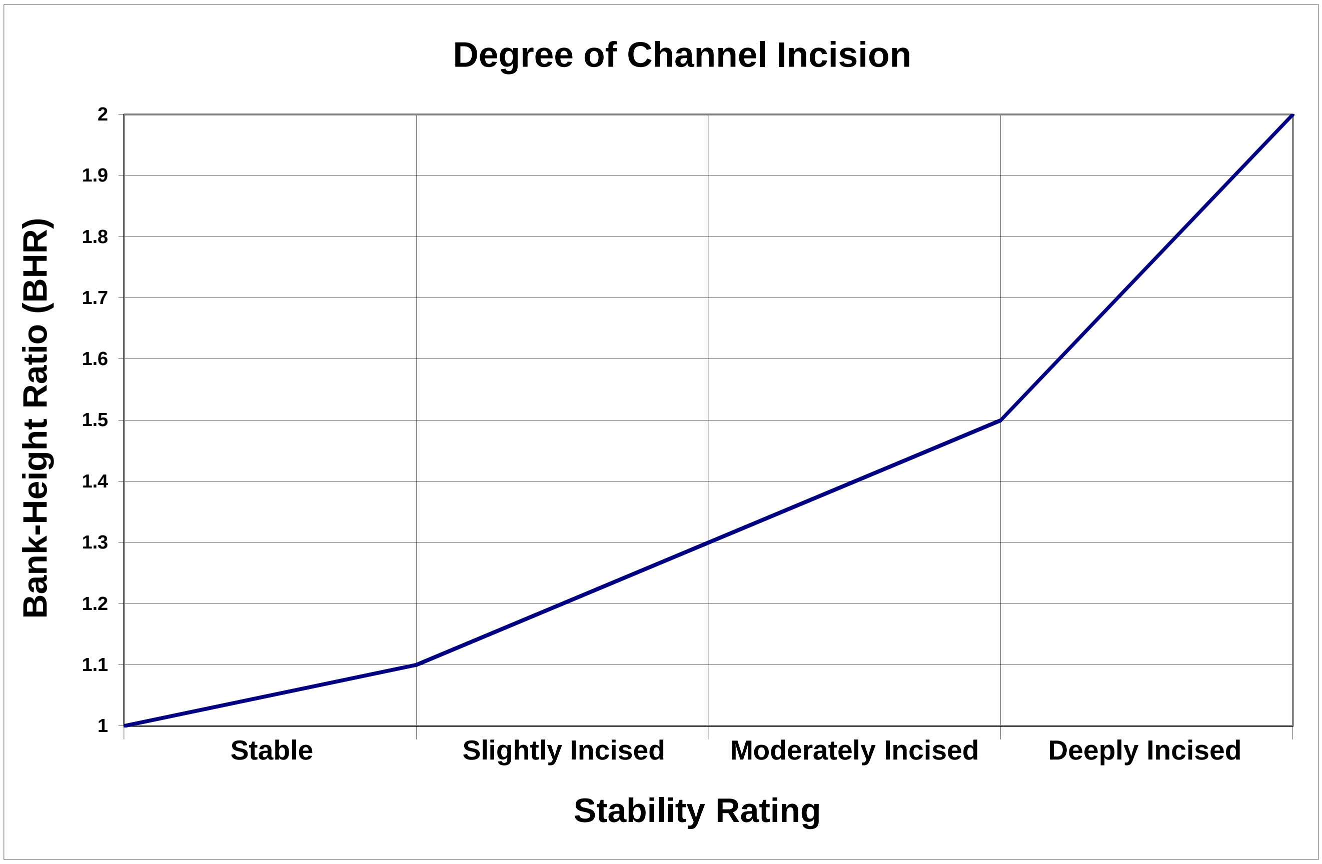


Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Wild Rice River**		Location: **Wild Rice River-5-**	
Observers: **KF, JB**		Date: **10/2/2011**	
Description/extent		**Materials that 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.	☐

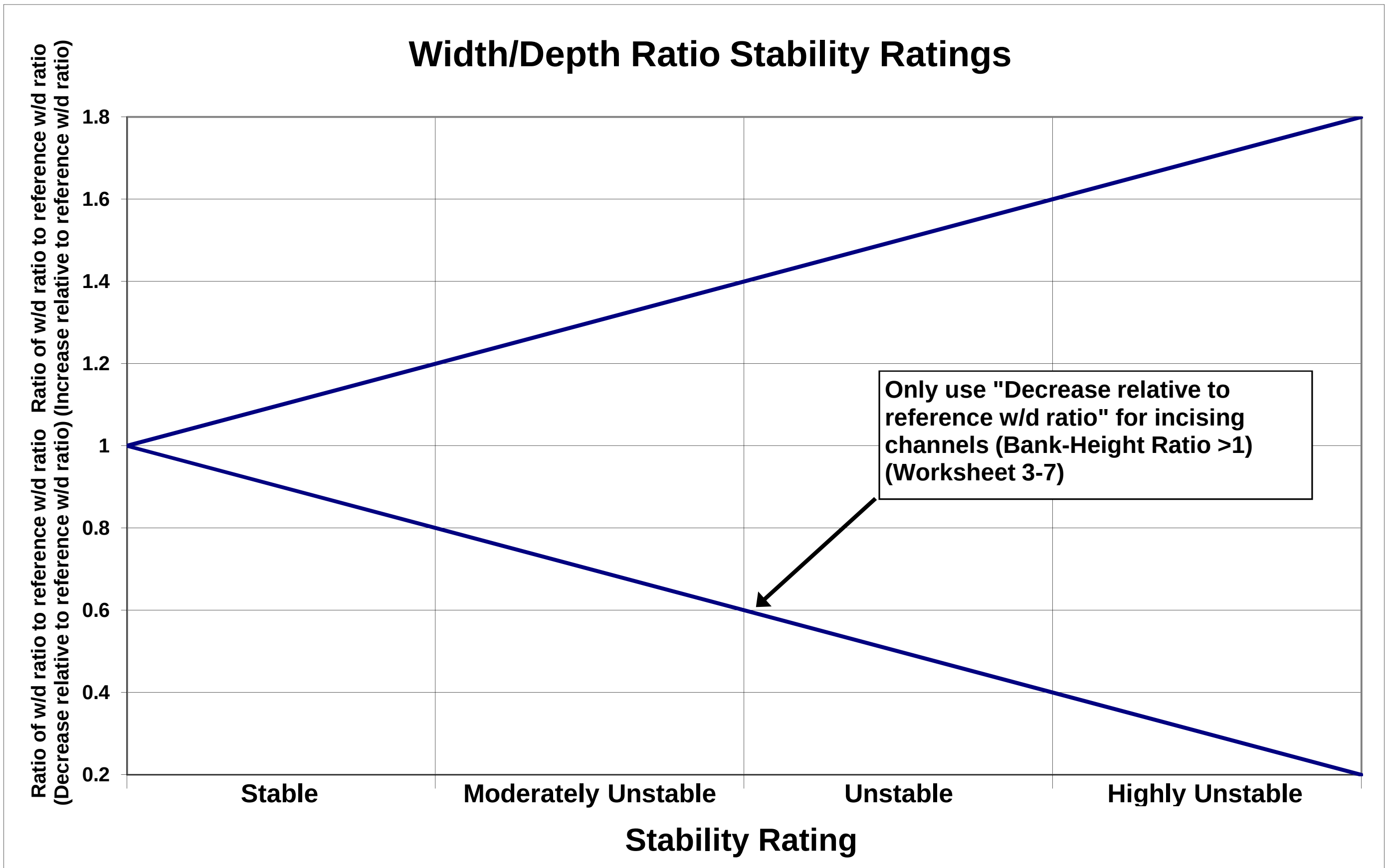
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision			
Low Bank Height:	24.6	Bank-Height Ratio:	2.6
Max Bankfull Depth:	9.577		
Degree of Channel Incision Stability Rating ☞			Deeply Incised



Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State			
Existing Width/Depth Ratio:	**10.6**	Ratio of existing W/d to reference W/d:	**1**
Reference Width/Depth Ratio:	**10.6**		
Width/Depth Ratio State Stability Rating ☞		**Stable**	

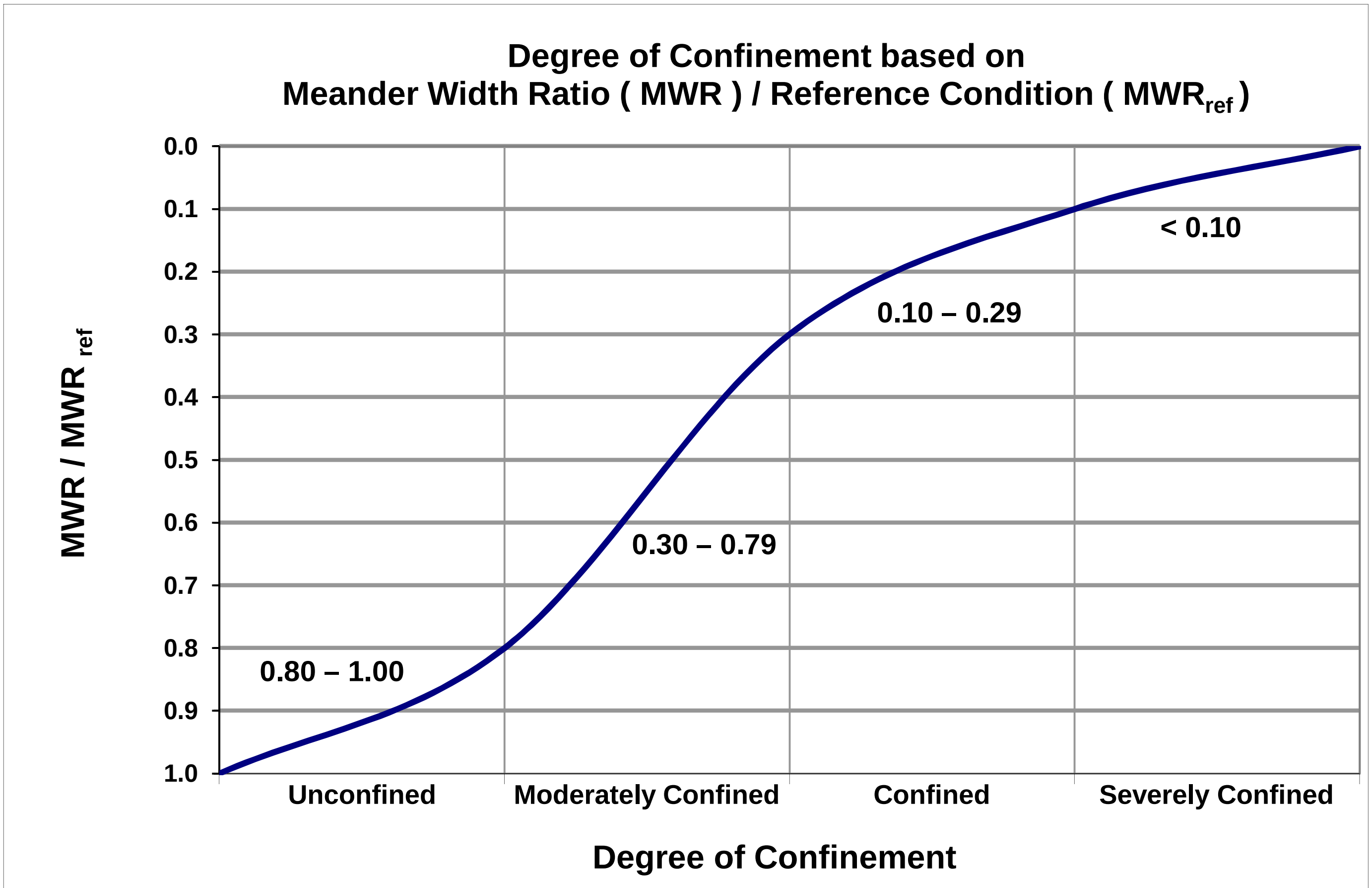


Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement

Existing Meander Width Ratio (MWR):	**23.1**		Ratio of MWR to MWR_{ref}:	**1**
Reference Meander Width Ratio (MWR_{ref}):	**23.1**			

Degree of Confinement Stability Rating ☞	**Unconfined**



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Wild Rice River | **Location:** Wild Rice River-5- | **Valley Type:** X | **Observers:** KF, JB | **Date:** 10/2/2011

Location	Key	Category	Excellent Description	Excellent Rating	Good Description	Good Rating	Fair Description	Fair Rating	Poor Description	Poor Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	**2**	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	**9**	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	**6**	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	**12**
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	**2**	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	**6**	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	**12**	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	23	Good total =	0	Fair total =	33	Poor total =	16

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	72
Existing stream type =	E6
*Potential stream type =	E6
Modified channel stability rating =	Fair

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream:	**Wild Rice River**	Location:	**Wild Rice River-5-**
Station:		Observers:	**KF, JB**
Date:	**10/2/2011**	Stream Type: **E6**	Valley Type: **X**

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	24.6 (A)	**Bankfull Height** (ft) =	8 (B)	(A) / (B) =	3.1 (C)	9

Root Depth / Study Bank Height (E)

Root Depth (ft) =	2 (D)	**Study Bank Height** (ft) =	24.6 (A)	(D) / (A) =	0.1 (E)	8

Weighted Root Density (G)

Root Density as **%** =	15% (F)	(F) x (E) =	1% (G)	10

Bank Angle (H)

Bank Angle as *Degrees* =	34 (H)	2

Surface Protection (I)

Surface Protection as **%** =	5% (I)	10

Bank Material Adjustment:

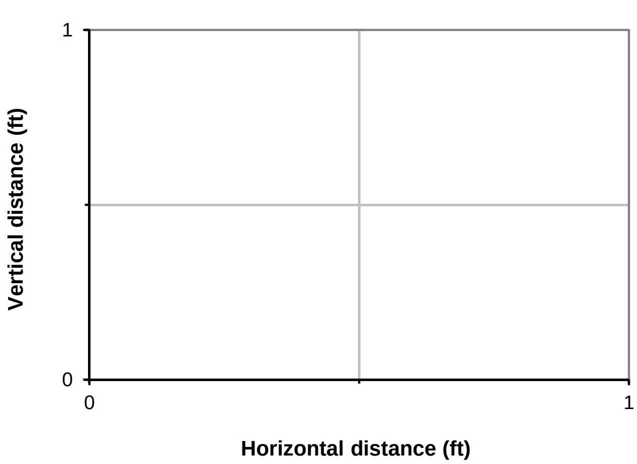
Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

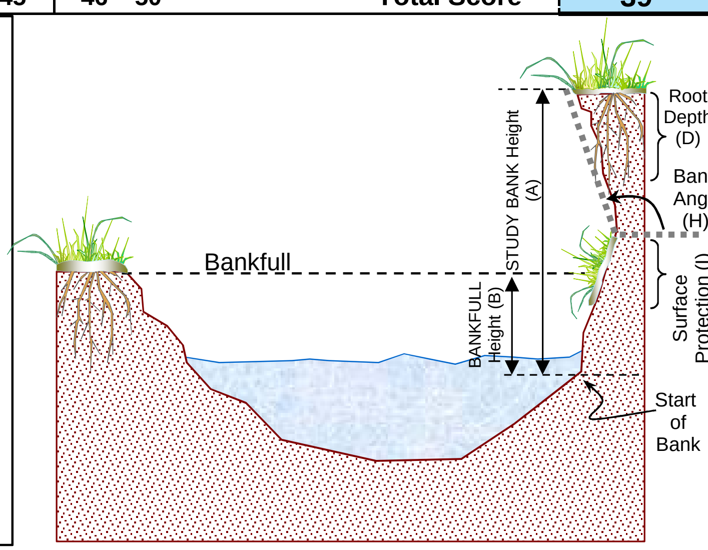
Bank Material Adjustment: 0

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** / **39**

Bank Sketch





Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Wild Rice River**	Location: **Wild Rice River-5-**	
Station: **0**	Stream Type: **E6**	Valley Type: **X**
Observers: **KF, JB**		Date: **10/2/11**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})...	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S)..	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})..	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})........................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient..	Level IV	Validation

Level I

(1)	Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
	Extensive deposition (continuous, cross-channel).. ....NBS = Extreme
	Chute cutoffs, down-valley meander migration, converging flow..NBS = Extreme

Level II

	Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)
(2)				

	Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)
(3)				

	Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)
(4)				

Dominant Near-Bank Stress
Very Low

Level III

	Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)
(5)				

	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)
(6)								

Level IV

	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
(7)	**0.01**	**Very Low**

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating	**Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Wild Rice River**		Location:	**Wild Rice River-5-**			
Graph Used:	**Fig 3-9**	Total Bank Length (ft):	**10300.8**			Date:	**10/2/2011**
Observers:	**KF, JB**		Valley Type:	**X**		Stream Type:	**E6**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**10300.8**	**24.6**	**41811**	**0.20**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**41811**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**1549**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**2013**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.20**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Wild Rice River**	Stream Type:	**E6**
Location:	**Wild Rice River-5-**	Valley Type:	**X**
Observers:	**KF, JB**	Date:	**10/2/2011**

Enter Required Information for Existing Condition

	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
0	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	**#DIV/0!**

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	**d**	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	**S**	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Sediment Competence Using Dimensional Shear Stress

0	Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope	
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**	
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**	
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope	$d = \dfrac{\tau}{\gamma S}$
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth	$S = \dfrac{\tau}{\gamma d}$

