Maryland Trust Fund Geomorphic Monitoring

Stream Habitat Assessment and Restoration Program
Chesapeake Bay Field Office
U.S. Fish and Wildlife Service

Richard Starr

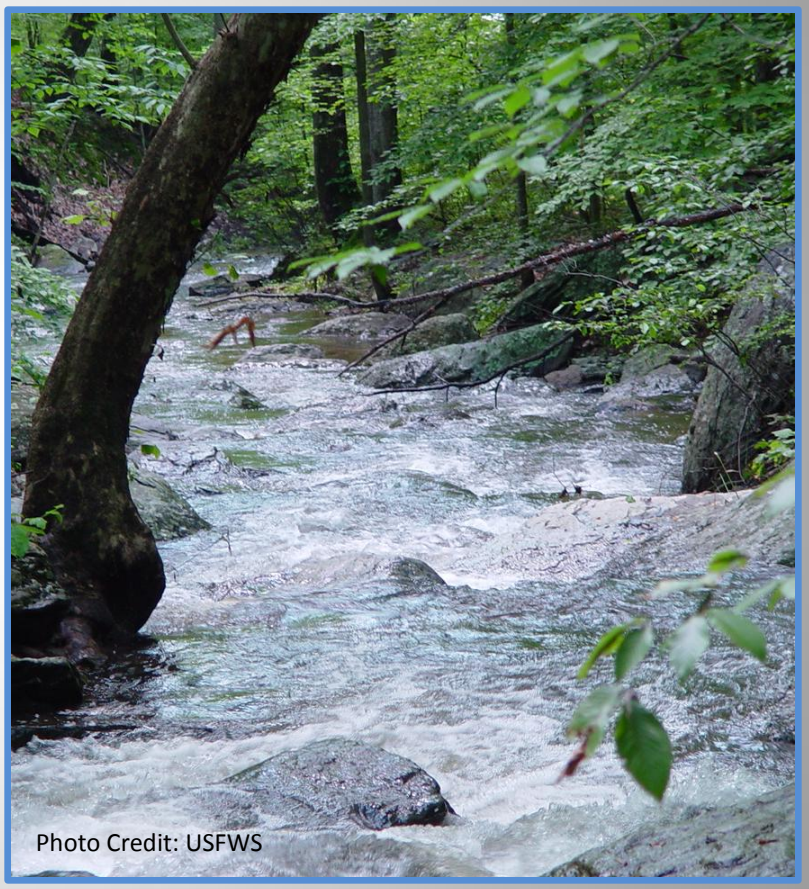


Photo Credit: USFWS

Maryland Trust Fund Geomorphic Monitoring

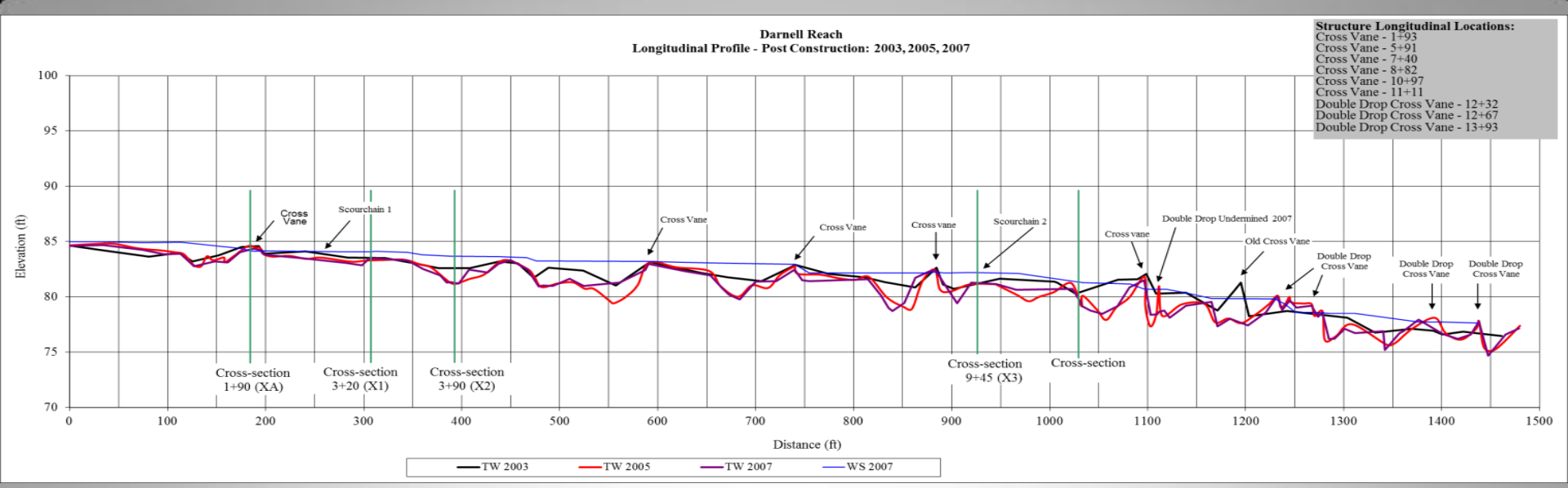
Collection Methods

- Cross Sections
- Longitudinal Profile
- Toe Pin and Bank Profile
- ***B***ank ***A***ssessment for ***N***on-point source ***C***onsequences of ***S***ediment (BANCS)
- Meander Width Ratio (MWR)

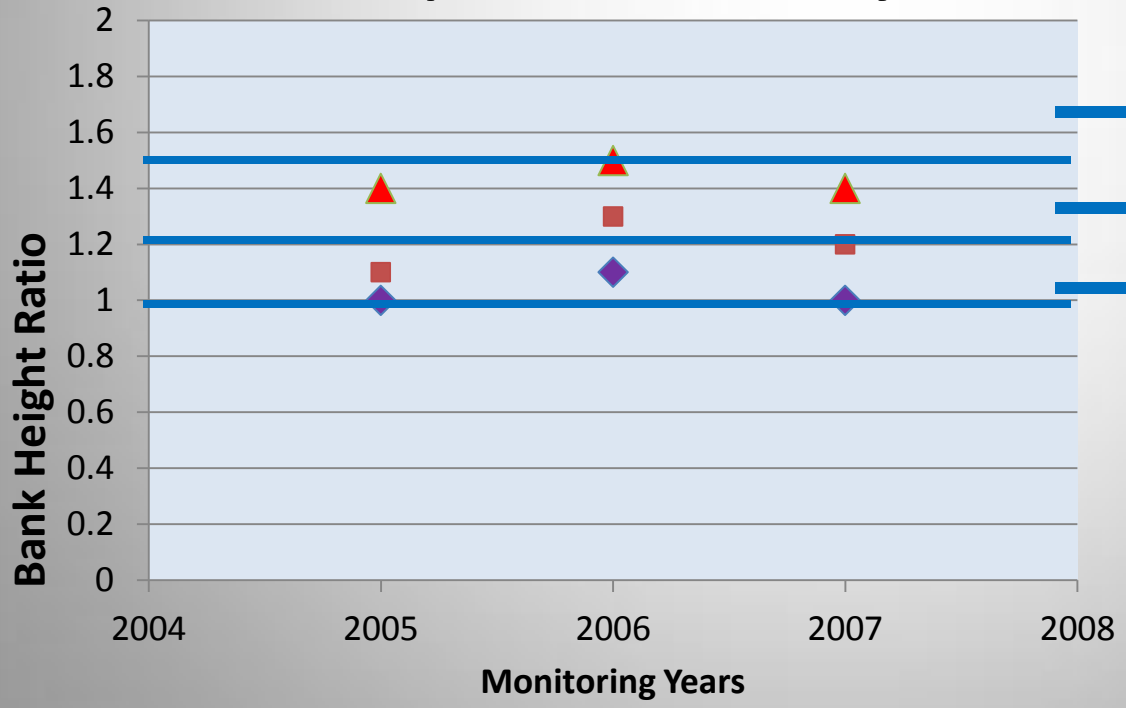
Geomorphic Functions Assessed

- **Lateral Stability**
  - ***B***ank ***A***ssessment for ***N***on-point source ***C***onsequences of ***S***ediment (BANCS)
  - Meander Width Ratio (MWR)
  - Toe Pin and Bank Profile Survey
- **Floodplain Connectivity**
  - Entrenchment Ratio (ER)
  - Bank Height Ratio (BHR)
- **Riparian Vegetation**
  - **TBD**
- **Bedform Diversity/Sediment Transport**
  - Pool Depth Variability
  - Pool-to-Pool Spacing