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis

Observers: **KF, JB**

Stream: **Wild Rice River**

Location: **Wild Rice River-5-**

Date: **10/2/2011**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		**100%**

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	**0**
Materials less than:	mm

Be sure to add separate material weights to grand total

0

GRAND TOTAL

Sample location notes		Sample location sketch	

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Wild Rice River**	Stream Type: **E6**
Location: **Wild Rice River-5-**	Valley Type: **X**
Observers: **KF, JB**	Date: **10/2/2011**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream:	**Wild Rice River**	Stream Type:	**E6**
Location:	**Wild Rice River-5-**	Valley Type:	**X**
Observers:	**KF, JB**	Date:	**10/2/2011**

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 3-8)**	< 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	> 1.6 **(8)**	**2**
2	**Depositional pattern (Worksheet 3-5)**	B1, B2 **(1)**	B4, B8 **(2)**	B3 **(3)**	B5, B6, B7 **(4)**	**1**
3	**Meander pattern (Worksheet 3-4)**	M1, M3, M4 **(1)**		M2, M5, M6, M7, M8 **(3)**		**3**
4	**Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL **(2)**	M/L, M/M, M/H, L/Ex, H/L **(4)**	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL **(6)**	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex **(8)**	**4**
5	**Degree of confinement (MWR / MWR$_{ref}$) (Worksheet 3-9)**	0.8 – 1.0 **(1)**	0.3 – 0.79 **(2)**	0.1 – 0.29 **(3)**	< 0.1 **(4)**	**1**
					Total points	**11**

	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** ☐

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Wild Rice River**	Stream Type:	**E6**
Location:	**Wild Rice River-5-**	Valley Type:	**X**
Observers:	**KF, JB**	Date:	**10/2/2011**

Vertical stability criteria (choose one stability category for each criterion 1–6)	Vertical Stability Categories for Excess Deposition / Aggradation: No deposition	Moderate deposition	Excess deposition	Aggradation	Selected points (from each row)
1 **Sediment competence (Worksheet 3-14)**	Sufficient depth and/or slope to transport largest size available **(2)**	Trend toward insufficient depth and/or slope-slightly incompetent **(4)**	Cannot move D_{35} of bed material and/or D_{100} of bar material **(6)**	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size **(8)**	**2**
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load **(2)**	Trend toward insufficient sediment capacity **(4)**	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand **(6)**	Reduction over 25% of annual sediment yield for bedload and/or suspended sand **(8)**	**2**
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	>1.6 **(8)**	**2**
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation **(2)**	(E→C) **(4)**	(C→High W/d C), (B→High W/d B), (C→F) **(6)**	(C→D), (F→D) **(8)**	**2**
5 **Depositional patterns (Worksheet 3-5)**	B1 **(1)**	B2, B4 **(2)**	B3, B5 **(3)**	B6, B7, B8 **(4)**	**1**
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 **(1)**	D4, D7 **(2)**	D5, D8 **(3)**	D6, D9, D10 **(4)**	**3**
				Total points	**12**

Vertical stability for excess deposition / aggradation (use total points and check stability rating)	Vertical stability category point range for excess deposition / aggradation: No deposition 10 – 14	Moderate deposition 15 – 20	Excess deposition 21 – 30	Aggradation > 30
	☑	☐	☐	☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream:	**Wild Rice River**	Stream Type:	**E6**
Location:	**Wild Rice River-5-**	Valley Type:	**X**
Observers:	**KF, JB**	Date:	**10/2/2011**

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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	2
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	2
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	8
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	4
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	1
				Total points	**17**

	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** ☐

Worksheet 3-20. Channel enlargement prediction summary.

Stream:	**Wild Rice River**			Stream Type:	**E6**
Location:	**Wild Rice River-5-**			Valley Type:	**X**
Observers:	**KF, JB**			Date:	**10/2/2011**

Channel enlargement prediction criteria (choose one stability category for each criterion 1–4)	**Channel Enlargement Prediction Categories**				**Selected points** (from each row)
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) (2)	(C→High W/d C), (E→C) (4)	(G→F), (F→D) (6)	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) (8)	**2**
2 **Lateral stability (Worksheet 3-17)**	Stable (2)	Moderately unstable (4)	Unstable (6)	Highly unstable (8)	**4**
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition (2)	Moderate deposition (4)	Excess deposition (6)	Aggradation (8)	**2**
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised (2)	Slightly incised (4)	Moderately incised (6)	Degradation (8)	**4**
				Total points	**12**

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

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream: Wild Rice River		Stream Type:	E6
Location: Wild Rice River-5-		Valley Type:	X
Observers: KF, JB		Date:	10/2/2011

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	Stability Rating	Points	Selected Points
1 Lateral stability (Worksheet 3-17)	Stable	1	2
	Mod. unstable	2	
	Unstable	3	
	Highly unstable	4	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition	1	1
	Mod. deposition	2	
	Excess deposition	3	
	Aggradation	4	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	2
	Slightly incised	2	
	Mod. Incised	3	
	Degradation	4	
4 Channel enlargement prediction (Worksheet 3-20)	No increase	1	2
	Slight increase	2	
	Mod. increase	3	
	Extensive	4	
5 Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	2
	Fair: mod unstable	2	
	Poor: unstable	4	
		Total Points	9

	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 ☐

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Wild Rice River**			Location: **Wild Rice River-5-**			
Observers:	**KF, JB**	Date: **10/2/2011**		Stream Type: **E6**		Valley Type: **X**	
Channel Dimension	Mean bankfull depth (ft): **6.98**	Mean bankfull width (ft): **74.1**	Cross-section area (ft^2): **516.1**	Width of flood-prone area (ft): **236**	Entrenchment ratio: **3.2**		
Channel Pattern	Mean: Range: MWR: **23.1**	Lm/W_{bkf}: **23.1**	Rc/W_{bkf}: **4.8**	Sinuosity: **1.94**			
River Profile and Bed Features	Check: ☐ Riffle/pool ☐ Step/pool ☐ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed						
	Max bankfull depth (ft): Riffle **9.6**; Pool	Depth ratio (max/mean): Riffle **1.4**; Pool	Pool to pool spacing: Ratio	Slope: Valley: ; Average bankfull: **8.1E-05**			
Level III Stream Stability Indices	Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:			
	Flow regime: **P1, 2, 9**	Stream size and order: **S-6**	Meander pattern(s): **M2**	Depositional pattern(s): **NONE**	Debris/channel blockage(s): **D1, 2, 4, 5**		
	Degree of incision (Bank-Height Ratio): **2.6**	Degree of incision stability rating: **Deeply Incised**	Modified Pfankuch stability rating (numeric and adjective rating): **Fair**				
	Width/depth ratio (W/d): **10.6**	Reference W/d ratio (W/d_{ref}): **10.6**	Width/depth ratio state $(W/d) / (W/d_{ref})$: **1.0**	W/d ratio state stability rating: **Stable**			
	Meander Width Ratio (MWR): **23.1**	Reference MWR_{ref}: **23.1**	Degree of confinement (MWR / MWR_{ref}): **1.0**	MWR / MWR_{ref} stability rating: **Unconfined**			
Bank Erosion Summary	Length of reach studied (ft): **####**	Annual streambank erosion rate: **2013** (tons/yr) **0.20** (tons/yr/ft)	Curve used: **Fig 3-9**	Remarks:			
Sediment Capacity (POWERSED)	☑ Sufficient capacity ☐ Insufficient capacity ☐ Excess capacity			Remarks:			
Entrainment/ Competence	Largest particle from bar sample (mm):	$\tau =$	$\tau^* =$	Existing $depth_{bkf}$:	Required $depth_{bkf}$:	Existing $slope_{bkf}$:	Required $slope_{bkf}$:
Successional Stage Shift	→ → → → →			Existing stream state (type): **E6**	Potential stream state (type): **E6**		
Lateral Stability	☐ Stable ☑ Mod. unstable ☐ Unstable ☐ Highly unstable			Remarks/causes:			
Vertical Stability (Aggradation)	☑ No deposition ☐ Mod. deposition ☐ Ex. deposition ☐ Aggradation			Remarks/causes:			
Vertical Stability (Degradation)	☐ Not incised ☑ Slightly incised ☐ Mod. incised ☐ Degradation			Remarks/causes:			
Channel Enlargement	☐ No increase ☑ Slight increase ☐ Mod. increase ☐ Extensive			Remarks/causes:			
Sediment Supply (Channel Source)	☐ Low ☑ Moderate ☐ High ☐ Very high			Remarks/causes:			

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Wild Rice River**		Location: **Wild Rice River-6-42.36**	
Observers: **KD, JB**	Reference reach [ ]	Disturbed (impacted reach) **X**	Date: **10/1/2011**
Existing species composition:		Potential species composition:	

	Riparian cover categories	Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**85%**	**5%**	**Trees**	**100%**
					100%
2. Understory	Shrub layer		**20%**	**Shrubs**	**100%**
					100%
3. Ground level	Herbaceous		**5%**	**Grass, weeds**	**100%**
					100%
	Leaf or needle litter		**5%**		
	Bare ground		**65%**		
			Column total = 100%		

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

Remarks:
Condition, vigor and/or usage of existing reach:

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Wild Rice River**			Location: **Wild Rice River-6-42.36**					
Observers: **KD, JB**						Date: **10/1/2011**		
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P9**					

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order			
Stream:	**Wild Rice River**		
Location:	**Wild Rice River-6-42.36**		
Observers:	**KD, JB**		
Date:	**10/1/2011**		
Stream Size Category and Order ☞			**S-7**
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).			

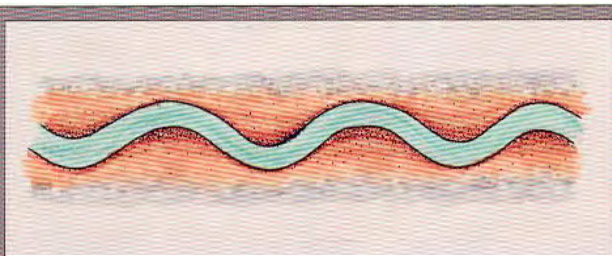
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

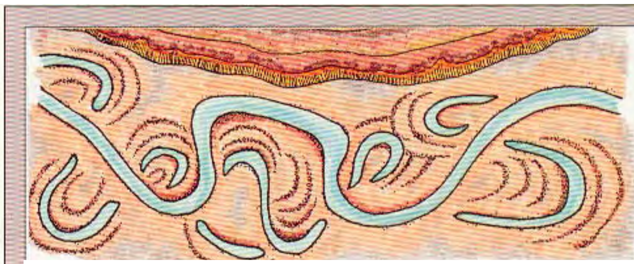
Stream:	**Wild Rice River**	Reach:	**Wild Rice River-6-42.36**
Observers:	**KD, JB**	Date:	**10/1/2011**

List ALL CATEGORIES that APPLY ☞	M2				

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

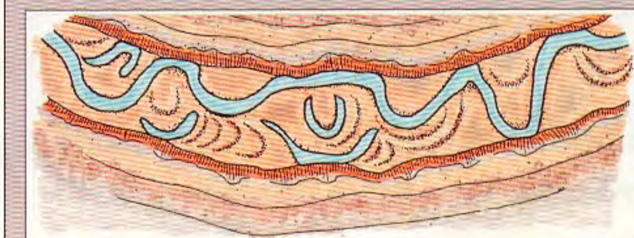


M1 REGULAR MEANDERS

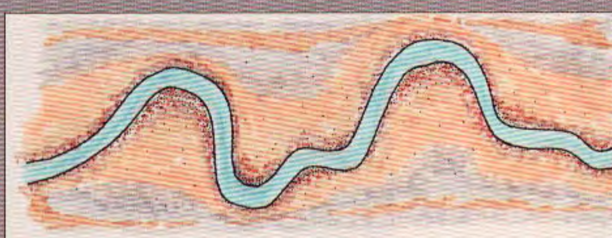


M5 UNCONFINED MEANDER SCROLLS

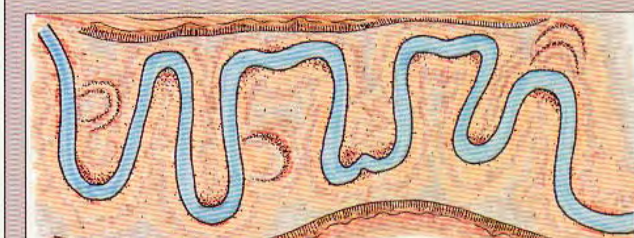
M2 TORTUOUS MEANDERS



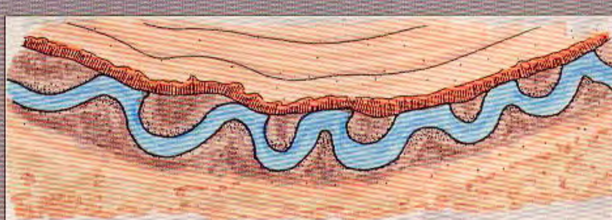
M6 CONFINED MEANDER SCROLLS



M3 IRREGULAR MEANDERS



M7 DISTORTED MEANDER LOOPS



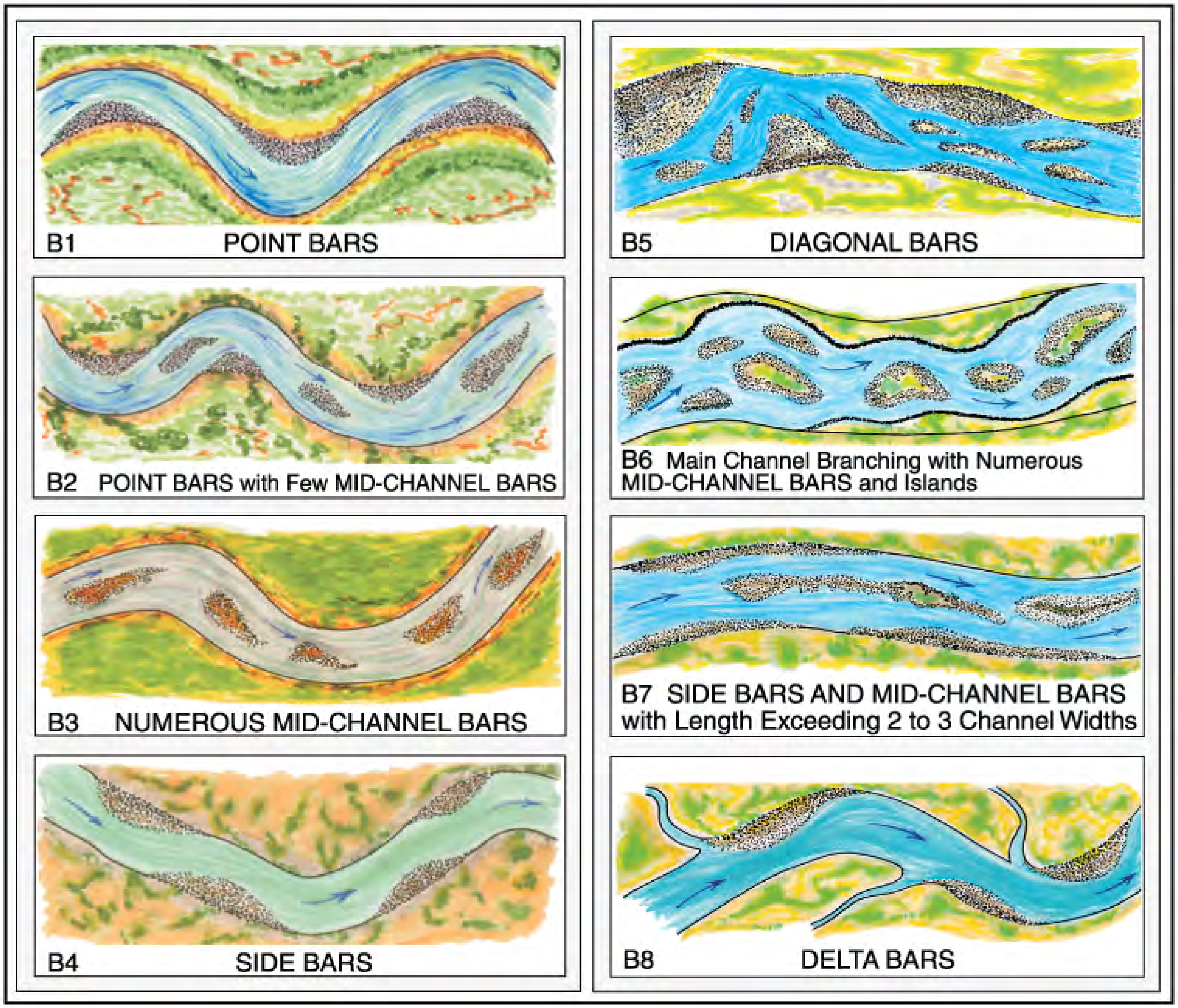
M4 TRUNCATED MEANDERS

M8 IRREGULAR MEANDERS with oxbows and

Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns					
Stream: **Wild Rice River**			Reach: **Wild Rice River-6-42.36**		
Observers: **KD, JB**			Date: **10/1/2011**		
List ALL CATEGORIES that APPLY ☞	**None**				

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



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Wild Rice River**		Location: **Wild Rice River-6-42.36**	
Observers: **KD, JB**		Date: **10/1/2011**	
Description/extent		**Materials that 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.	☐

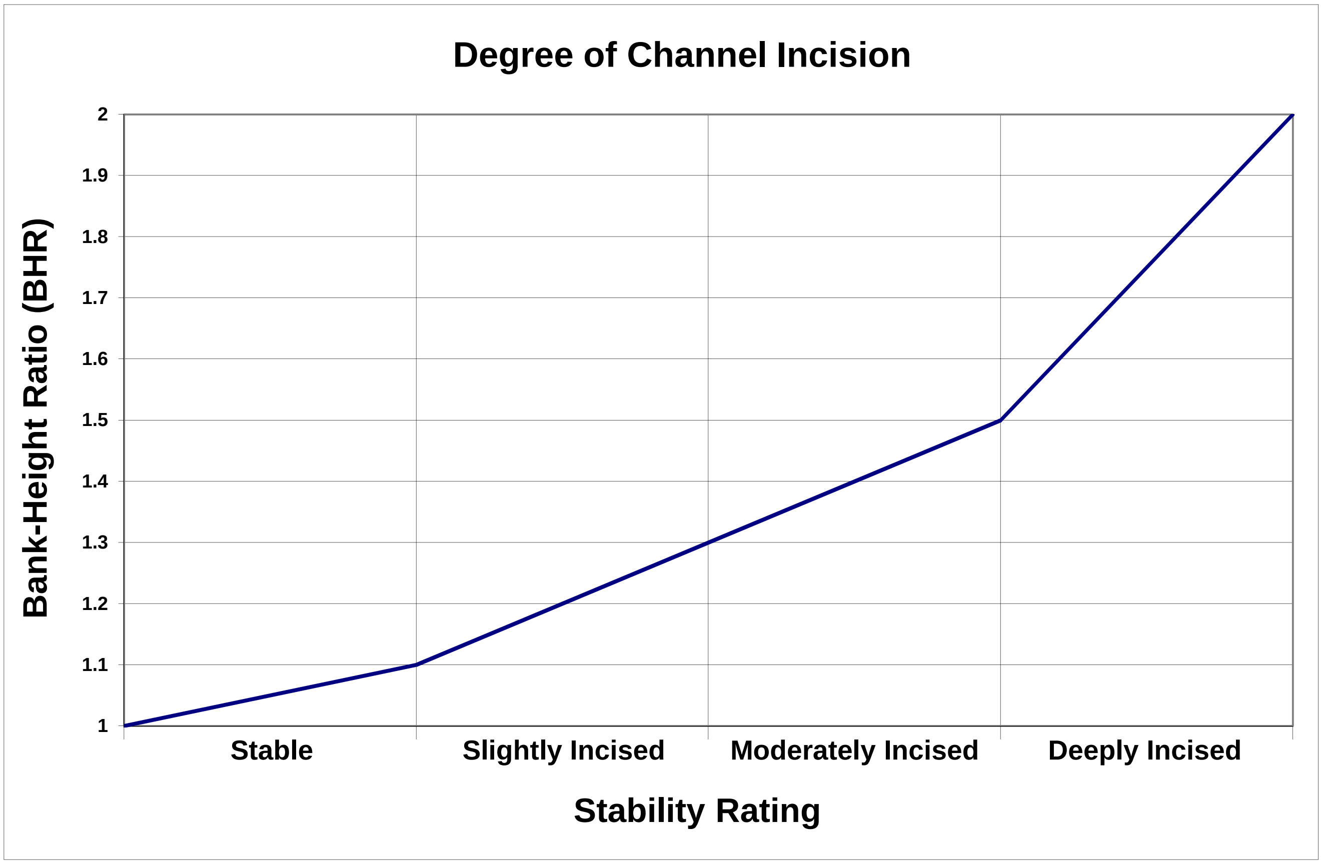
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision

Low Bank Height:	**19.6**
Max Bankfull Depth:	**8.39**

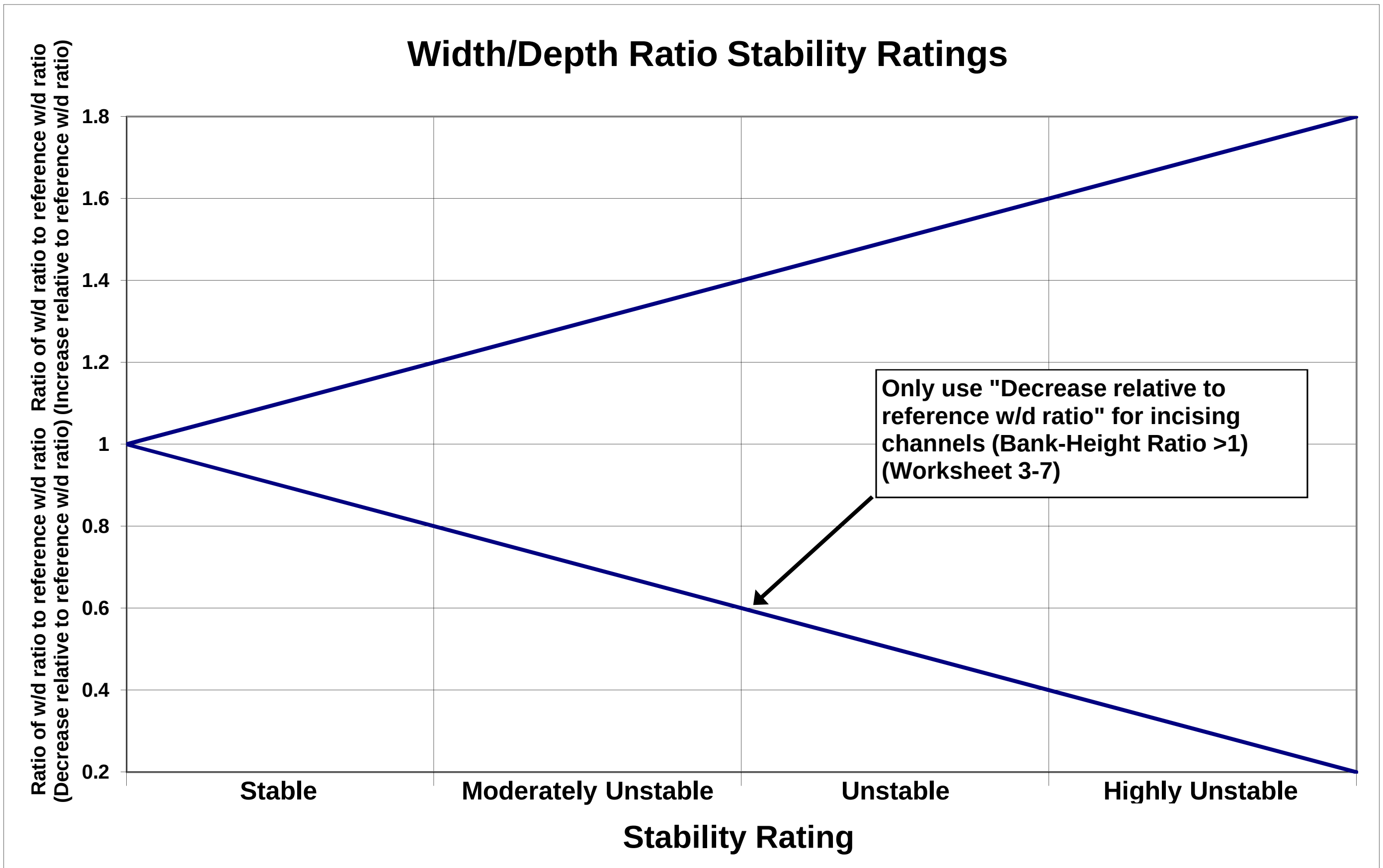
Bank-Height Ratio:	**2.3**

Degree of Channel Incision Stability Rating ☞	**Deeply Incised**



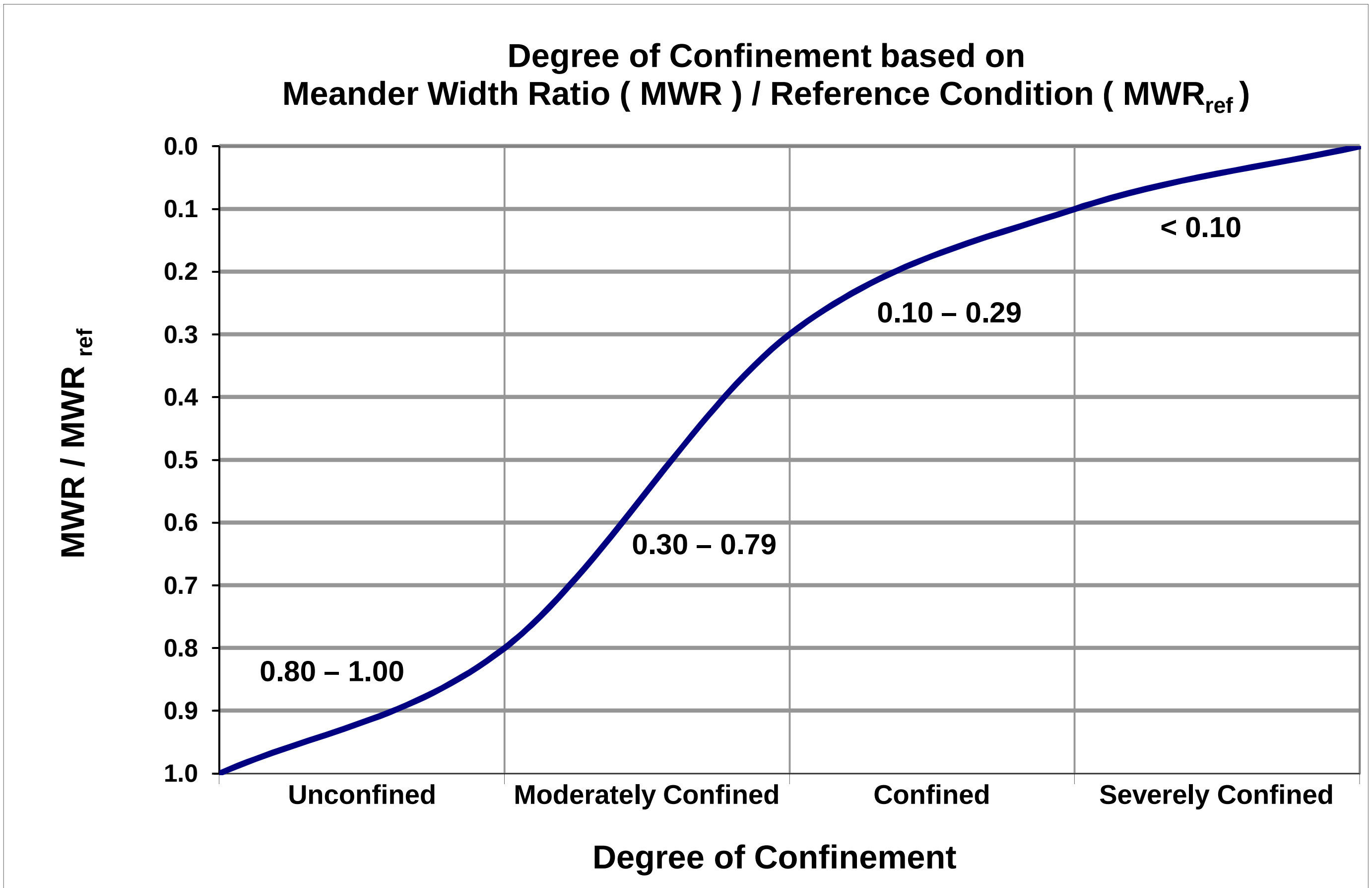
Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State			
Existing Width/Depth Ratio:	**12.6**	Ratio of existing W/d to reference W/d:	**1**
Reference Width/Depth Ratio:	**12.6**		
Width/Depth Ratio State Stability Rating ☞		**Stable**	



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	**17.8**	Ratio of MWR to MWR_{ref}:	**1**
Reference Meander Width Ratio (MWR_{ref}):	**17.8**		
Degree of Confinement Stability Rating ☞		**Unconfined**	



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Wild Rice River **Location:** Wild Rice River-6-42.3 **Valley Type:** X **Observers:** KD, JB **Date:** 10/1/2011

Location	Key	Category	Excellent Description	Excellent Rating	Good Description	Good Rating	Fair Description	Fair Rating	Poor Description	Poor Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	**6**	Bank slope gradient > 60%.	8
	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	**12**
	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	**6**	Moderate to heavy amounts, predominantly larger sizes.	8
	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	**12**
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	**2**	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	**6**	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	**16**
	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	21	Good total =	0	Fair total =	18	Poor total =	44

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	83
Existing stream type =	E6
*Potential stream type =	E6
Modified channel stability rating =	Fair

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream:	**Wild Rice River**	Location:	**Wild Rice River-6-42.36**
Station:		Observers:	**KD, JB**
Date:	**10/1/2011**	Stream Type: **E6**	Valley Type: **X**

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	20.8 (A)	Bankfull Height (ft) =	6.3 (B)	(A) / (B) =	3.3 (C)	9

Root Depth / Study Bank Height (E)

Root Depth (ft) =	3 (D)	Study Bank Height (ft) =	20.8 (A)	(D) / (A) =	0.1 (E)	8

Weighted Root Density (G)

Root Density as % =	10% (F)	(F) x (E) =	1% (G)	10

Bank Angle (H)

Bank Angle as *Degrees* =	30 (H)	2

Surface Protection (I)

Surface Protection as % =	5% (I)	10

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)

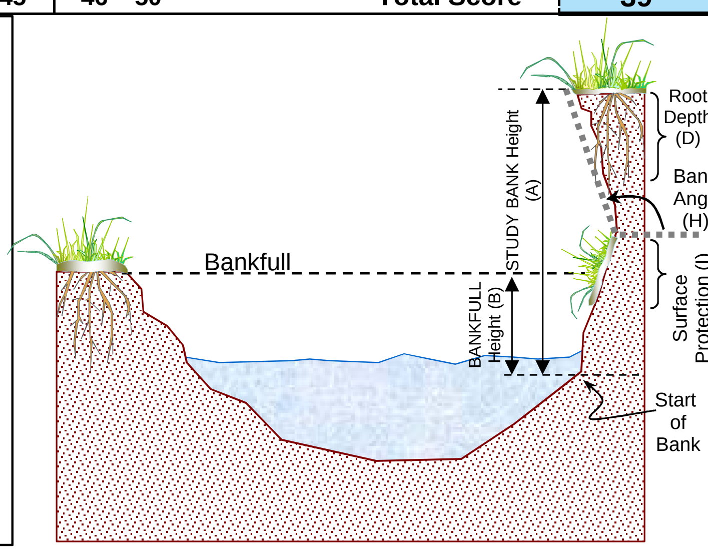
Bank Material Adjustment: 0

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**: **High** / **39**

Bank Sketch



Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Wild Rice River** Location: **Wild Rice River-6-42.36**

Station: **0** Stream Type: **E6** Valley Type: **X**

Observers: **KD, JB** Date: **10/1/11**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})..	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S)..	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})..	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})........................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient..	Level IV	Validation

Level I

(1)
- Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
- Extensive deposition (continuous, cross-channel).. ....NBS = Extreme
- Chute cutoffs, down-valley meander migration, converging flow..NBS = Extreme

Level II

(2)

Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)

(3)

Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)

(4)

Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)

Dominant Near-Bank Stress
Very Low

Level III

(5)

Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)

(6)

Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)

Level IV

(7)

Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
0.04	**Very Low**

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating | **Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Wild Rice River**			Location:	**Wild Rice River-6-42.36**		
Graph Used:	**Fig 3-9**	Total Bank Length (ft):	**9723.3**			Date:	**10/1/2011**
Observers:	**KD, JB**	Valley Type:	**X**			Stream Type:	**E6**

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**9723.3**	**20.8**	**33370**	**0.17**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**33370**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**1236**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**1607**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.17**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Wild Rice River**		Stream Type: **E6**		
Location:	**Wild Rice River-6-42.36**		Valley Type: **X**		
Observers:	**KD, JB**		Date: **10/1/2011**		
Enter Required Information for Existing Condition					
	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
0	**D_{max}**	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			
Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress					
#DIV/0!	**$D_{50}/\hat{D}_{50}$**	Range: 3 – 7	Use EQUATION 1: $\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$		
#DIV/0!	**D_{max}/D_{50}**	Range: 1.3 – 3.0	Use EQUATION 2: $\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$		
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:		**#DIV/0!**
Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample					
#DIV/0!	**d**	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$		(use D_{max} in ft)
	Check:	☐ Stable ☐ Aggrading ☐ Degrading			
Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample					
#DIV/0!	**S**	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$		(use D_{max} in ft)
	Check:	☐ Stable ☐ Aggrading ☐ Degrading			
Sediment Competence Using Dimensional Shear Stress					
0	Bankfull shear stress $\tau = \gamma d S$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope				
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**				
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**				
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope			$d = \dfrac{\tau}{\gamma S}$	
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth			$S = \dfrac{\tau}{\gamma d}$	

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis

Observers: **KD, JB**

Stream: **Wild Rice River** | Location: **Wild Rice River-6-42.36** | Date: **10/1/2011**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total	0		0		0		0		0		0		0		0		0	
% Grand total	#####		#####		#####		#####		#####		#####		#####		#####		#####	
Accum. % =<	#####		#####		#####		#####		#####		#####		#####		#####		100%	

SURFACE MATERIALS DATA (Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	0
Materials less than:	mm