Level and Category	Parameter	Measurement Method	Pre-Restoration Condition		Post-Restoration Condition	
			Value	Rating	Value	Rating
1 - Hydrology	Channel-Forming Discharge	Regional Curves	N/A	N/A	N/A	N/A Used as an input parameter for Level 2 and 3
2- Hydraulics	Floodplain Connectivity	Bank Height Ratio	1.5	Not Functioning	1.0	Functioning
		Entrenchment Ratio	1.73	Not Functioning	>2.2	Functioning
		HEC-RAS	n/a			
3 – Geomorphology	Bed Form diversity	Pool-to-pool spacing	1.5 to 9	Not Functioning	4 to 5	Functioning
		Pool Depth Variability	2.0 to 3.0	Functioning	2.0 to 3.0	Functioning
		Riffle Length to Riffle Width	2.9 to 4.3	Functioning	3 to 5	Functioning
		Riffle Slope to Reach Slope	1.2 to 3.9	FAR	1 to 2	Functioning
		Pool Slope to Reach Slope	0.3 to 0.6	FAR	0.2 to 0.3	Functioning
		Rosgen	F → C →E	FAR	E	Functioning
	Channel Evolution	PFC	Not Functional	Not Functioning	Functional	Functioning
	Riparian Vegetation	Buffer Width based on Beltwidth	0	Not Functioning	300	Functioning
		BEHI/NBS	Mod / Low	FAR	Low/Low	Functioning
	Lateral Stability	Lateral Erosion Rate	0.09 yr/ft	Functioning	<0.01	
		Confinement	0.69 to 1.14	Functioning	>1.0	Functioning
		MWR	2.4 to 4.0	Functioning	>3.5	Functioning
		W/D_{proj} /W/D_{ref}	1.4	FAR	1.0 to 1.2	Functioning
		Wavelength to Riffle Width	9 to 14	Functioning	7 to 14	Functioning



Floodplain Connectivity



Not Functioning

Functioning - At-Risk

Functioning

Baker, 2008

Bank Assessment for Non-point source Consequences of Sediment (BANCS)


Photo Credit: USFWS


Photo Credit: USFWS

Stream Habitat Assessment and Restoration Program
Chesapeake Bay Field Office
U.S. Fish and Wildlife Service

Sandy Davis
Rich Starr

Bank Assessment for Non-point source Consequences of Sediment (BANCS)

- Model to predict streambank erosion rates
- Methods based on Rosgen (2006)

  Rosgen, D.L. 2006. Watershed Assessment of River Stability & Sediment Supply (WARSSS). Wildland Hydrology. Pagosa Springs, CO.

- Two measurements
  - Bank Erosion Hazard Index (BEHI)
  - Near Bank Stress (NBS)
- Erosion rates estimated using bank erodibility curves

Stream: Location:

Station: Observers:

Date: Stream Type: Valley Type:

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	(A)	Bankfull Height (ft) =	(B)	(A) / (B) =	(C)

Root Depth / Study Bank Height (E)

Root Depth (ft) =	(D)	Study Bank Height (ft) =	(A)	(D) / (A) =	(E)

Weighted Root Density (G)

Root Density as % =	(F)	(F) x (E) =	(G)

Bank Angle (H)

Bank Angle as *Degrees* =	(H)

Surface Protection (I)

Surface Protection as % =	(I)

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)

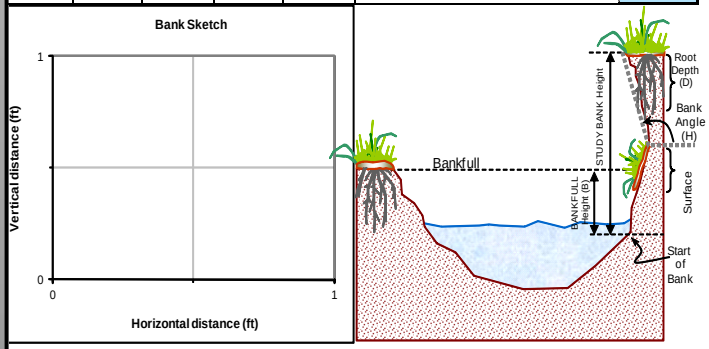
Bank Material Adjustment

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

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

Bank Sketch



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 w idth (R_c / W_{bkf})	Level II	General prediction
(3)	Ratio of pool slope to average w ater 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

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)

Rosgen, 2006

Rosgen, 2006

BEHI

- Evaluates erodibility potential
- Several Bank Characteristics
  - Top of Bank
  - Bankfull Height
  - Rooting Depth
  - Root Density
  - Bank Angle
  - Percent Bank Protection
  - Bank Composition
  - Bank Material Stratification

BEHI

Bank Erosion Hazard Rating Guide

Stream _____ Reach _____ Date _____ Crew _____

Bank Erosion Potential		Bank Height/ Bankfull Ht	Root Depth/ Bank Height	Root Density %	Bank Angle (Degrees)	Surface Protection%
		Bank Height (ft): / Bankfull Height (ft):				
VERY LOW	Value	1.0-1.1	1.0-0.9	100-80	0-20	100-80
	Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
LOW	Value	1.11-1.19	0.89-0.5	79-55	21-60	79-55
	Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
MODERATE	Value	1.2-1.5	0.49-0.3	54-30	61-80	54-30
	Index	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
HIGH	Value	1.6-2.0	0.29-0.15	29-15	81-90	29-15
	Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
VERY HIGH	Value	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10
	Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
EXTREME	Value	>2.8	<0.05	<5	>119	<10
	Index	10	10	10	10	10
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
V = value, I = index			**SUB-TOTAL** (Sum one index from each column)			**Rosgen, 1996**

Bank

Selecting Stream Banks for Evaluation

- Assess all stream banks prone to erosion
- Partition study banks based on BEHI/NBS conditions
- Select representative or typical bank condition for prediction
- Avoid evaluating upstream or downstream influences
- Note study bank location on map, site sketch or aerial photo with mylar overlay


Photo Credit: USFWS

BEHI

Measure Bank Height (A)

Select a Representative or Typical Bank Condition for Prediction

Measure Bankfull Height (B)

Measure Root Depth (C)

Measure Root Density (D)

A/B

C/A

D*(C/A)