Be sure to add separate material weights to grand total

GRAND TOTAL: 0

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Wild Rice River**	Stream Type: **E6**
Location: **Wild Rice River-6-42.36**	Valley Type: **X**
Observers: **KD, JB**	Date: **10/1/2011**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream: **Wild Rice River**			Stream Type:	**E6**	
Location: **Wild Rice River-6-42.36**			Valley Type:	**X**	
Observers: **KD, JB**			Date:	**10/1/2011**	
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 3-8)	< 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	> 1.6 **(8)**	**2**
2 Depositional pattern (Worksheet 3-5)	B1, B2 **(1)**	B4, B8 **(2)**	B3 **(3)**	B5, B6, B7 **(4)**	**1**
3 Meander pattern (Worksheet 3-4)	M1, M3, M4 **(1)**		M2, M5, M6, M7, M8 **(3)**		**3**
4 Dominant BEHI / NBS (Worksheet 3-13)	L/VL, L/L, L/M, L/H, L/VH, M/VL **(2)**	M/L, M/M, M/H, L/Ex, H/L **(4)**	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL **(6)**	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex **(8)**	**4**
5 Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)	0.8 – 1.0 **(1)**	0.3 – 0.79 **(2)**	0.1 – 0.29 **(3)**	< 0.1 **(4)**	**1**
				Total points	**11**
	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** ☐	

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Wild Rice River**			Stream Type:	**E6**	
Location:	**Wild Rice River-6-42.36**			Valley Type:	**X**	
Observers:	**KD, JB**			Date:	**10/1/2011**	

Vertical stability criteria (choose one stability category for each criterion 1–6)	**Vertical Stability Categories for Excess Deposition / Aggradation:** No deposition	Moderate deposition	Excess deposition	Aggradation	**Selected points (from each row)**
1 **Sediment competence (Worksheet 3-14)**	Sufficient depth and/or slope to transport largest size available **(2)**	Trend toward insufficient depth and/or slope-slightly incompetent **(4)**	Cannot move D_{35} of bed material and/or D_{100} of bar material **(6)**	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size **(8)**	**2**
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load **(2)**	Trend toward insufficient sediment capacity **(4)**	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand **(6)**	Reduction over 25% of annual sediment yield for bedload and/or suspended sand **(8)**	**2**
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	>1.6 **(8)**	**2**
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation **(2)**	(E→C) **(4)**	(C→High W/d C), (B→High W/d B), (C→F) **(6)**	(C→D), (F→D) **(8)**	**2**
5 **Depositional patterns (Worksheet 3-5)**	B1 **(1)**	B2, B4 **(2)**	B3, B5 **(3)**	B6, B7, B8 **(4)**	**1**
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 **(1)**	D4, D7 **(2)**	D5, D8 **(3)**	D6, D9, D10 **(4)**	**1**
				Total points	**10**

Vertical stability for excess deposition / aggradation (use total points and check stability rating)	**Vertical stability category point range for excess deposition / aggradation:** No deposition 10 – 14	Moderate deposition 15 – 20	Excess deposition 21 – 30	Aggradation > 30
	☑	☐	☐	☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream: **Wild Rice River**			Stream Type: **E6**		
Location: **Wild Rice River-6-42.36**			Valley Type: **X**		
Observers: **KD, JB**			Date: **10/1/2011**		
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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	**2**
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	**2**
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	**8**
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	**4**
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	**1**
				Total points	**17**
	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** ☐	

Worksheet 3-20. Channel enlargement prediction summary.

Stream:	Wild Rice River			Stream Type:	E6
Location:	Wild Rice River-6-42.36			Valley Type:	X
Observers:	KD, JB			Date:	10/1/2011

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 3-16)	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) (2)	(C→High W/d C), (E→C) (4)	(G→F), (F→D) (6)	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) (8)	2
2 Lateral stability (Worksheet 3-17)	Stable (2)	Moderately unstable (4)	Unstable (6)	Highly unstable (8)	4
3 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition (2)	Moderate deposition (4)	Excess deposition (6)	Aggradation (8)	2
4 Vertical stability incision/ degradation (Worksheet 3-19)	Not incised (2)	Slightly incised (4)	Moderately incised (6)	Degradation (8)	4
				Total points	**12**

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

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream: Wild Rice River		Stream Type:	E6
Location: Wild Rice River-6-42.36		Valley Type:	X
Observers: KD, JB		Date:	10/1/2011

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	Stability Rating	Points	Selected Points
1 Lateral stability (Worksheet 3-17)	Stable	1	2
	Mod. unstable	2	
	Unstable	3	
	Highly unstable	4	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition	1	1
	Mod. deposition	2	
	Excess deposition	3	
	Aggradation	4	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	2
	Slightly incised	2	
	Mod. Incised	3	
	Degradation	4	
4 Channel enlargement prediction (Worksheet 3-20)	No increase	1	2
	Slight increase	2	
	Mod. increase	3	
	Extensive	4	
5 Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	2
	Fair: mod unstable	2	
	Poor: unstable	4	
		Total Points	9

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

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Wild Rice River**					Location:	**Wild Rice River-6-42.36**		
Observers:	**KD, JB**		Date: **10/1/2011**			Stream Type: **E6**		Valley Type: **X**	
Channel Dimension	Mean bankfull depth (ft):	**6.07**	Mean bankfull width (ft):	**76.21**	Cross-section area (ft^2):	**462.2**	Width of flood-prone area (ft):	**157.6667**	Entrenchment ratio: **2.1**
Channel Pattern	Mean: Range:	MWR: **17.8**	Lm/W_{bkf}:	**17.8**	Rc/W_{bkf}:	**4.3**	Sinuosity:	**2.7**	
River Profile and Bed Features	Check: ☐ Riffle/pool	☐ Step/pool	☐ Plane bed	☐ Convergence/divergence	☑ Dunes/antidunes/smooth bed				
	Max bankfull depth (ft):	Riffle: **8.4**	Pool:	Depth ratio (max/mean): Riffle: **1.4**	Pool:	Pool to pool spacing:	Ratio:	Slope: Valley:	Average bankfull: **8.8E-05**
Level III Stream Stability Indices	Riparian vegetation	Current composition/density:		Potential composition/density:		Remarks: Condition, vigor and/or usage of existing reach:			
	Flow regime:	**P1, 2, 9**	Stream size and order:	**S-7**	Meander pattern(s):	**M2**	Depositional pattern(s):	**NONE**	Debris/channel blockage(s): **D1-3**
	Degree of incision (Bank-Height Ratio):	**2.3**	Degree of incision stability rating:	**Deeply Incised**	Modified Pfankuch stability rating (numeric and adjective rating):		**Fair**		
	Width/depth ratio (W/d):	**12.6**	Reference W/d ratio (W/d_{ref}):	**12.6**	Width/depth ratio state $(W/d) / (W/d_{ref})$:	**1.0**	W/d ratio state stability rating:	**Stable**	
	Meander Width Ratio (MWR):	**17.8**	Reference MWR_{ref}:	**17.8**	Degree of confinement (MWR / MWR_{ref}):	**1.0**	MWR / MWR_{ref} stability rating:	**Unconfined**	
Bank Erosion Summary	Length of reach studied (ft):	**9723**	Annual streambank erosion rate: **1607** (tons/yr)	**0.17** (tons/yr/ft)	Curve used: **Fig 3-9**		Remarks:		
Sediment Capacity (POWERSED)	☑ Sufficient capacity	☐ Insufficient capacity	☐ Excess capacity				Remarks:		
Entrainment/ Competence	Largest particle from bar sample (mm):		$\tau =$		$\tau^* =$		Existing $depth_{bkf}$:	Required $depth_{bkf}$:	Existing $slope_{bkf}$: / Required $slope_{bkf}$:
Successional Stage Shift	→ → → → →						Existing stream state (type): **E6**		Potential stream state (type): **E6**
Lateral Stability	☐ Stable	☑ Mod. unstable	☐ Unstable	☐ Highly unstable			Remarks/causes:		
Vertical Stability (Aggradation)	☑ No deposition	☐ Mod. deposition	☐ Ex. deposition	☐ Aggradation			Remarks/causes:		
Vertical Stability (Degradation)	☐ Not incised	☑ Slightly incised	☐ Mod. incised	☐ Degradation			Remarks/causes:		
Channel Enlargement	☐ No increase	☑ Slight increase	☐ Mod. increase	☐ Extensive			Remarks/causes:		
Sediment Supply (Channel Source)	☐ Low	☑ Moderate	☐ High	☐ Very high			Remarks/causes:		

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Wolverton Creek**		Location: **Wolverton Creek - 1 - 0.64**	
Observers: **KP, AL**	Reference reach [ ]	Disturbed (impacted reach) **X**	Date: **11/19/2010**
Existing species composition:		Potential species composition:	

	Riparian cover categories	Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer				
					100%
2. Understory	Shrub layer				
					100%
3. Ground level	Herbaceous				
					100%
	Leaf or needle litter				
	Bare ground				
			Column total = 100%		

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

Remarks:
Condition, vigor and/or usage of existing reach:
None

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Wolverton Creek**		Location: **Wolverton Creek - 1 - 0.64**						
Observers: **KP, AL**						Date: **11/19/2010**		
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P9**					

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order

Stream:	**Wolverton Creek**
Location:	**Wolverton Creek - 1 - 0.64**
Observers:	**KP, AL**
Date:	**11/19/2010**

Stream Size Category and Order ☞ **S-4**

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

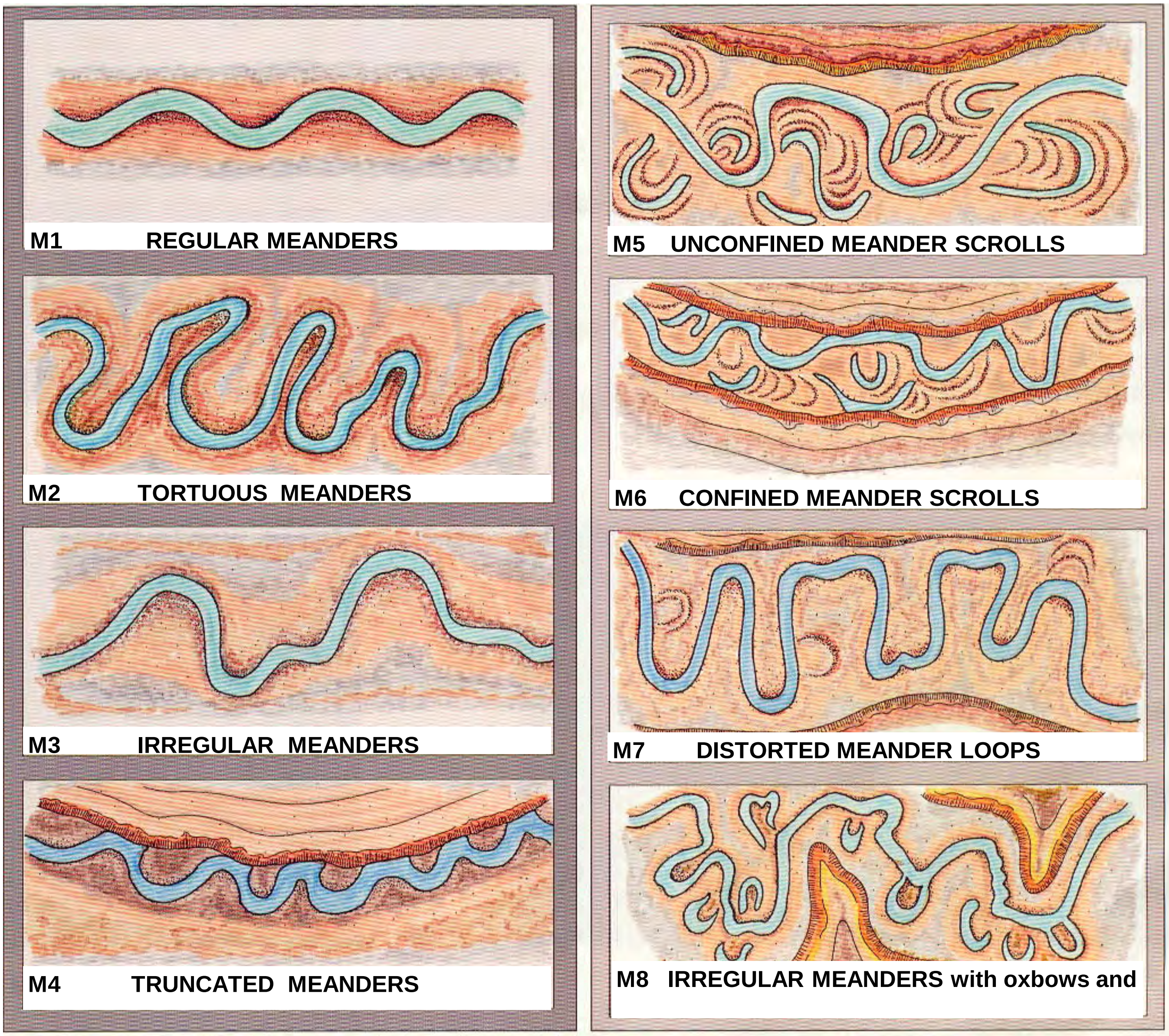
Add categories in parenthesis for specific stream order of reach. For example a third order stream with a bankfull width of 6.1 meters (20 feet) would be indexed as: S-4(3).

Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream: **Wolverton Creek**			Reach: **Wolverton Creek - 1 - 0.64**		
Observers: **KP, AL**			Date: **11/19/2010**		
List ALL CATEGORIES that APPLY ☞	**M1**				

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



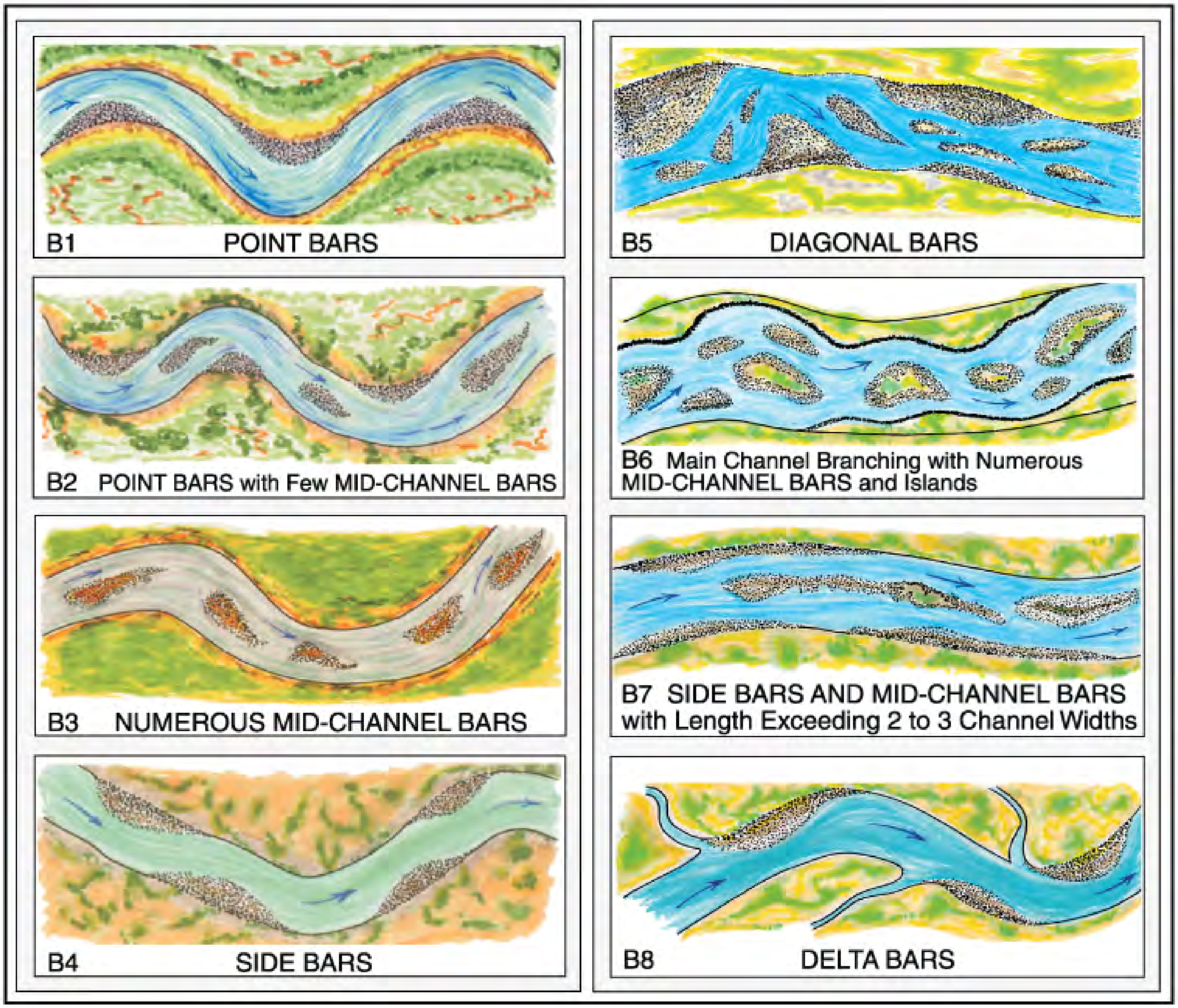
Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns

Stream:	**Wolverton Creek**	Reach:	**Wolverton Creek - 1 - 0.64**
Observers:	**KP, AL**	Date:	**11/19/2010**

List ALL CATEGORIES that APPLY ☞	**NONE**				

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

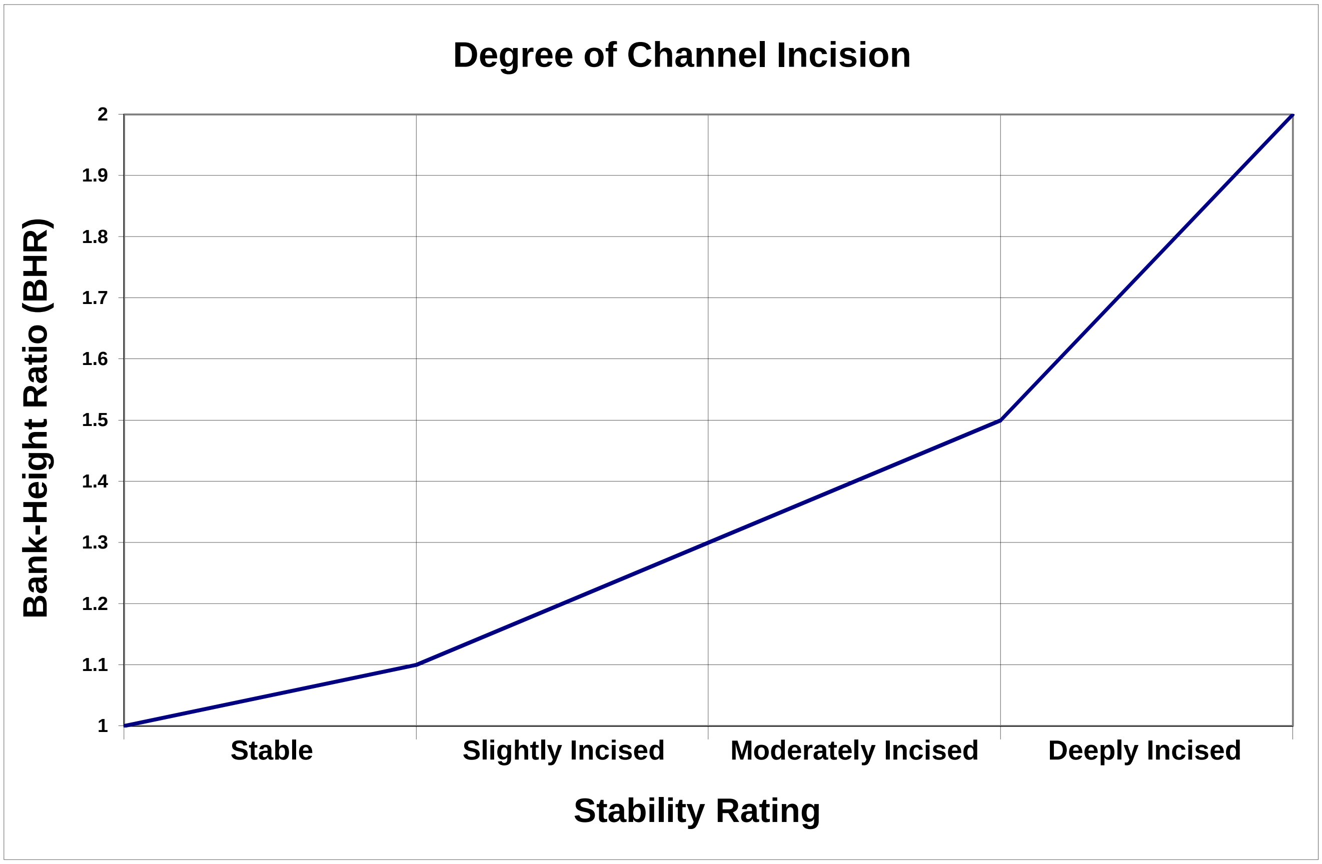


Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Wolverton Creek**		Location: **Wolverton Creek - 1 - 0.64**	
Observers: **KP, AL**		Date: **11/19/2010**	
Description/extent		**Materials that 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.	☐

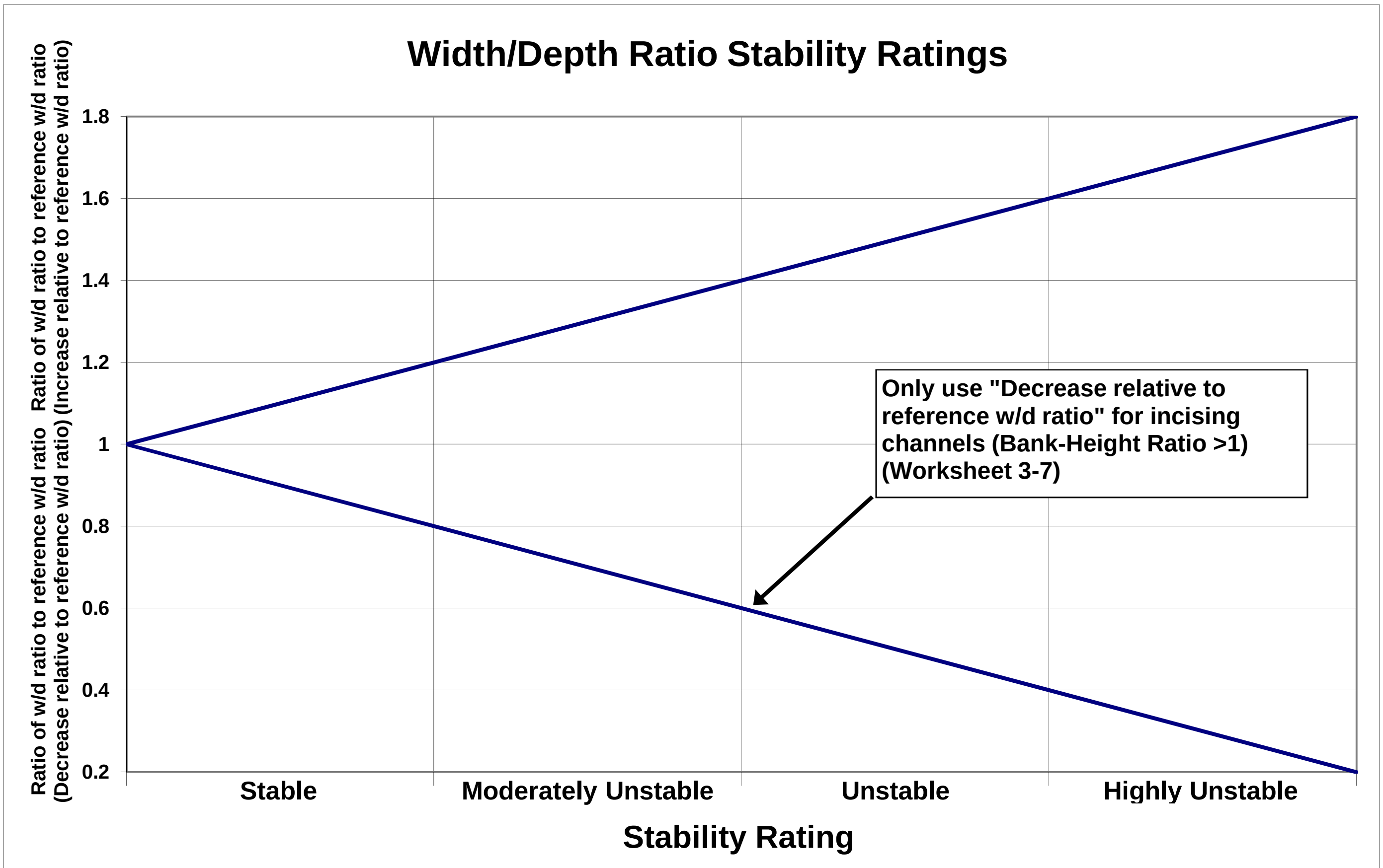
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision			
Low Bank Height:	5.1	Bank-Height Ratio:	1.5
Max Bankfull Depth:	3.3		
Degree of Channel Incision Stability Rating ☞		Moderately Incised	



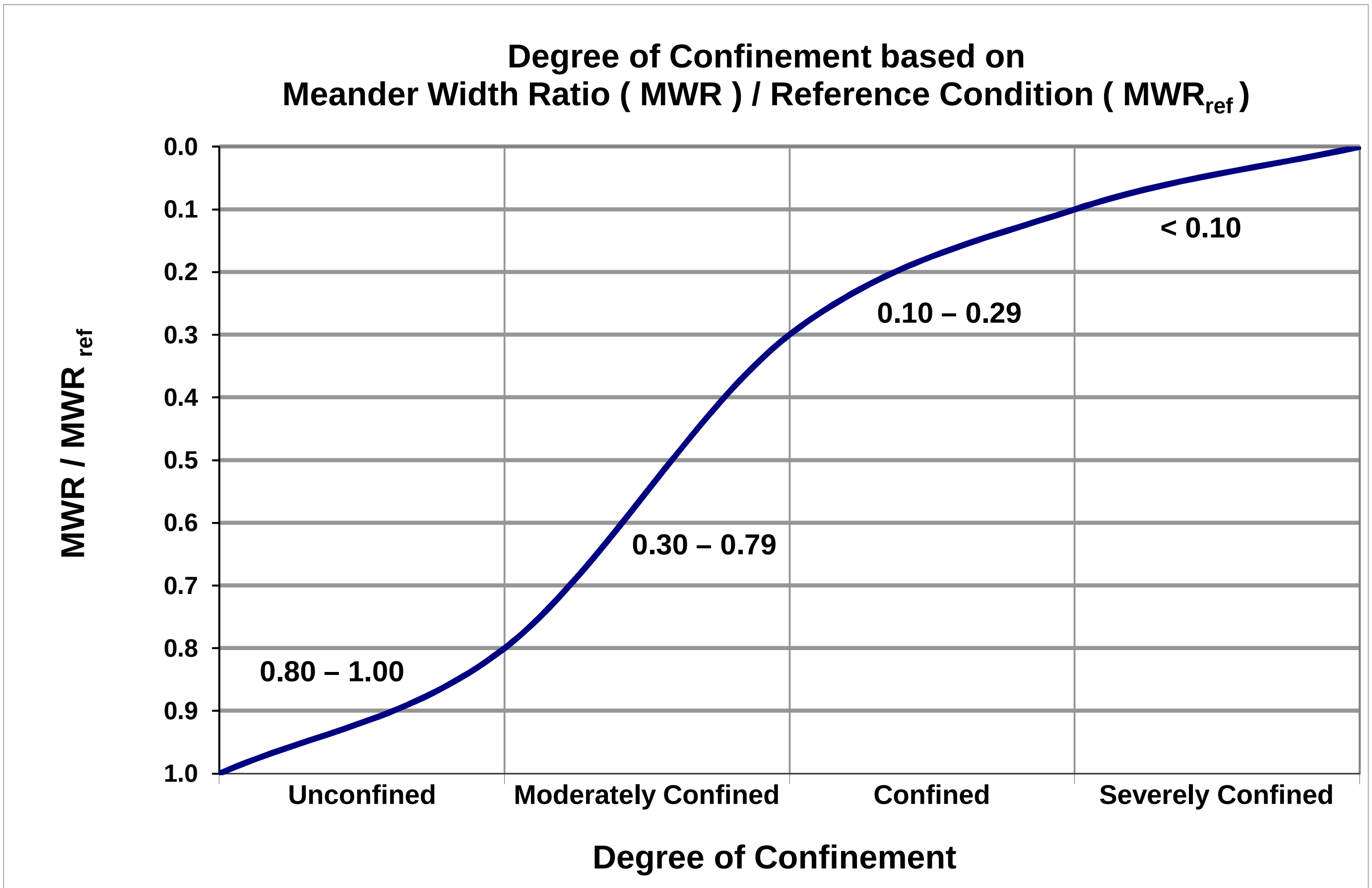
Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State			
Existing Width/Depth Ratio:	12.2	Ratio of existing W/d to reference W/d:	1.007
Reference Width/Depth Ratio:	12.1		
Width/Depth Ratio State Stability Rating ☞		Stable	



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	12.4	Ratio of MWR to MWR_{ref}:	1.097
Reference Meander Width Ratio (MWR_{ref}):	11.3		
Degree of Confinement Stability Rating ☞		**Unconfined**	



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Wolverton Creek **Location:** Wolverton Creek - 1 - (**Valley Type:** X **Observers:** KP, AL **Date:** 11/19/2010

Location	Key	Category	Excellent: Description	Rating	Good: Description	Rating	Fair: Description	Rating	Poor: Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	**4**	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	**9**	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	**6**	Moderate to heavy amounts, predominantly larger sizes.	8
	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	**12**
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	**2**	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	**6**	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	**16**
	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	21	Good total =	4	Fair total =	21	Poor total =	32

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	78
Existing stream type =	B6c
*Potential stream type =	B6c
Modified channel stability rating =	Fair

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream:	**Wolverton Creek**	Location:	**Wolverton Creek - 1 - 0.64**
Station:		Observers:	**KP, AL**
Date: **11/19/2010**	Stream Type: **B6c**	Valley Type: **X**	

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	**5.2** **(A)**	**Bankfull Height** (ft) =	**4** **(B)**	(A) / (B) =	**1.3** **(C)**	**4**

Root Depth / Study Bank Height (E)

Root Depth (ft) =	**3** **(D)**	**Study Bank Height** (ft) =	**5.2** **(A)**	(D) / (A) =	**0.6** **(E)**	**3**

Weighted Root Density (G)

Root Density as **%** =	**25%** **(F)**	(F) x (E) =	**14%** **(G)**	**8**

Bank Angle (H)

Bank Angle as *Degrees* =	**27** **(H)**	**2**

Surface Protection (I)

Surface Protection as **%** =	**5%** **(I)**	**10**

Bank Material Adjustment:

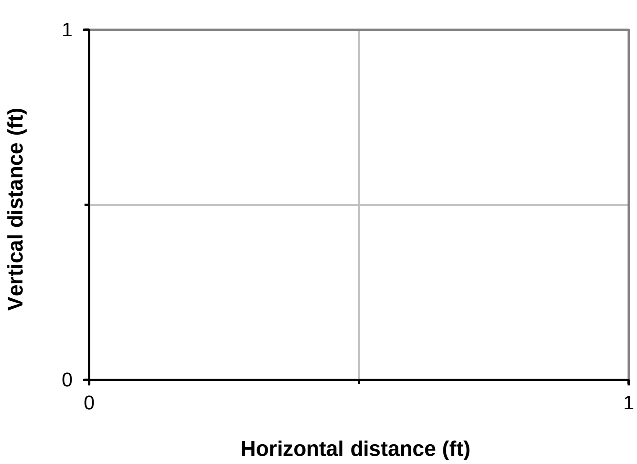
Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

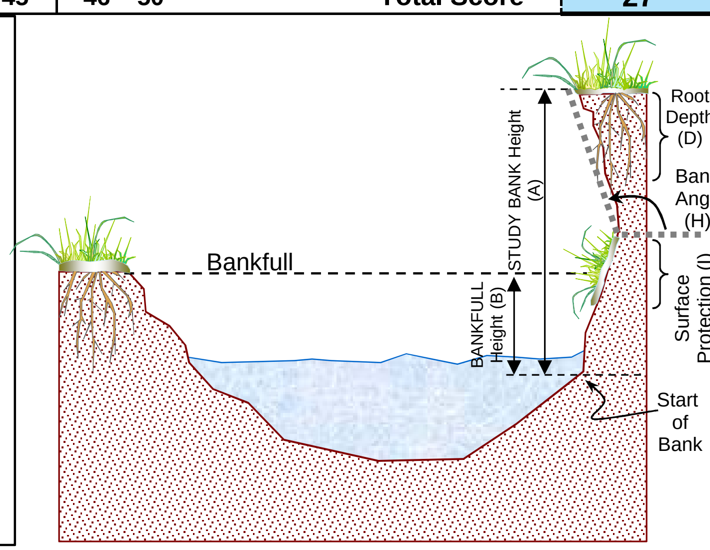
Bank Material Adjustment | **0**

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**

Bank Sketch





Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Wolverton Creek** Location: **Wolverton Creek - 1 - 0.64**

Station: **0** Stream Type: **B6c** Valley Type: **X**

Observers: **KP, AL** Date: **11/19/10**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})..	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S)..	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})..	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf})...........................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient..	Level IV	Validation

Level I

(1)
Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
Extensive deposition (continuous, cross-channel).. ....NBS = Extreme
Chute cutoffs, down-valley meander migration, converging flow...NBS = Extreme

Level II

(2)

Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)

(3)

Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)

(4)

Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)

Dominant Near-Bank Stress
Very Low

Level III

(5)

Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)

(6)

Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)

Level IV

(7)

Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
	Very Low

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating	**Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Wolverton Creek**				Location: **Wolverton Creek - 1 - 0.64**		
Graph Used:	**Fig 3-9**	Total Bank Length (ft): **2165.2**				Date: **11/19/2010**	
Observers:	**KP, AL**		Valley Type: **X**			Stream Type: **B6c**	
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**Moderate**	**Very Low**	**0.092**	**2165.2**	**5.2**	**1036**	**0.02**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**1036**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**38**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**50**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.02**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Wolverton Creek**		Stream Type:	**B6c**	
Location:	**Wolverton Creek - 1 - 0.64**		Valley Type:	**X**	
Observers:	**KP, AL**		Date:	**11/19/2010**	

Enter Required Information for Existing Condition

	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\ (D_{50}/\hat{D}_{50})^{-0.872}$
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\ (D_{max}/D_{50})^{-0.887}$
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	**#DIV/0!**