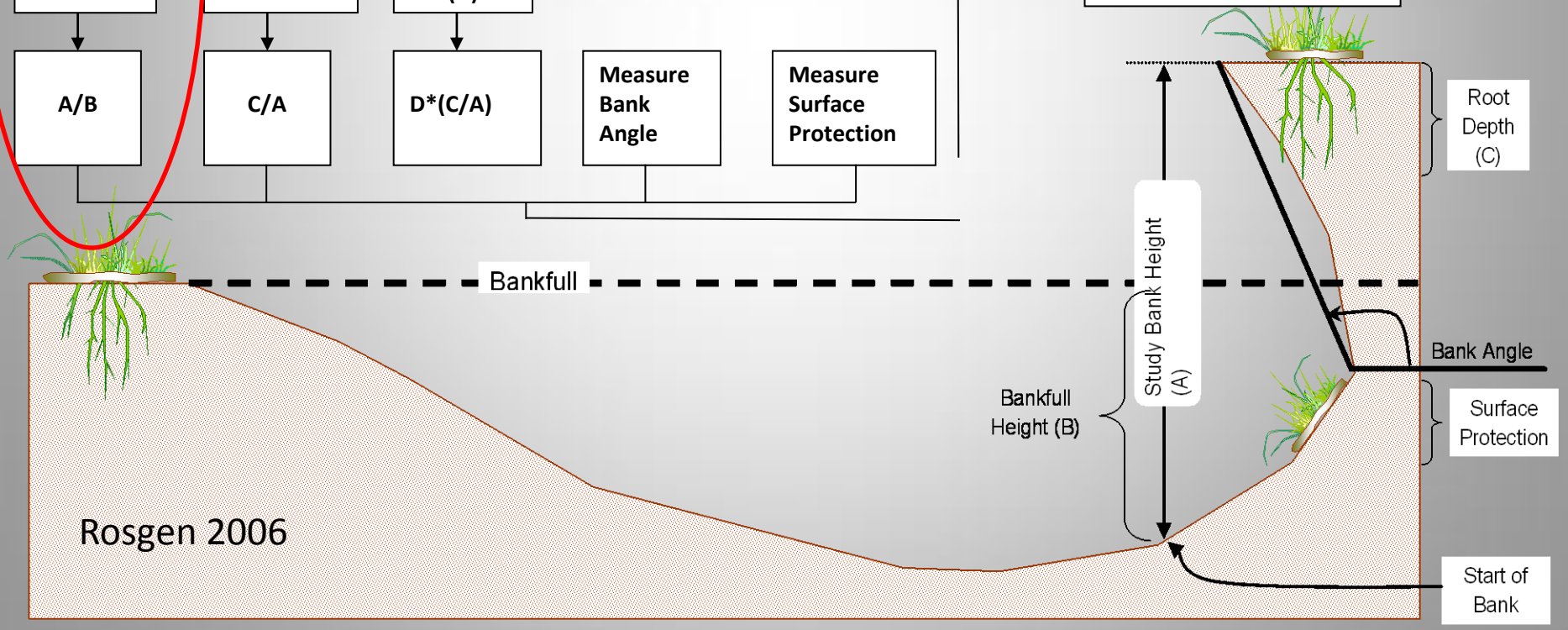
Measure Bank Angle

Measure Surface Protection

Adjust Index for Bank Materials

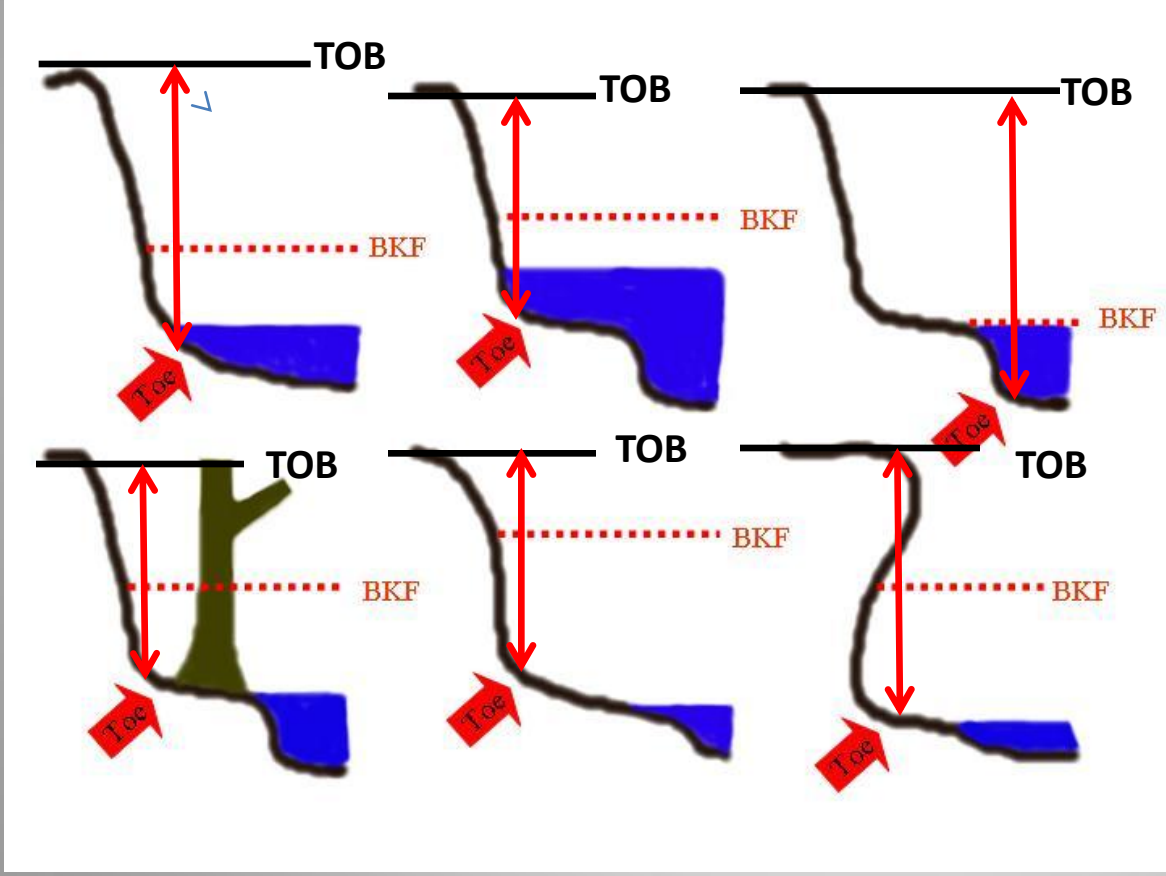
Adjust Index for Stratification

Obtain a Total Score



Rosgen 2006

Study Bank Height/Bankfull Height Ratio (Study Bank Height Ratio)



- Study bank height is measured from bank toe to bank top
- Bankfull height is measured from bank toe to bankfull stage
- The higher the study bank ratio is above 1.0, the higher the erosion risk

BEHI

Measure Bank Height (A)

Select a Representative or Typical Bank Condition for Prediction

Measure Bankfull Height (B)

Measure Root Depth (C)

Measure Root Density (D)

A/B

C/A

D*(C/A)

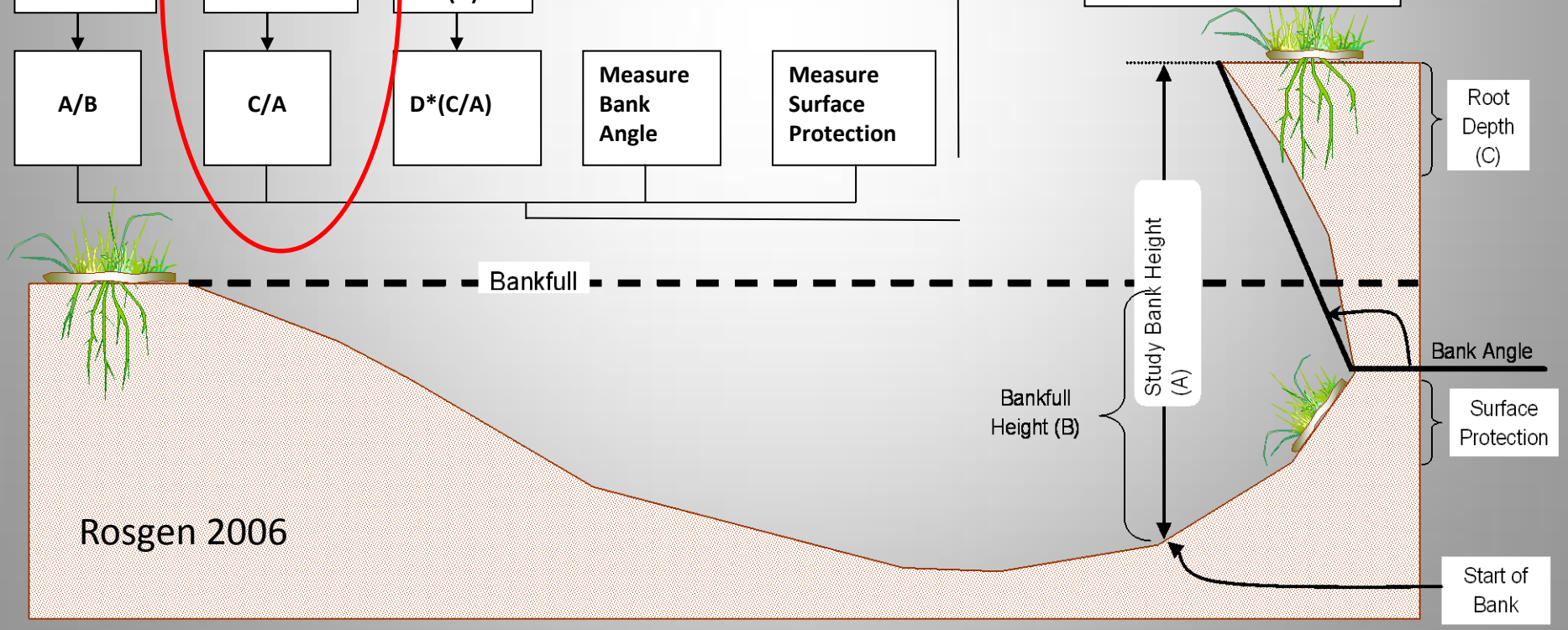
Measure Bank Angle

Measure Surface Protection

Adjust Index for Bank Materials

Adjust Index for Stratification

Obtain a Total Score

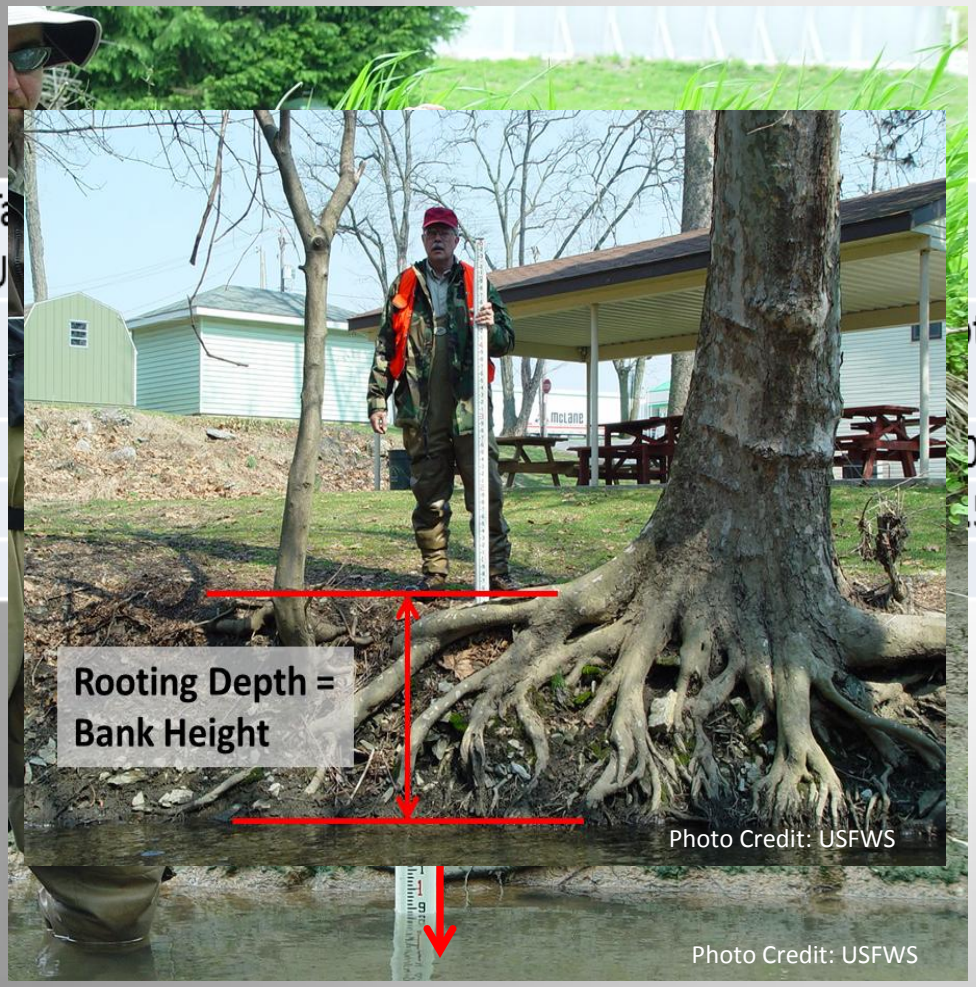


Rosgen 2006

Root Depth/Study Bank Height Ratio (Root Depth Ratio)

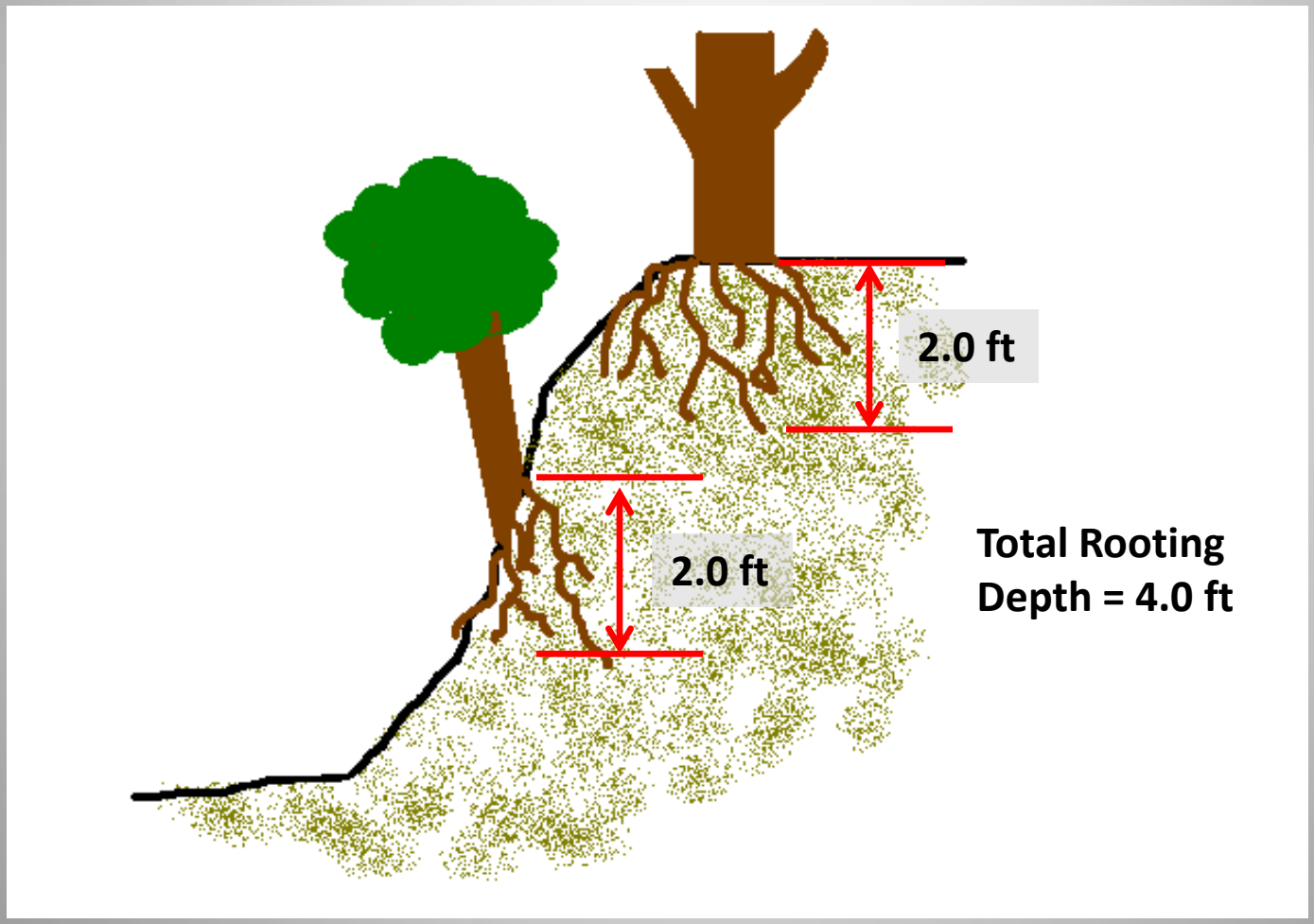
- Measure of rooting depth in relation to top of bank height (Root Depth Ratio)
- The greater the ratio the lower the risk of erosion
- Highly variable and depends on
  - Vegetation Type
  - Soil conditions
- Familiarity with annual and perennial growth and seasonal condition change is essential

Determining Root Depth



- **Where upper bank is accessible, clear soil to expose roots and assess root depth**
- **If upper bank is not accessible look for areas with exposed roots**
- **Consider soil conditions**
  - Duripans and fragipans retard rooting depths
  - Hemic soils promote rooting depth
- **Where trees/tree roots extend down the bank the extent of the roots is the rooting depth**

Combining Rooting Depths



BEHI

Measure Bank Height (A)

Select a Representative or Typical Bank Condition for Prediction

Measure Bankfull Height (B)

Measure Root Depth (C)

Measure Root Density (D)

A/B

C/A

D*(C/A)

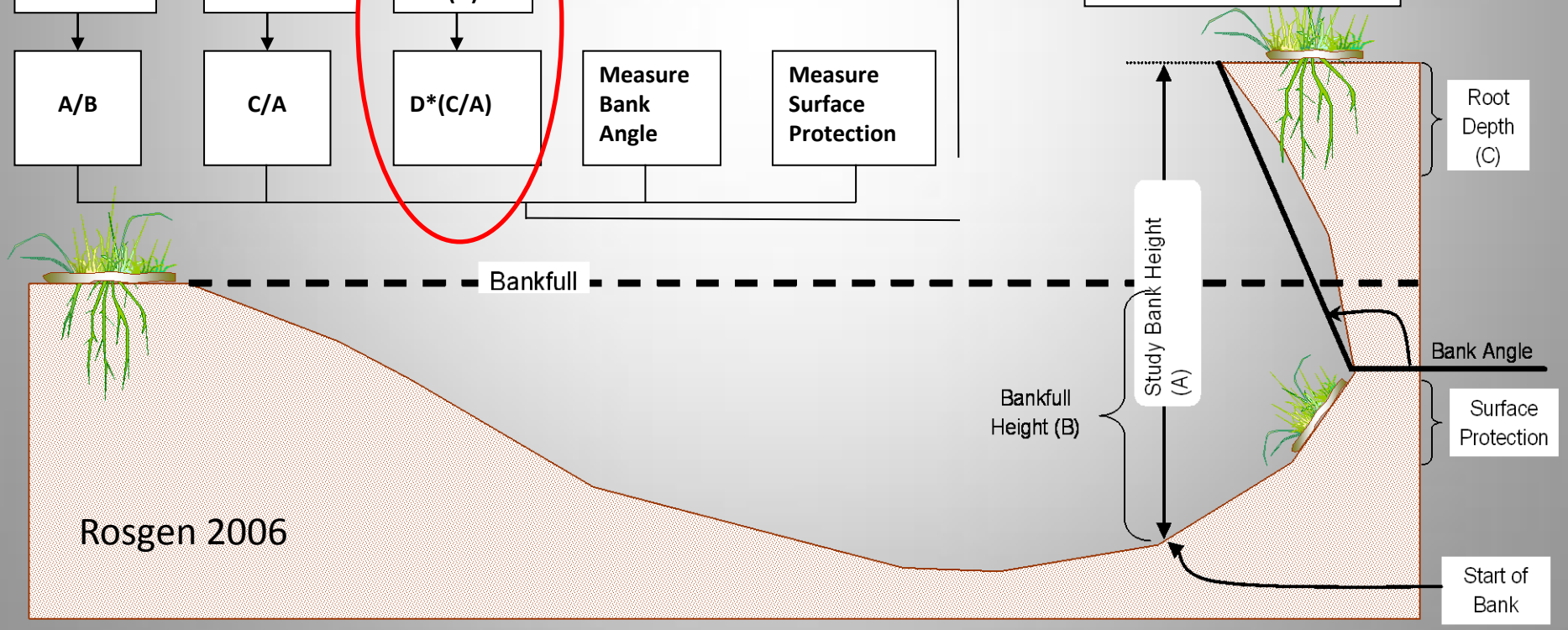
Measure Bank Angle

Measure Surface Protection

Adjust Index for Bank Materials

Adjust Index for Stratification

Obtain a Total Score

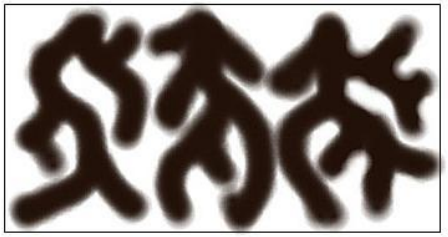


Rosgen 2006

Weighted Root Density

- Determine density of root mass within the rooting depth
- Visual assessment
- Percent of the soil composed of roots
- Multiply by the Root Depth Ratio for BEHI Rating
- Greater the weighted density of roots the lower the risk of erosion

Determining Root Density

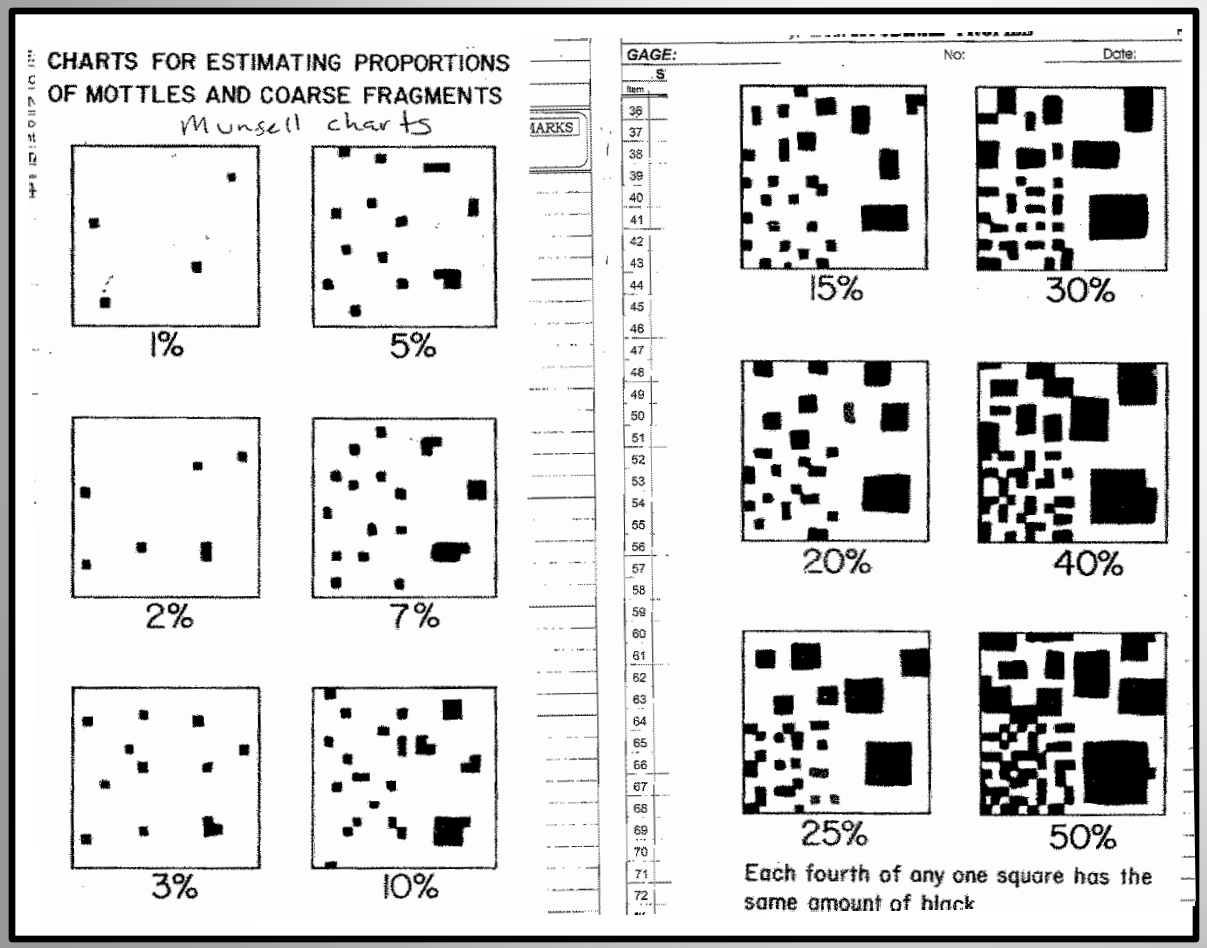


75% Root Density

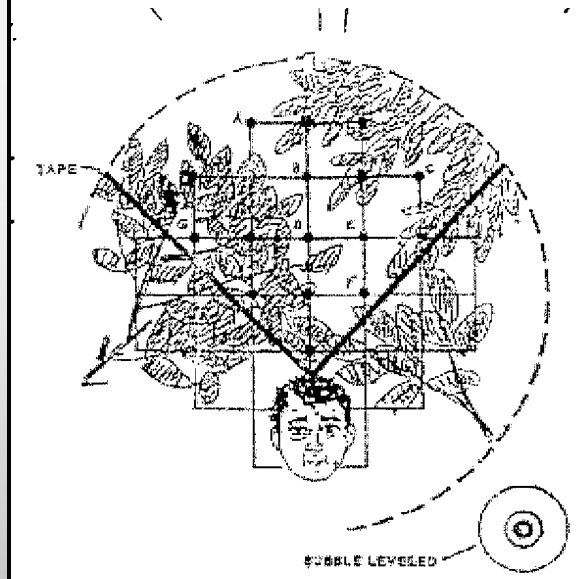
50% Root Density

25% Root Density

Methods to Estimate Percent Roots



% Coverage = # of dots covered by vegetation / 17



BEHI

Measure Bank Height (A)

Select a Representative or Typical Bank Condition for Prediction

Measure Bankfull Height (B)

Measure Root Depth (C)

Measure Root Density (D)

A/B

C/A

D*(C/A)

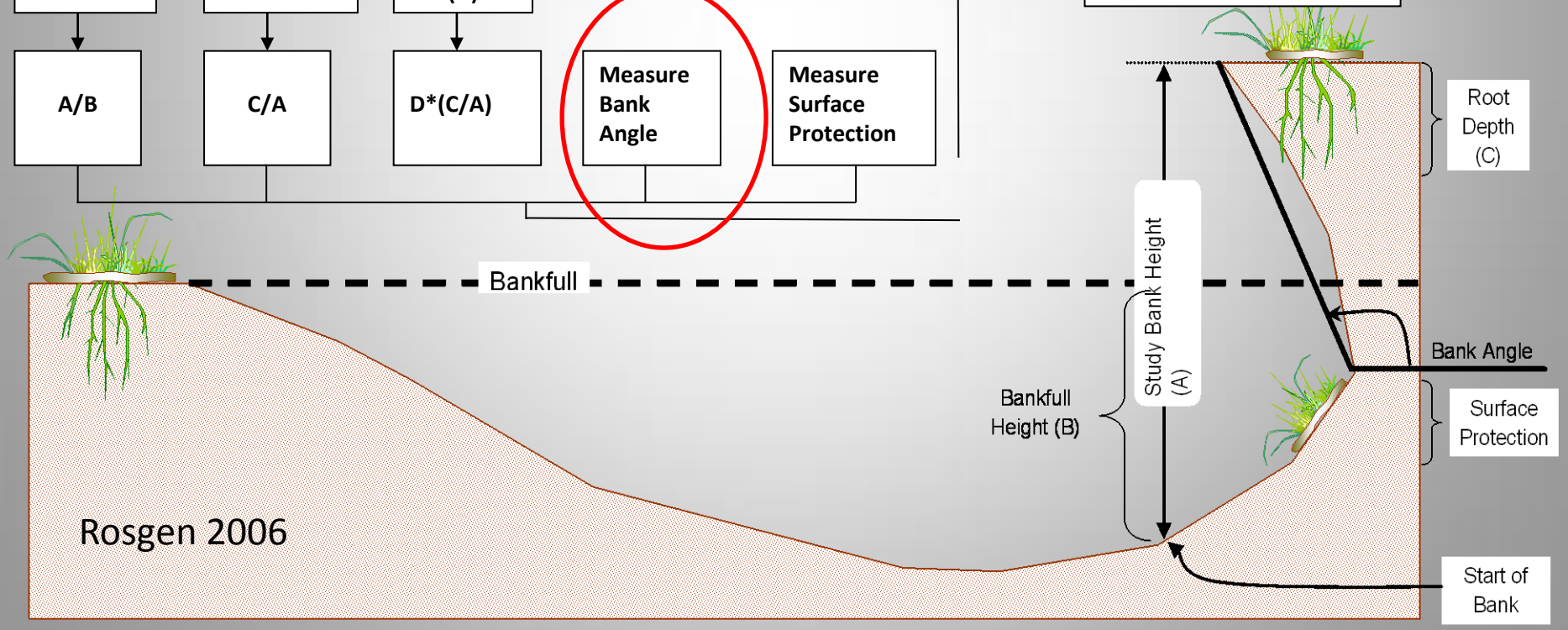
Measure Bank Angle

Measure Surface Protection

Adjust Index for Bank Materials

Adjust Index for Stratification

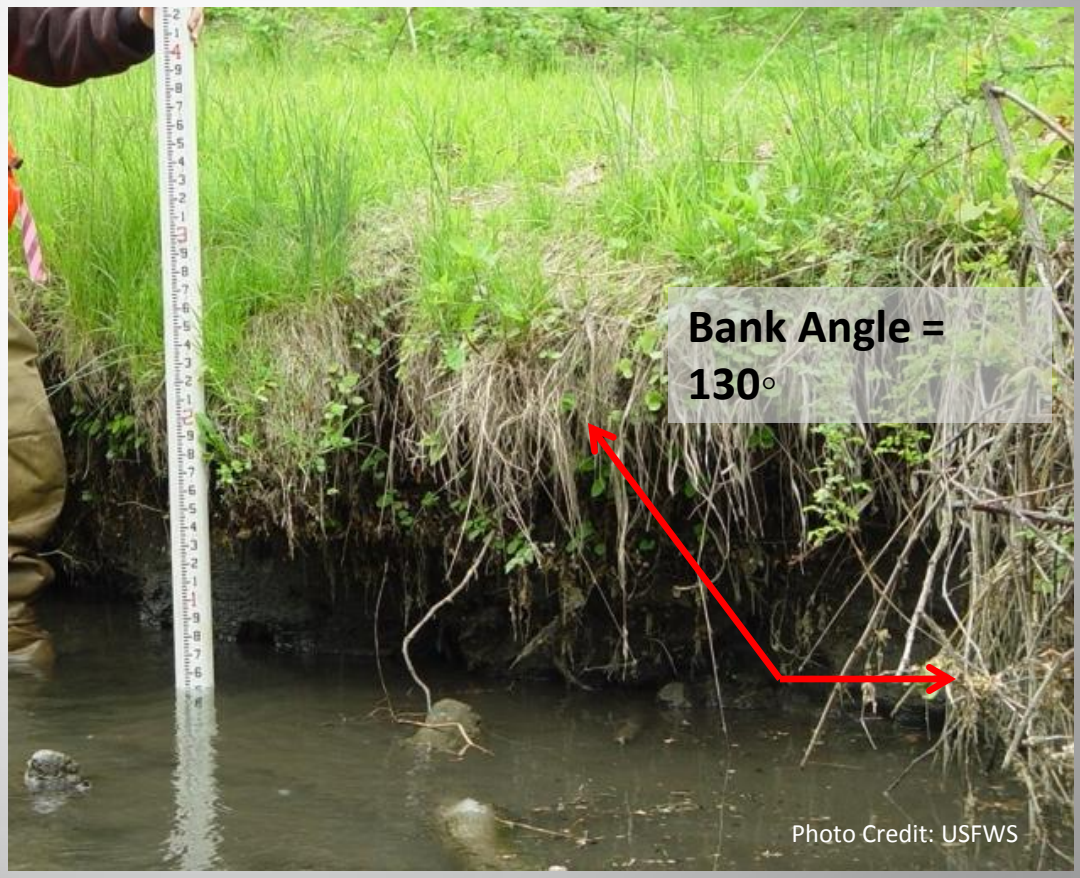
Obtain a Total Score



Rosgen 2006

Bank Angle

- Used to determine risk of bank failure
- Steeper the bank the more susceptible to erosion

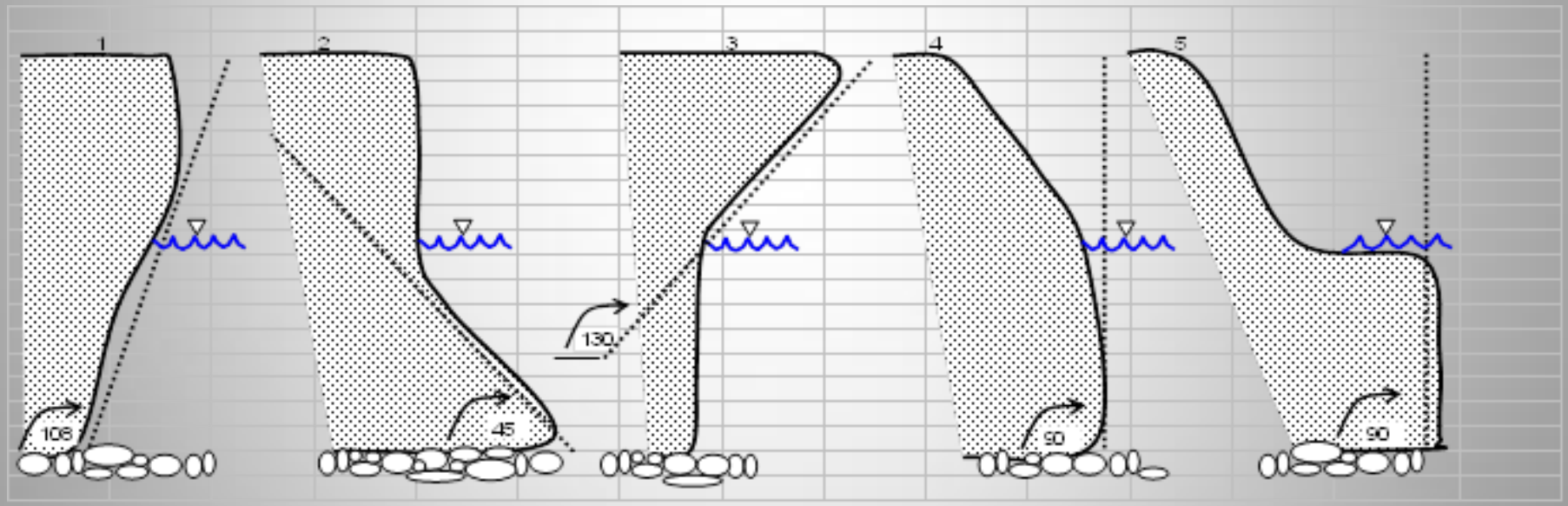


Measuring Bank Angle

- Measure angle of steepest slope or slope most prone to failure at bankfull flow
- If possible place a survey rod on the slope face
- Use clinometer to measure the angle


Photo Credit: USFWS

Where to Measure Bank Angle



Rosgen, 2003

BEHI

Measure Bank Height (A)

Select a Representative or Typical Bank Condition for Prediction

Measure Bankfull Height (B)

Measure Root Depth (C)

Measure Root Density (D)

A/B

C/A

D*(C/A)

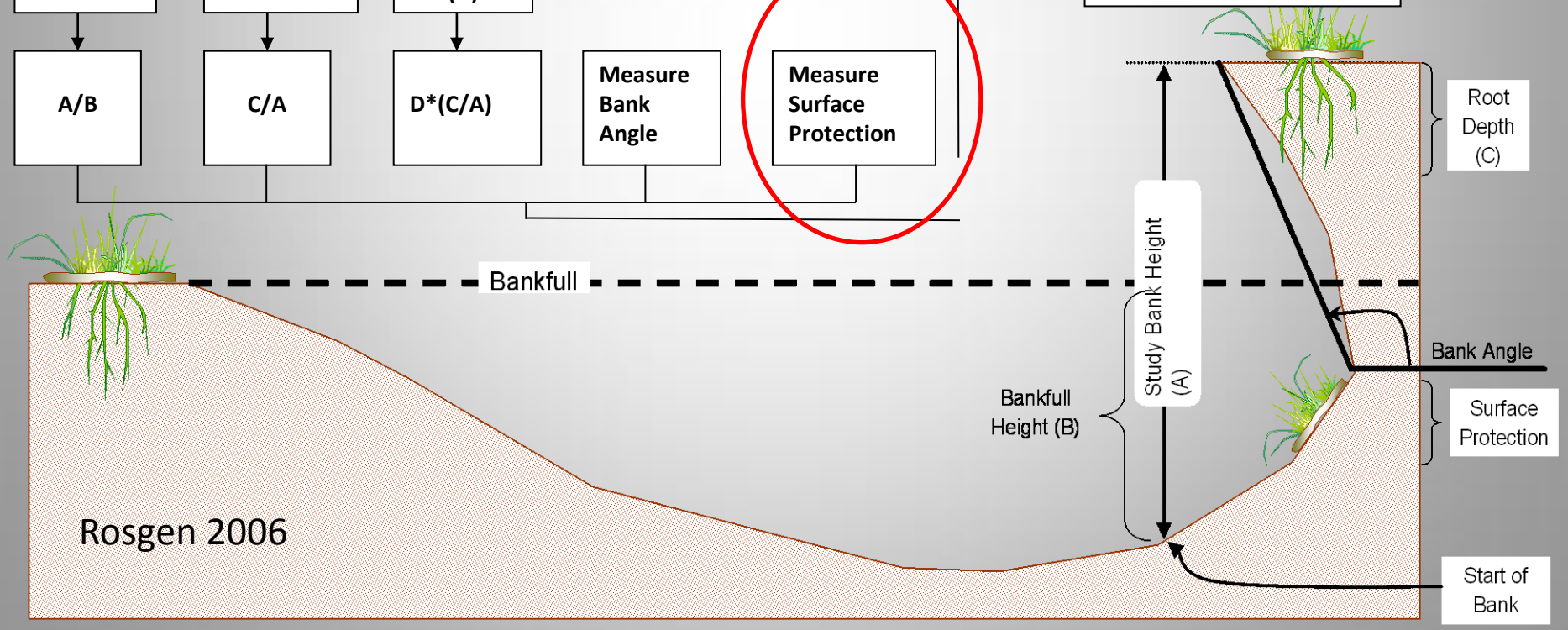
Measure Bank Angle

Measure Surface Protection

Adjust Index for Bank Materials

Adjust Index for Stratification

Obtain a Total Score



Rosgen 2006

Surface Protection

- Characterizes how much of the streambank is exposed to erosion
- Measured as the surface area protected from erosion
- Surface protection can be vegetation, root wads, debris, etc.

Measuring Surface Protection

- Determine areas along bank that have surface protection
- Determine protected percent of total bank height
- Can use same methods as root density (Munsell Charts, etc.)

Surface Protection

When Banks are vegetated by shrubs or trees, determine percent of bank influenced by the root fan

BEHI

Measure Bank Height (A)

Select a Representative or Typical Bank Condition for Prediction

Measure Bankfull Height (B)

Measure Root Depth (C)

Measure Root Density (D)

A/B

C/A

D*(C/A)

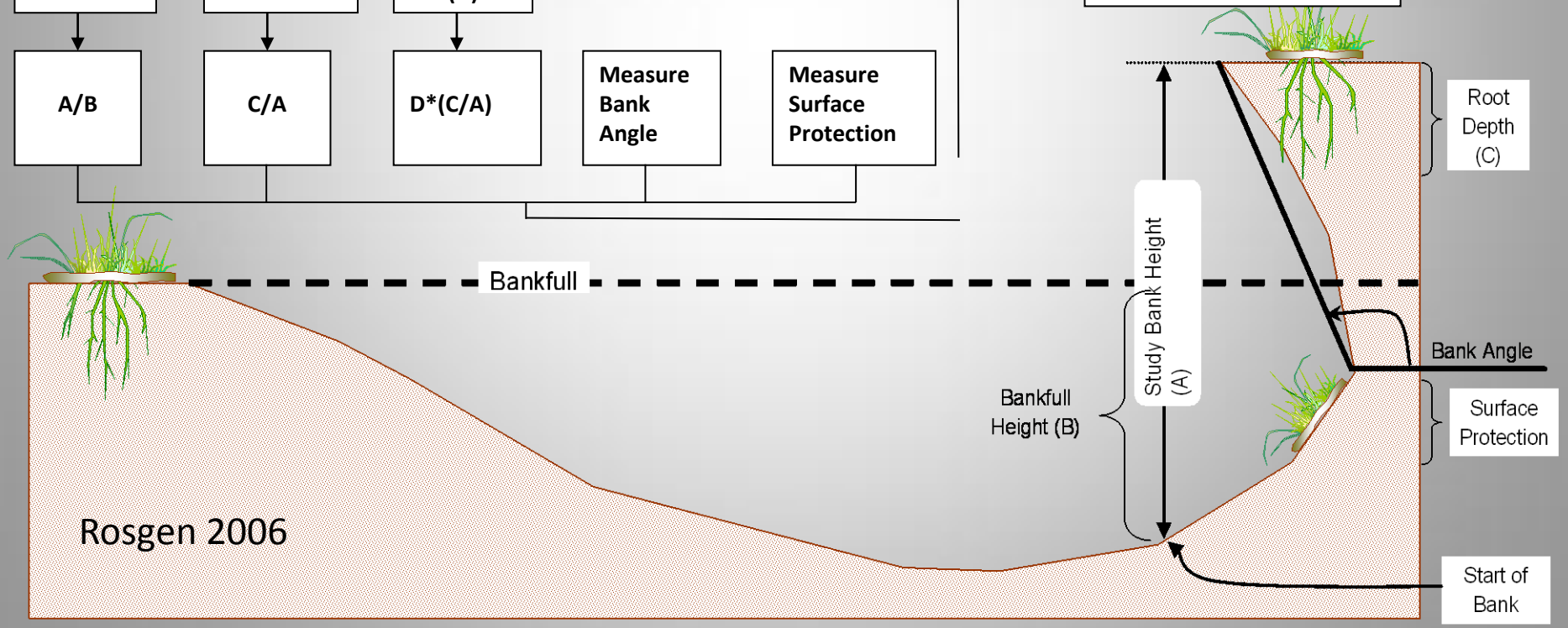
Measure Bank Angle

Measure Surface Protection

Adjust Index for Bank Materials

Adjust Index for Stratification

Obtain a Total Score



Rosgen 2006

Bank Material Adjustment

- Characterizes the composition and consolidation of bank
- More erodible the soil type, the higher the susceptibility to erosion

Determining Bank Material Adjustment

Bank Material	BEHI Rating Adjustment
Bedrock	BEHI for bedrock banks are “very low erosion potential”.
Boulders	BEHI for boulder banks are “low erosion potential”.
Cobble	Subtract 10 points. No adjustment if sand/gravel composes greater than 50 percent of bank.
Sand/Silt/Clay Loam	Add 5 points, if composition is 50 – 75 percent sand.
Gravel	Add 5-10 points depending on percentage of bank material composed of sand.
Sand	Add 10 points if sand comprises greater than 75 percent and is exposed to erosional processes.
Silt/Clay	Subtract up to 20 points depending on percentage of bank material composed of clay. *Note: this is a new adjustment

- Determine general bank composition
- Adjust BEHI score

BEHI

Measure Bank Height (A)

Select a Representative or Typical Bank Condition for Prediction

Measure Bankfull Height (B)

Measure Root Depth (C)

Measure Root Density (D)

A/B

C/A

D*(C/A)

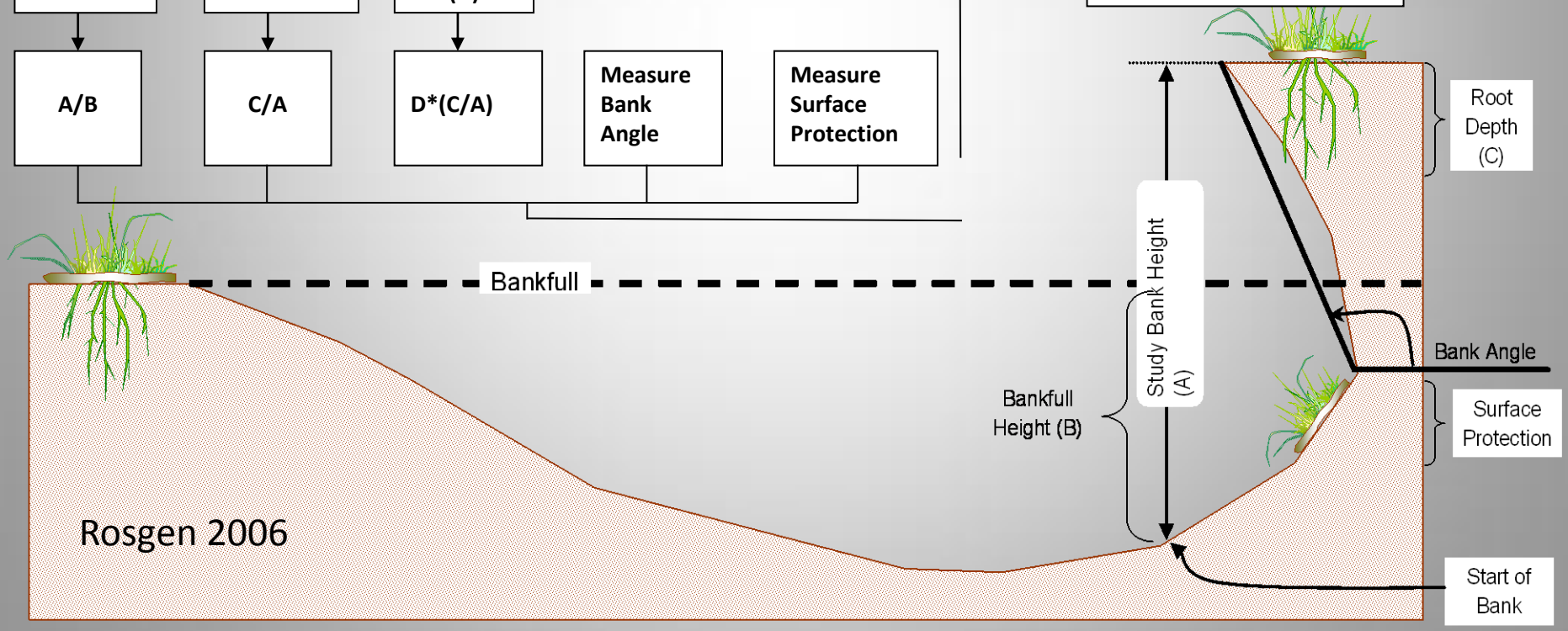
Measure Bank Angle

Measure Surface Protection

Adjust Index for ~~Bank Materials~~

Adjust Index for Stratification

Obtain a Total Score



Rosgen 2006

Stratification Adjustment

- Characterizes unstable soil horizons prone to erosion in relation to bankfull stage

- Processes to consider include
  - Fluvial entrainment
  - Rotational failure
  - Soil piping
  - Freeze/thaw

Determining Stratification Adjustment

- Observe bank profiles and soil horizons
- Identify zones where
  - Water concentrates
  - Rotational failures
  - Soil Piping
- Evaluate horizon consolidation
- Adjustment is dependent on location of horizons prone to erosion
- Add 5 to 10 points depending on position of unstable layers in relation to the bankfull stage

Photo Credit: USFWS

BEHI

Measure Bank Height (A)

Select a Representative or Typical Bank Condition for Prediction

Measure Bankfull Height (B)

Measure Root Depth (C)

Measure Root Density (D)

A/B

C/A

D*(C/A)

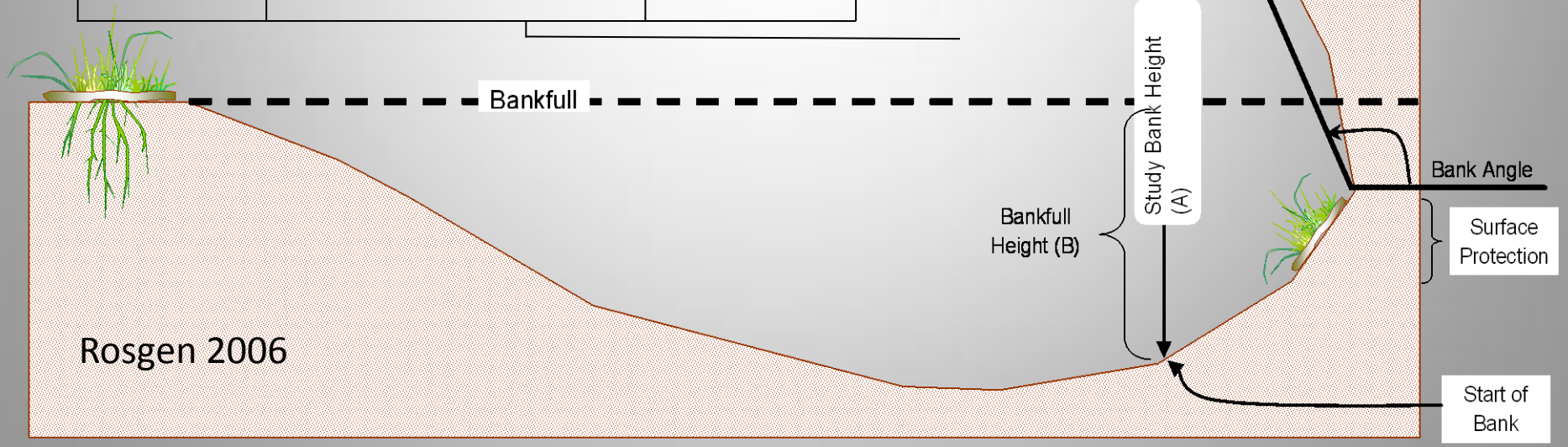
Measure Bank Angle

Measure Surface Protection

Adjust Index for Bank Materials

Adjust Index for Stratification

Obtain a Total Score



Rosgen 2006

BEHI Form and Index

Stream: Location:

Station: Observers:

Date: Stream Type: Valley Type:

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	(A)	Bankfull Height (ft) =	(B)	(A) / (B) =	(C)

Root Depth / Study Bank Height (E)

Root Depth (ft) =	(D)	Study Bank Height (ft) =	(A)	(D) / (A) =	(E)

Weighted Root Density (G)

Root Density as % =	(F)	(F) X (E) =	(G)

Bank Angle (H)

Bank Angle as *Degrees* =	(H)

Surface Protection (I)

Surface Protection as % =	(I)

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

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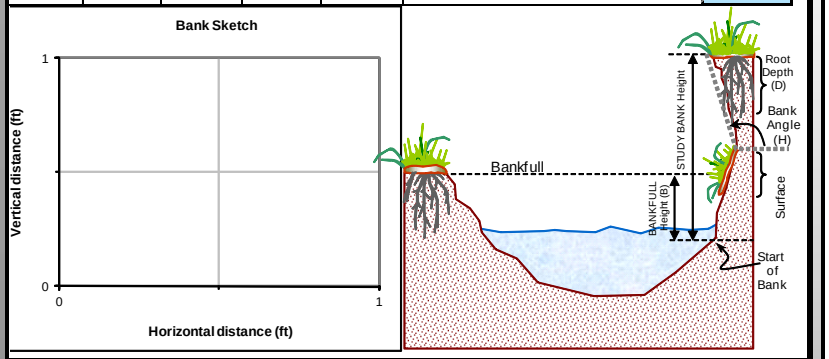
Adjective Rating and Total Score



Bank Erosion Hazard Rating Guide

Stream Reach Date Crew

Bank Erosion Potential

Bank Height (ft): / Bankfull Height (ft):		Bank Height/ Bankfull Ht	Root Depth/ Bank Height	Root Density %	Bank Angle (Degrees)	Surface Protection%
VERY LOW	Value	1.0-1.1	1.0-0.9	100-80	0-20	100-80
	Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
LOW	Value	1.11-1.19	0.89-0.5	79-55	21-60	79-55
	Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
MODERATE	Value	1.2-1.5	0.49-0.3	54-30	61-80	54-30
	Index	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
HIGH	Value	1.6-2.0	0.29-0.15	29-15	81-90	29-15
	Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
VERY HIGH	Value	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10
	Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
EXTREME	Value	>2.8	<0.05	<5	>119	<10
	Index	10	10	10	10	10
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:

V = value, I = index **SUB-TOTAL** (Sum one index from each column)

Rosgen, 2006

Rosgen, 1996

Near Bank Stress

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

Level III

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

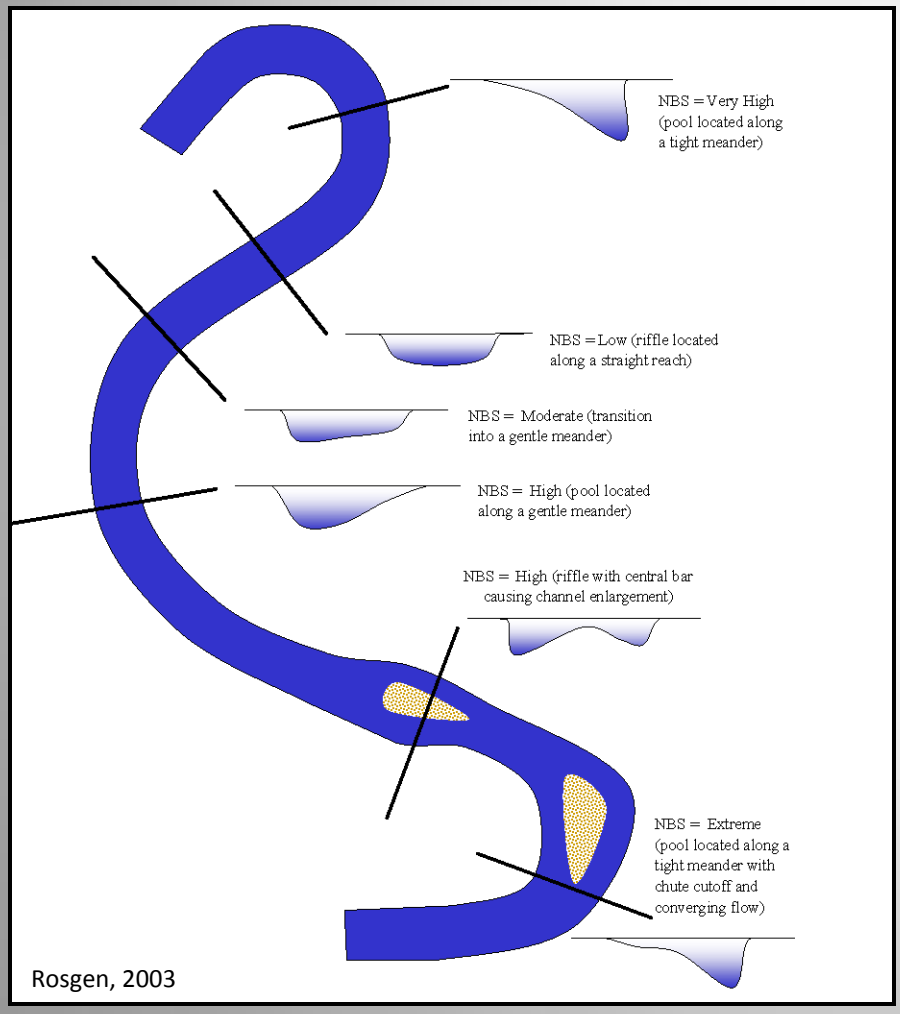
(6)	Near-Bank Max Depth d_{nb} (ft)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d_{bkf} (ft)	Average Slope S	Bankfull Shear Stress τ_{bkf} (lb/ft^2)	Ratio τ_{nb} / τ_{bkf}	Near-Bank Stress (NBS)

Level IV

(7)	Velocity Gradient (ft / sec / ft)	Near-Bank Stress (NBS)	
			Rosgen