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	**d**	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	**S**	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Sediment Competence Using Dimensional Shear Stress

0	Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope	
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**	
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**	
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope	$d = \dfrac{\tau}{\gamma S}$
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth	$S = \dfrac{\tau}{\gamma d}$

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis | Observers: **KP, AL**

Stream: **Wolverton Creek** | Location: **Wolverton Creek - 1 - 0.64** | Date: **11/19/2010**

Sub-samples	Catch Pan or BUCKET / Tare weight / Sample weights: Total	Net	Sieve SIZE mm / Tare weight / Sample weights: Total	Net	Sieve SIZE mm / Tare weight / Sample weights: Total	Net	Sieve SIZE mm / Tare weight / Sample weights: Total	Net	Sieve SIZE mm / Tare weight / Sample weights: Total	Net	Sieve SIZE mm / Tare weight / Sample weights: Total	Net	Sieve SIZE mm / Tare weight / Sample weights: Total	Net	Sieve SIZE mm / Tare weight / Sample weights: Total	Net	Sieve SIZE mm / Tare weight / Sample weights: Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		0		0		0		0		0		0		0		0		0
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		100%

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	0
Materials less than:	mm

Be sure to add separate material weights to grand total

GRAND TOTAL: 0

Sample location notes	Sample location sketch

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Wolverton Creek**	Stream Type: **B6c**
Location: **Wolverton Creek - 1 - 0.64**	Valley Type: **X**
Observers: **KP, AL**	Date: **11/19/2010**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream:	**Wolverton Creek**	Stream Type:	**B6c**
Location:	**Wolverton Creek - 1 - 0.64**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**11/19/2010**

	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 3-8)**	< 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	> 1.6 **(8)**	**2**
2	**Depositional pattern (Worksheet 3-5)**	B1, B2 **(1)**	B4, B8 **(2)**	B3 **(3)**	B5, B6, B7 **(4)**	**1**
3	**Meander pattern (Worksheet 3-4)**	M1, M3, M4 **(1)**		M2, M5, M6, M7, M8 **(3)**		**1**
4	**Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL **(2)**	M/L, M/M, M/H, L/Ex, H/L **(4)**	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL **(6)**	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex **(8)**	**2**
5	**Degree of confinement (MWR / MWR$_{ref}$) (Worksheet 3-9)**	0.8 – 1.0 **(1)**	0.3 – 0.79 **(2)**	0.1 – 0.29 **(3)**	< 0.1 **(4)**	**1**
					Total points	**7**

	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** ☐

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Wolverton Creek**	Stream Type:	**B6c**
Location:	**Wolverton Creek - 1 - 0.64**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**11/19/2010**

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 3-14)**	Sufficient depth and/or slope to transport largest size available (2)	Trend toward insufficient depth and/or slope-slightly incompetent (4)	Cannot move D_{35} of bed material and/or D_{100} of bar material (6)	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size (8)	**2**
2	**Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load (2)	Trend toward insufficient sediment capacity (4)	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand (6)	Reduction over 25% of annual sediment yield for bedload and/or suspended sand (8)	**2**
3	**W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 (2)	1.2 – 1.4 (4)	1.4 – 1.6 (6)	>1.6 (8)	**2**
4	**Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation (2)	(E→C) (4)	(C→High W/d C), (B→High W/d B), (C→F) (6)	(C→D), (F→D) (8)	**2**
5	**Depositional patterns (Worksheet 3-5)**	B1 (1)	B2, B4 (2)	B3, B5 (3)	B6, B7, B8 (4)	**1**
6	**Debris / blockages (Worksheet 3-6)**	D1, D2, D3 (1)	D4, D7 (2)	D5, D8 (3)	D6, D9, D10 (4)	**3**
					Total points	**12**

Vertical stability for excess deposition / aggradation (use total points and check stability rating)	Vertical stability category point range for excess deposition / aggradation			
	No deposition 10 – 14 ☑	**Moderate deposition 15 – 20** ☐	**Excess deposition 21 – 30** ☐	**Aggradation > 30** ☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream:	**Wolverton Creek**	Stream Type:	**B6c**
Location:	**Wolverton Creek - 1 - 0.64**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**11/19/2010**

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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	**2**
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	**2**
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	**6**
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	**4**
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	**1**
				Total points	**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** ☐

Worksheet 3-20. Channel enlargement prediction summary.

Stream: **Wolverton Creek**			Stream Type:	**B6c**	
Location: **Wolverton Creek - 1 - 0.64**			Valley Type:	**X**	
Observers: **KP, AL**			Date:	**11/19/2010**	
Channel enlargement prediction criteria **(choose one stability category for each criterion 1–4)**	**Channel Enlargement Prediction Categories**				**Selected points (from each row)**
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) **(2)**	(C→High W/d C), (E→C) **(4)**	(G→F), (F→D) **(6)**	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) **(8)**	**2**
2 **Lateral stability (Worksheet 3-17)**	Stable **(2)**	Moderately unstable **(4)**	Unstable **(6)**	Highly unstable **(8)**	**2**
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition **(2)**	Moderate deposition **(4)**	Excess deposition **(6)**	Aggradation **(8)**	**2**
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised **(2)**	Slightly incised **(4)**	Moderately incised **(6)**	Degradation **(8)**	**4**
				Total points	**10**
	Category point range				
Channel enlargement prediction (use total points and check stability rating)	**No increase 8 – 10** ☑	**Slight increase 11 – 16** ☐	**Moderate increase 17 – 24** ☐	**Extensive > 24** ☐	

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream: **Wolverton Creek**		Stream Type:	**B6c**
Location: **Wolverton Creek - 1 - 0.64**		Valley Type:	**X**
Observers: **KP, AL**		Date:	**11/19/2010**

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	Stability Rating	Points	Selected Points
1 Lateral stability (Worksheet 3-17)	Stable	1	1
	Mod. unstable	2	
	Unstable	3	
	Highly unstable	4	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition	1	1
	Mod. deposition	2	
	Excess deposition	3	
	Aggradation	4	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	2
	Slightly incised	2	
	Mod. Incised	3	
	Degradation	4	
4 Channel enlargement prediction (Worksheet 3-20)	No increase	1	1
	Slight increase	2	
	Mod. increase	3	
	Extensive	4	
5 Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	2
	Fair: mod unstable	2	
	Poor: unstable	4	
		Total Points	7

	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 ☐

Worksheet 3-22. Summary of stability condition categories.

Stream:	**Wolverton Creek**	Location:	**Wolverton Creek - 1 - 0.64**
Observers:	**KP, AL**	Date: **11/19/2010**	Stream Type: **B6c** Valley Type: **X**

Channel Dimension									
	Mean bankfull depth (ft):	**2.09**	Mean bankfull width (ft):	**25.43**	Cross-section area (ft^2):	**53.73**	Width of flood-prone area (ft):	**47.5**	Entrenchment ratio: **1.9**

Channel Pattern							
Mean: Range:	MWR:	**12.4**	Lm/W_{bkf}:	**12.4**	Rc/W_{bkf}:	**2.2**	Sinuosity: **1.73**

River Profile and Bed Features

Check: ☐ Riffle/pool ☐ Step/pool ☑ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed

Max bankfull depth (ft):	Riffle	Pool	Depth ratio (max/mean):	Riffle	Pool	Pool to pool spacing:	Ratio	Slope: Valley	Slope: Average bankfull
	3.3			**1.6**					**0.00124**

Level III Stream Stability Indices

Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:

Flow regime:	**P1, 2, 9**	Stream size and order:	**S-4**	Meander pattern(s):	**M1**	Depositional pattern(s):	**NONE**
Debris/channel blockage(s):	**D4, 5**						
Degree of incision (Bank-Height Ratio):	**1.5**	Degree of incision stability rating:	**Moderately Incised**	Modified Pfankuch stability rating (numeric and adjective rating):	**Fair**		
Width/depth ratio (W/d):	**12.2**	Reference W/d ratio (W/d_{ref}):	**12.1**	Width/depth ratio state $(W/d) / (W/d_{ref})$:	**1.0**	W/d ratio state stability rating:	**Stable**
Meander Width Ratio (MWR):	**12.4**	Reference MWR_{ref}:	**11.3**	Degree of confinement (MWR / MWR_{ref}):	**1.1**	MWR / MWR_{ref} stability rating:	**Unconfined**

Bank Erosion Summary

Length of reach studied (ft):	Annual streambank erosion rate: (tons/yr)	Annual streambank erosion rate: (tons/yr/ft)	Curve used:	Remarks:
2165	**50**	**0.02**	**Fig 3-9**	

Sediment Capacity (POWERSED)

☑ Sufficient capacity ☐ Insufficient capacity ☐ Excess capacity — Remarks:

Entrainment/ Competence

Largest particle from bar sample (mm):	$\tau =$	$\tau^* =$	Existing $depth_{bkf}$:	Required $depth_{bkf}$:	Existing $slope_{bkf}$:	Required $slope_{bkf}$:

Successional Stage Shift

→ → → → → — Existing stream state (type): **B6c** — Potential stream state (type): **B6c**

Lateral Stability	☑ Stable	☐ Mod. unstable	☐ Unstable	☐ Highly unstable	Remarks/causes: **None**
Vertical Stability (Aggradation)	☑ No deposition	☐ Mod. deposition	☐ Ex. deposition	☐ Aggradation	Remarks/causes: **None**
Vertical Stability (Degradation)	☐ Not incised	☑ Slightly incised	☐ Mod. incised	☐ Degradation	Remarks/causes: **None**
Channel Enlargement	☑ No increase	☐ Slight increase	☐ Mod. increase	☐ Extensive	Remarks/causes: **None**
Sediment Supply (Channel Source)	☐ Low	☑ Moderate	☐ High	☐ Very high	Remarks/causes: **None**

Worksheet 3-1. Riparian vegetation composition/density used for channel stability assessment.

Riparian Vegetation

Stream: **Wolverton Creek**			Location: **Wovlerton Creek-2-2.02**	
Observers: **KP, AL**	Reference reach [ ]	Disturbed (impacted reach) [**X**]	Date: **9/28/2011**	
Existing species composition:			Potential species composition:	

	Riparian cover categories	Percent aerial cover*	Percent of site coverage**	Species composition	Percent of total species composition
1. Overstory	Canopy layer	**1%**	**<1%**		
					100%
2. Understory	Shrub layer		**13%**		
					100%
3. Ground level	Herbaceous		**15%**		
					100%
	Leaf or needle litter		**2%**	**Remarks:** Condition, vigor and/or usage of existing reach:	
	Bare ground		**70%**		
			Column total = 100%		

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

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Wolverton Creek**	Location: **Wovlerton Creek-2-2.02**							
Observers: **KP, AL**	Date: **9/28/2011**							
List ALL COMBINATIONS that APPLY..............☞	**P1**	**P2**	**P9**					

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
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: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
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.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order			
Stream:	**Wolverton Creek**		
Location:	**Wovlerton Creek-2-2.02**		
Observers:	**KP, AL**		
Date:	**9/28/2011**		
Stream Size Category and Order ☞			**S-4**
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).			

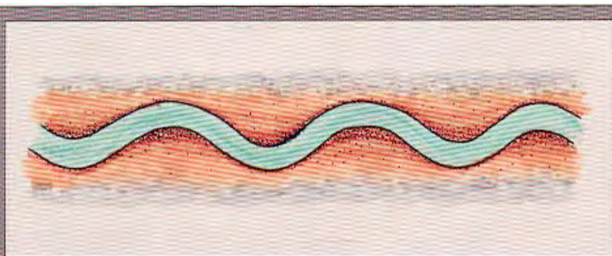
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Wolverton Creek**	Reach:	**Wovlerton Creek-2-2.02**
Observers:	**KP, AL**	Date:	**9/28/2011**

List ALL CATEGORIES that APPLY ☞	M1				

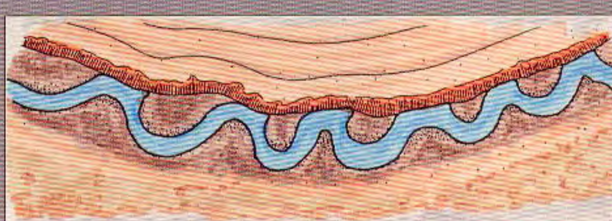
Various Meander Pattern variables modified from Galay et al. (1973)



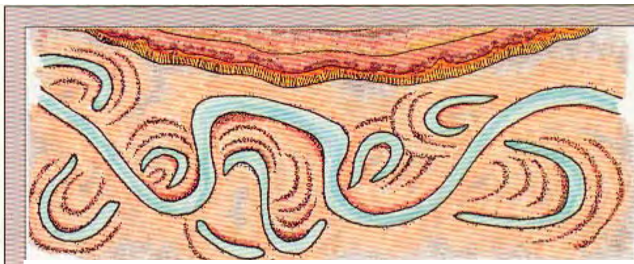
M1 REGULAR MEANDERS

M2 TORTUOUS MEANDERS

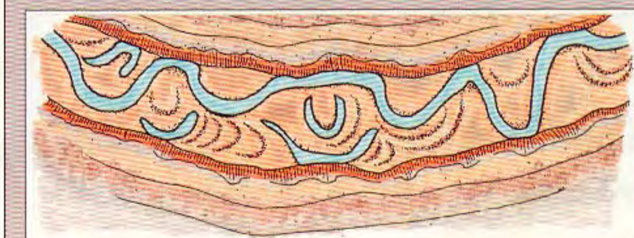
M3 IRREGULAR MEANDERS



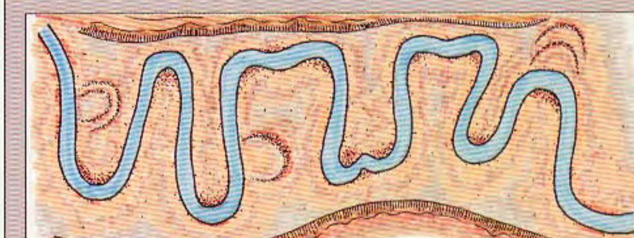
M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS



M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

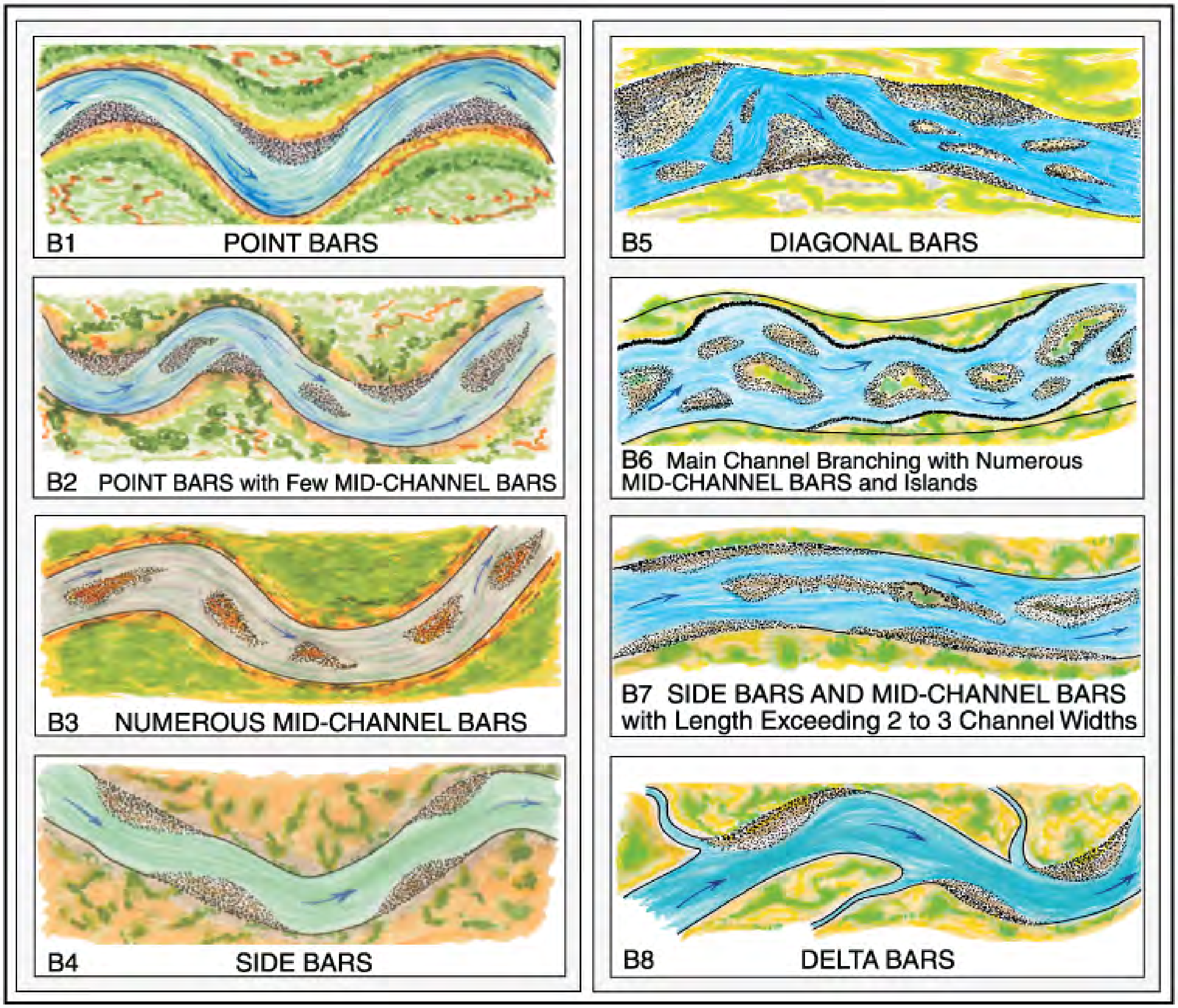
Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns

Stream:	**Wolverton Creek**	Reach:	**Wovlerton Creek-2-2.02**
Observers:	**KP, AL**	Date:	**9/28/2011**

List ALL CATEGORIES that APPLY ☞	**N/A**				

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



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Wolverton Creek**		Location: **Wovlerton Creek-2-2.02**	
Observers: **KP, AL**		Date: **9/28/2011**	
Description/extent		**Materials that 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.	☐

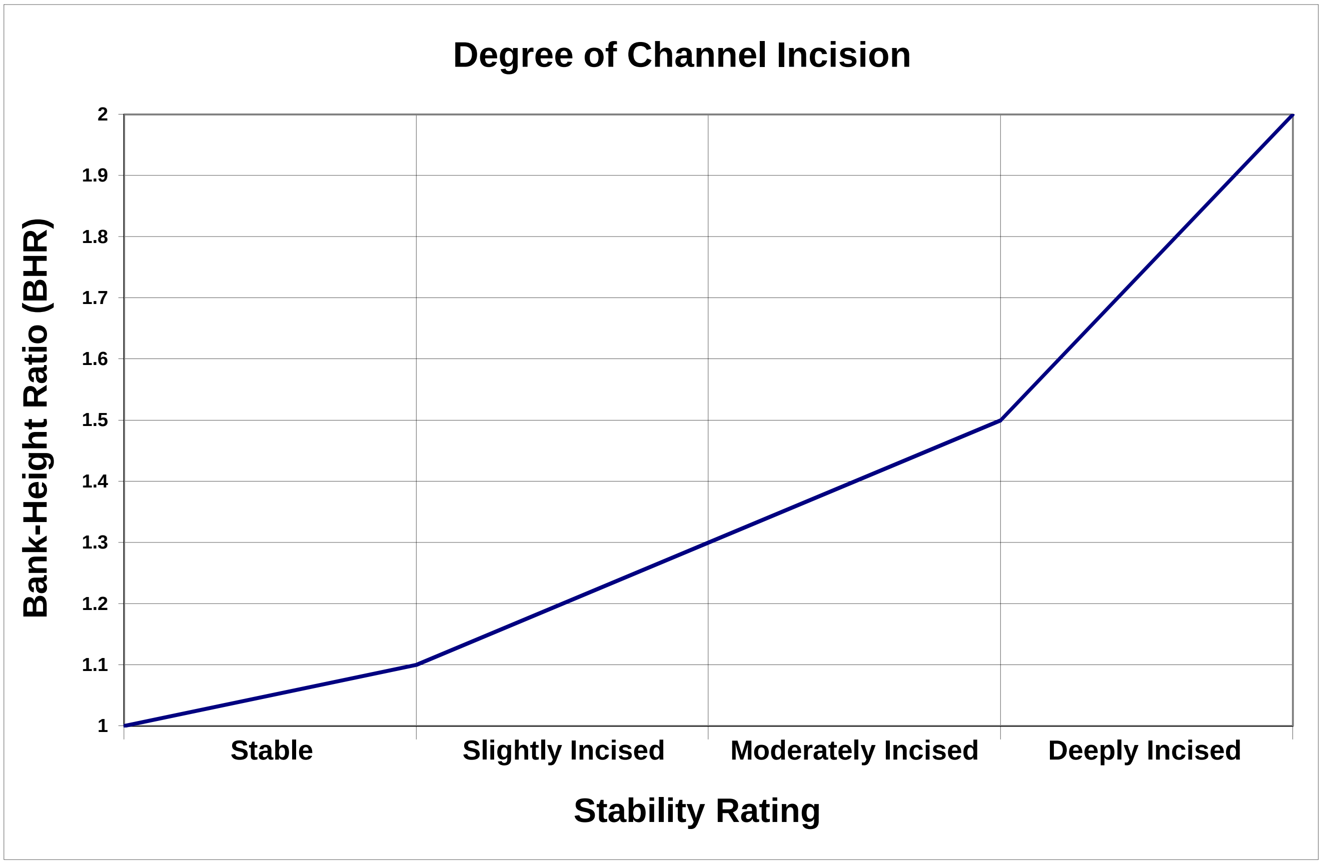
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision

Low Bank Height:	**5.1**
Max Bankfull Depth:	**4.8**

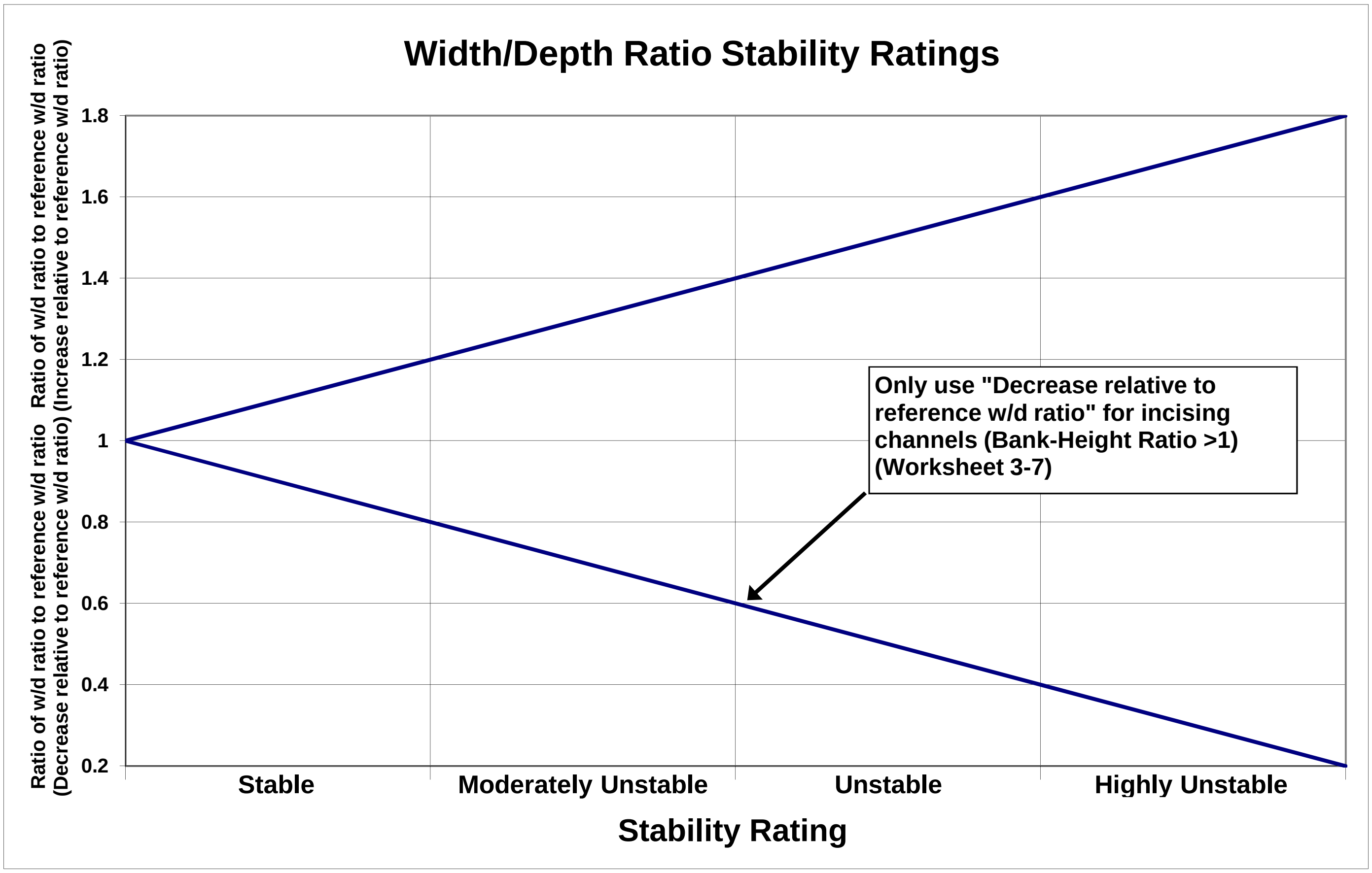
Bank-Height Ratio:	**1.1**

Degree of Channel Incision Stability Rating ☞ **Stable**



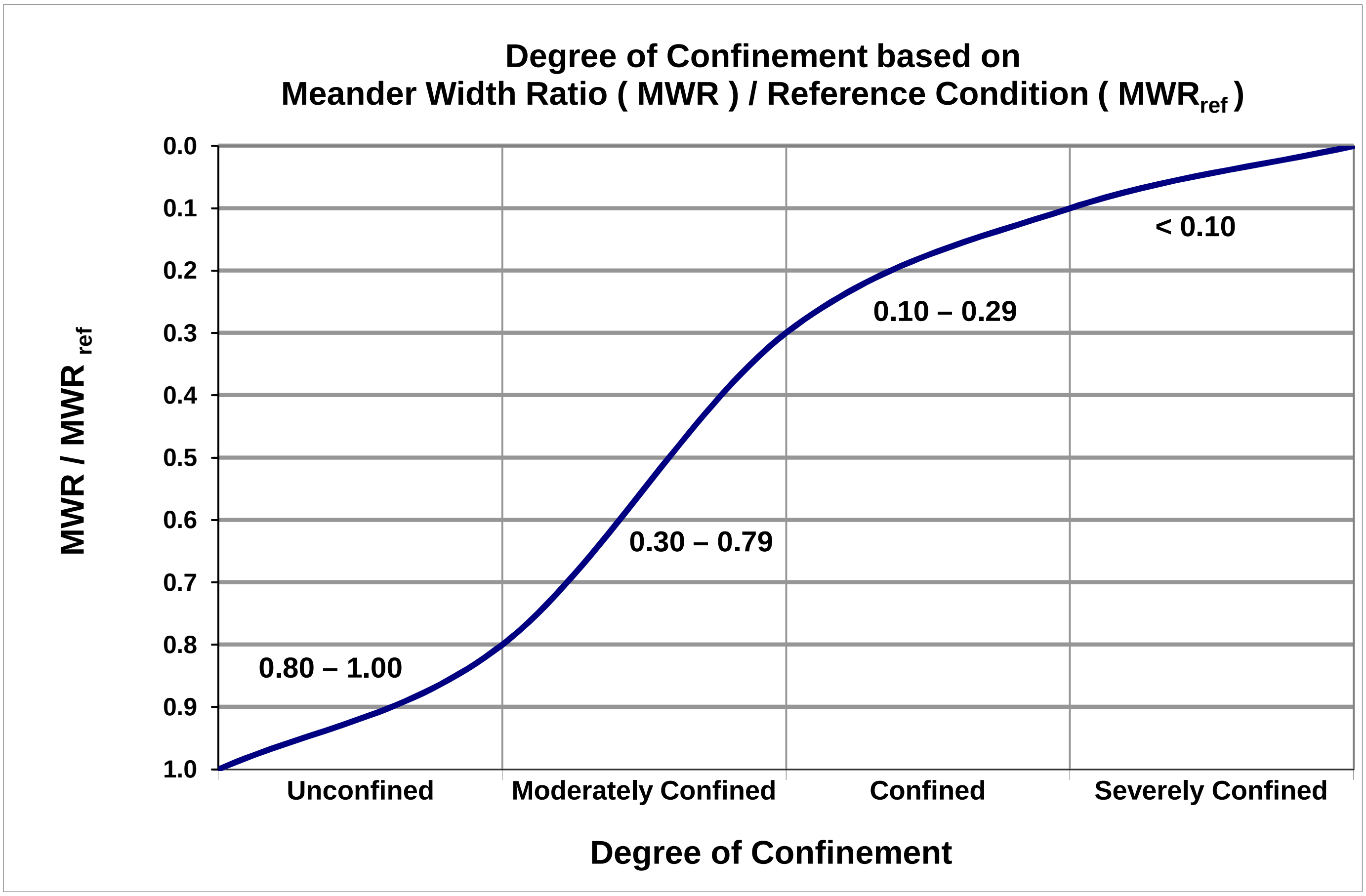
Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State			
Existing Width/Depth Ratio:	7.6	Ratio of existing W/d to reference W/d:	1
Reference Width/Depth Ratio:	7.6		
Width/Depth Ratio State Stability Rating ☞		Stable	



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	25.8	Ratio of MWR to MWR_{ref}:	1
Reference Meander Width Ratio (MWR_{ref}):	25.8		
Degree of Confinement Stability Rating ☞			**Unconfined**



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Wolverton Creek **Location:** Wovlerton Creek-2-2.0 **Valley Type:** X **Observers:** KP, AL **Date:** 9/28/2011

Location	Key	Category	Excellent Description	Excellent Rating	Good Description	Good Rating	Fair Description	Fair Rating	Poor Description	Poor Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	**8**
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	**9**	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	**2**	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	**3**	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	**2**	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	**2**	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	**12**	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	**4**	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	**1**	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	**4**	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	**6**	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	**4**
			Excellent total =	28	Good total =	0	Fair total =	21	Poor total =	12

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	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 (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	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 (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	61
Existing stream type =	E6
*Potential stream type =	E6
Modified channel stability rating =	Good

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream:	**Wolverton Creek**	Location:	**Wovlerton Creek-2-2.02**
Station:		Observers:	**KP, AL**
Date:	**9/28/2011**	Stream Type: **E6**	Valley Type: **X**

Study Bank Height / Bankfull Height (C) — **BEHI Score (Fig. 3-7)**

Study Bank Height (ft) =	**5.2** **(A)**	**Bankfull Height** (ft) =	**4** **(B)**	(A) / (B) =	**1.3** **(C)**	**4**

Root Depth / Study Bank Height (E)

Root Depth (ft) =	**1.5** **(D)**	**Study Bank Height** (ft) =	**5.2** **(A)**	(D) / (A) =	**0.3** **(E)**	**6**

Weighted Root Density (G)

Root Density as **%** =	**25%** **(F)**	(F) x (E) =	**7%** **(G)**	**9**

Bank Angle (H)

Bank Angle as *Degrees* =	**27** **(H)**	**2**

Surface Protection (I)

Surface Protection as **%** =	**20%** **(I)**	**7**

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)

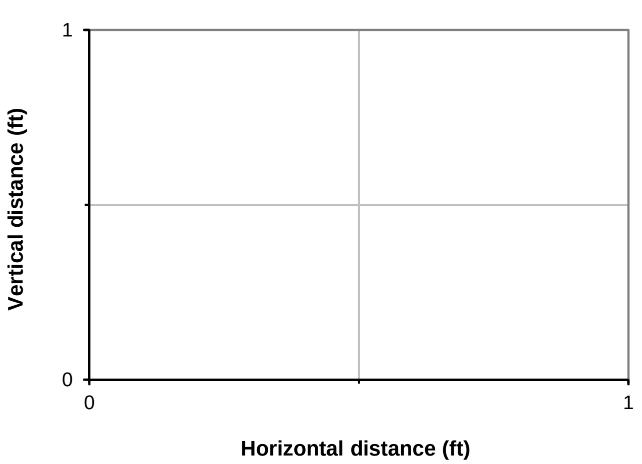
Bank Material Adjustment: **5**

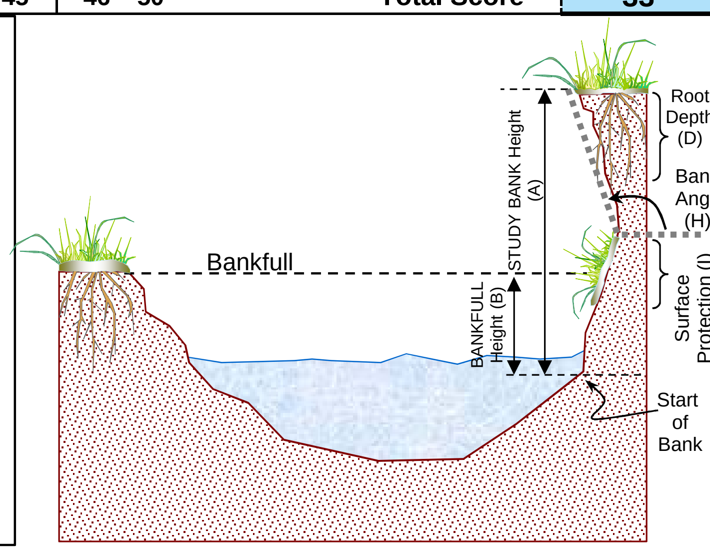
Stratification Adjustment
Add 5–10 points, depending on position of unstable layers in relation to bankfull stage: **0**

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: **High**
and
Total Score: **33**

Bank Sketch





Worksheet 3-12. Various field methods of estimating Near-Bank Stress (NBS) risk ratings to calculate erosion rate.

Estimating Near-Bank Stress (NBS)

Stream: **Wolverton Creek** | Location: **Wovlerton Creek-2-2.02**

Station: **0** | Stream Type: **E6** | Valley Type: **X**

Observers: **KP, AL** | Date: **9/28/11**

Methods for Estimating Near-Bank Stress (NBS)

(1) Channel pattern, transverse bar or split channel/central bar creating NBS..........	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c / W_{bkf})...	Level II	General prediction
(3) Ratio of pool slope to average water surface slope (S_p / S).......................................	Level II	General prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})..	Level II	General prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})......................	Level III	Detailed prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (τ_{nb} / τ_{bkf}).........................	Level III	Detailed prediction
(7) Velocity profiles / Isovels / Velocity gradient..	Level IV	Validation

Level I

(1)
- Transverse and/or central bars-short and/or discontinuous............ ....NBS = High / Very High
- Extensive deposition (continuous, cross-channel)....................................... ....NBS = Extreme
- Chute cutoffs, down-valley meander migration, converging flow.......................................NBS = Extreme

Level II

(2)

Radius of Curvature R_c (ft)	Bankfull Width W_{bkf} (ft)	*Ratio* R_c / W_{bkf}	Near-Bank Stress (NBS)

(3)

Pool Slope S_p	Average Slope S	*Ratio* S_p / S	Near-Bank Stress (NBS)

(4)

Pool Slope S_p	Riffle Slope S_{rif}	*Ratio* S_p / S_{rif}	Near-Bank Stress (NBS)

Dominant Near-Bank Stress
Very Low

Level III

(5)

Near-Bank Max Depth d_{nb} (ft)	Mean Depth d_{bkf} (ft)	*Ratio* d_{nb} / d_{bkf}	Near-Bank Stress (NBS)

(6)

Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)

Level IV

(7)

Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)
	Very Low

Converting Values to a Near-Bank Stress (NBS) Rating

Near-Bank Stress (NBS) ratings	Method number (1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N / A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N / A	2.21 – 3.00	0.20 – 0.40	0.41 – 0.60	1.00 – 1.50	0.80 – 1.05	0.50 – 1.00
Moderate	N / A	2.01 – 2.20	0.41 – 0.60	0.61 – 0.80	1.51 – 1.80	1.06 – 1.14	1.01 – 1.60
High	See	1.81 – 2.00	0.61 – 0.80	0.81 – 1.00	1.81 – 2.50	1.15 – 1.19	1.61 – 2.00
Very High	(1)	1.50 – 1.80	0.81 – 1.00	1.01 – 1.20	2.51 – 3.00	1.20 – 1.60	2.01 – 2.40
Extreme	Above	< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress (NBS) rating | **Very Low**

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**Wolverton Creek**			Location:	**Wovlerton Creek-2-2.02**		
Graph Used:	**Fig 3-9**	Total Bank Length (ft):	**3095.6**			Date:	**9/28/2011**
Observers:	**KP, AL**	Valley Type:	**X**			Stream Type:	**E6**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (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.	**High**	**Very Low**	**0.165**	**3095.6**	**5.2**	**2656**	**0.04**
2.						**0**	**#DIV/0!**
3.						**0**	**#DIV/0!**
4.						**0**	**#DIV/0!**
5.						**0**	**#DIV/0!**
6.						**0**	**#DIV/0!**
7.						**0**	**#DIV/0!**
8.						**0**	**#DIV/0!**
9.						**0**	**#DIV/0!**
10.						**0**	**#DIV/0!**
11.						**0**	**#DIV/0!**
12.						**0**	**#DIV/0!**
13.						**0**	**#DIV/0!**
14.						**0**	**#DIV/0!**
15.						**0**	**#DIV/0!**
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**2656**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**98**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**128**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Total Erosion (tons/yr/ft)**	**0.04**	

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Wolverton Creek**	Stream Type:	**E6**
Location:	**Wovlerton Creek-2-2.02**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**9/28/2011**

Enter Required Information for Existing Condition

	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
0	D_{max}	Largest particle from bar sample (ft)		**(mm)**	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

#DIV/0!	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$
#DIV/0!	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$
#DIV/0!	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	**#DIV/0!**

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	**d**	Required bankfull mean depth (ft)	$d = \dfrac{\tau^* \gamma_s D_{max}}{S}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

#DIV/0!	**S**	Required bankfull water surface slope (ft/ft)	$S = \dfrac{\tau^* \gamma_s D_{max}}{d}$	(use D_{max} in ft)

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Sediment Competence Using Dimensional Shear Stress

0	Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope	
	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**	
	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**	
#DIV/0!	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope	$d = \dfrac{\tau}{\gamma S}$
#DIV/0!	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth	$S = \dfrac{\tau}{\gamma d}$

Worksheet 3-15. Bar sample data collection and sieve analysis form.

Point / Side BAR-BULK MATERIALS SAMPLE DATA: Size Distribution Analysis	Observers: **KP, AL**	
Stream: **Wolverton Creek**	Location: **Wovlerton Creek-2-2.02**	Date: **9/28/2011**

Sub-samples	Catch Pan or BUCKET		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm		Sieve SIZE mm	
	Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight		Tare weight	
	Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights		Sample weights	
	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net	Total	Net
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
Net wt. total		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**
% Grand total		#####		#####		#####		#####		#####		#####		#####		#####		#####
Accum. % =<		#####		#####		#####		#####		#####		#####		#####		#####		**100%**

SURFACE MATERIALS DATA
(Two largest particles)

No.	Dia.	WT.
1		
2		

Bucket + materials weight	
Bucket tare weight	
Materials weight	**0**
Materials less than:	mm

Be sure to add separate material weights to grand total

0

GRAND TOTAL

Sample location notes		Sample location sketch	

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Wolverton Creek**	Stream Type: **E6**
Location: **Wovlerton Creek-2-2.02**	Valley Type: **X**
Observers: **KP, AL**	Date: **9/28/2011**
Stream type changes due to successional stage shifts (Figure 3-14)	**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), (C→High W/d C)	☐ Moderately unstable
(G→F), (F→D), (C→F)	☐ Unstable
(C→D), (B→G), (D→G), (C→G), (E→G)	☐ Highly unstable

Worksheet 3-17. Lateral stability prediction summary.

Stream:	**Wolverton Creek**	Stream Type:	**E6**
Location:	**Wovlerton Creek-2-2.02**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**9/28/2011**

	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 3-8)**	< 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	> 1.6 **(8)**	**2**
2	**Depositional pattern (Worksheet 3-5)**	B1, B2 **(1)**	B4, B8 **(2)**	B3 **(3)**	B5, B6, B7 **(4)**	**1**
3	**Meander pattern (Worksheet 3-4)**	M1, M3, M4 **(1)**		M2, M5, M6, M7, M8 **(3)**		**1**
4	**Dominant BEHI / NBS (Worksheet 3-13)**	L/VL, L/L, L/M, L/H, L/VH, M/VL **(2)**	M/L, M/M, M/H, L/Ex, H/L **(4)**	M/VH, M/Ex, H/L, H/M, H/H, VH/VL, Ex/VL **(6)**	H/H, H/Ex, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex **(8)**	**4**
5	**Degree of confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.8 – 1.0 **(1)**	0.3 – 0.79 **(2)**	0.1 – 0.29 **(3)**	< 0.1 **(4)**	**1**
					Total points	**9**

Overall lateral stability category (use total points and check stability rating)	**Lateral stability category point range**			
	Stable 7 – 9 ☑	**Moderately unstable 10 – 12** ☐	**Unstable 13 – 21** ☐	**Highly unstable > 21** ☐

Worksheet 3-18. Vertical stability prediction for excess deposition or aggradation.

Stream:	**Wolverton Creek**		Stream Type:	**E6**		
Location:	**Wovlerton Creek-2-2.02**		Valley Type:	**X**		
Observers:	**KP, AL**		Date:	**9/28/2011**		

Vertical stability criteria (choose one stability category for each criterion 1–6)	**Vertical Stability Categories for Excess Deposition / Aggradation:** No deposition	Moderate deposition	Excess deposition	Aggradation	**Selected points (from each row)**
1 **Sediment competence (Worksheet 3-14)**	Sufficient depth and/or slope to transport largest size available **(2)**	Trend toward insufficient depth and/or slope-slightly incompetent **(4)**	Cannot move D_{35} of bed material and/or D_{100} of bar material **(6)**	Cannot move D_{16} of bed material and/or D_{100} of bar or sub-pavement size **(8)**	**2**
2 **Sediment capacity (POWERSED)**	Sufficient capacity to transport annual load **(2)**	Trend toward insufficient sediment capacity **(4)**	Reduction up to 25% of annual sediment yield of bedload and/or suspended sand **(6)**	Reduction over 25% of annual sediment yield for bedload and/or suspended sand **(8)**	**2**
3 **W/d ratio state (Worksheet 3-8)**	1.0 – 1.2 **(2)**	1.2 – 1.4 **(4)**	1.4 – 1.6 **(6)**	>1.6 **(8)**	**2**
4 **Stream succession states (Worksheet 3-16)**	Current stream type at potential or does not indicate deposition/ aggradation **(2)**	(E→C) **(4)**	(C→High W/d C), (B→High W/d B), (C→F) **(6)**	(C→D), (F→D) **(8)**	**2**
5 **Depositional patterns (Worksheet 3-5)**	B1 **(1)**	B2, B4 **(2)**	B3, B5 **(3)**	B6, B7, B8 **(4)**	**1**
6 **Debris / blockages (Worksheet 3-6)**	D1, D2, D3 **(1)**	D4, D7 **(2)**	D5, D8 **(3)**	D6, D9, D10 **(4)**	**1**
				Total points	**10**

Vertical stability for excess deposition / aggradation (use total points and check stability rating)	**Vertical stability category point range for excess deposition / aggradation:** No deposition 10 – 14 ☑	Moderate deposition 15 – 20 ☐	Excess deposition 21 – 30 ☐	Aggradation > 30 ☐

Worksheet 3-19. Vertical stability prediction for channel incision or degradation.

Stream:	**Wolverton Creek**	Stream Type:	**E6**
Location:	**Wovlerton Creek-2-2.02**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**9/28/2011**

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 3-14)**	Does not indicate excess competence (2)	Trend to move larger sizes than D_{100} of bar or > D_{84} of bed (4)	D_{100} of bed moved (6)	Particles much larger than D_{100} of bed moved (8)	2
2 **Sediment capacity (POWERSED)**	Does not indicate excess capacity (2)	Slight excess energy: up to 10% increase above reference (4)	Excess energy sufficient to increase load up to 50% of annual load (6)	Excess energy transporting more than 50% of annual load (8)	2
3 **Degree of channel incision (BHR) (Worksheet 3-7)**	1.00 – 1.10 (2)	1.11 – 1.30 (4)	1.31 – 1.50 (6)	> 1.50 (8)	2
4 **Stream succession states (Worksheets 3-16 and 3-7)**	Does not indicate incision or degradation (2)	If BHR > 1.1 and stream type has w/d between 5–10 (4)	If BHR > 1.1 and stream type has w/d less than 5 (6)	(B→G), (C→G), (E→G), (D→G) (8)	2
5 **Confinement (MWR / MWR_{ref}) (Worksheet 3-9)**	0.80 – 1.00 (1)	0.30 – 0.79 (2)	0.10 – 0.29 (3)	< 0.10 (4)	1
				Total points	**9**

	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** ☐

Worksheet 3-20. Channel enlargement prediction summary.

Stream: **Wolverton Creek**				Stream Type: **E6**	
Location: **Wovlerton Creek-2-2.02**				Valley Type: **X**	
Observers: **KP, AL**				Date: **9/28/2011**	
Channel enlargement prediction criteria (choose one stability category for each criterion 1–4)	**Channel Enlargement Prediction Categories**				**Selected points (from each row)**
	No increase	**Slight increase**	**Moderate increase**	**Extensive**	
1 **Successional stage shift (Worksheet 3-16)**	Stream type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C) **(2)**	(C→High W/d C), (E→C) **(4)**	(G→F), (F→D) **(6)**	(C→D), (B→G), (D→G), (C→G), (E→G), (C→F) **(8)**	**2**
2 **Lateral stability (Worksheet 3-17)**	Stable **(2)**	Moderately unstable **(4)**	Unstable **(6)**	Highly unstable **(8)**	**2**
3 **Vertical stability excess deposition/ aggradation (Worksheet 3-18)**	No deposition **(2)**	Moderate deposition **(4)**	Excess deposition **(6)**	Aggradation **(8)**	**2**
4 **Vertical stability incision/ degradation (Worksheet 3-19)**	Not incised **(2)**	Slightly incised **(4)**	Moderately incised **(6)**	Degradation **(8)**	**2**
				Total points	**8**
	Category point range				
Channel enlargement prediction (use total points and check stability rating)	**No increase 8 – 10** ☑	**Slight increase 11 – 16** ☐	**Moderate increase 17 – 24** ☐	**Extensive > 24** ☐	

Worksheet 3-21. Overall sediment supply rating determined from individual stability rating categories.

Stream:	**Wolverton Creek**	Stream Type:	**E6**
Location:	**Wovlerton Creek-2-2.02**	Valley Type:	**X**
Observers:	**KP, AL**	Date:	**9/28/2011**

Overall sediment supply prediction criteria (choose corresponding points for each criterion 1–5)	Stability Rating	Points	Selected Points
1 Lateral stability (Worksheet 3-17)	Stable	1	1
	Mod. unstable	2	
	Unstable	3	
	Highly unstable	4	
2 Vertical stability excess deposition/ aggradation (Worksheet 3-18)	No deposition	1	1
	Mod. deposition	2	
	Excess deposition	3	
	Aggradation	4	
3 Vertical stability channel incision/ degradation (Worksheet 3-19)	Not incised	1	1
	Slightly incised	2	
	Mod. Incised	3	
	Degradation	4	
4 Channel enlargement prediction (Worksheet 3-20)	No increase	1	1
	Slight increase	2	
	Mod. increase	3	
	Extensive	4	
5 Pfankuch channel stability (Worksheet 3-10)	Good: stable	1	1
	Fair: mod unstable	2	
	Poor: unstable	4	
		Total Points	5

	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 ☐

Worksheet 3-22. Summary of stability condition categories.

Stream: **Wolverton Creek**		Location: **Wovlerton Creek-2-2.02**	
Observers: **KP, AL**	Date: **9/28/2011**	Stream Type: **E6**	Valley Type: **X**

Channel Dimension	Mean bankfull depth (ft): **3.17**	Mean bankfull width (ft): **24.21**	Cross-section area (ft^2): **73.13**	Width of flood-prone area (ft): **129**	Entrenchment ratio: **5.3**
Channel Pattern	Mean: Range:	MWR: **25.8**	Lm/W_{bkf}: **25.8**	Rc/W_{bkf}: **7.1**	Sinuosity: **1.26**

River Profile and Bed Features

Check: ☐ Riffle/pool ☐ Step/pool ☐ Plane bed ☐ Convergence/divergence ☑ Dunes/antidunes/smooth bed

Max bankfull depth (ft): Riffle	Max bankfull depth (ft): Pool	Depth ratio (max/mean): Riffle	Depth ratio (max/mean): Pool	Pool to pool spacing:	Ratio	Slope: Valley	Slope: Average bankfull
4.8		**1.5**					**0.0011**

Level III Stream Stability Indices

Riparian vegetation	Current composition/density:	Potential composition/density:	Remarks: Condition, vigor and/or usage of existing reach:
	0	**0**	**0**

Flow regime:	**P1, 2, 9**	Stream size and order:	**S-4**	Meander pattern(s):	**M1**	Depositional pattern(s):	**NONE**	Debris/channel blockage(s):	**D1**
Degree of incision (Bank-Height Ratio):	**1.1**	Degree of incision stability rating:	**Stable**	Modified Pfankuch stability rating (numeric and adjective rating):	**Good**				
Width/depth ratio (W/d):	**7.6**	Reference W/d ratio (W/d_{ref}):	**7.6**	Width/depth ratio state $(W/d) / (W/d_{ref})$:	**1.0**	W/d ratio state stability rating:	**Stable**		
Meander Width Ratio (MWR):	**25.8**	Reference MWR_{ref}:	**25.8**	Degree of confinement (MWR / MWR_{ref}):	**1.0**	MWR / MWR_{ref} stability rating:	**Unconfined**		

Bank Erosion Summary	Length of reach studied (ft): **3096**	Annual streambank erosion rate: **128** (tons/yr)	**0.04** (tons/yr/ft)	Curve used: **Fig 3-9**	Remarks:
Sediment Capacity (POWERSED)	☑ Sufficient capacity	☐ Insufficient capacity	☐ Excess capacity	Remarks:	

Entrainment/ Competence	Largest particle from bar sample (mm):	$\tau =$	$\tau^* =$	Existing $depth_{bkf}$:	Required $depth_{bkf}$:	Existing $slope_{bkf}$:	Required $slope_{bkf}$:

Successional Stage Shift	→ → → → →	Existing stream state (type): **E6**	Potential stream state (type): **E6**

Lateral Stability	☑ Stable	☐ Mod. unstable	☐ Unstable	☐ Highly unstable	Remarks/causes:
Vertical Stability (Aggradation)	☑ No deposition	☐ Mod. deposition	☐ Ex. deposition	☐ Aggradation	Remarks/causes:
Vertical Stability (Degradation)	☑ Not incised	☐ Slightly incised	☐ Mod. incised	☐ Degradation	Remarks/causes:
Channel Enlargement	☑ No increase	☐ Slight increase	☐ Mod. increase	☐ Extensive	Remarks/causes:
Sediment Supply (Channel Source)	☑ Low	☐ Moderate	☐ High	☐ Very high	Remarks/causes: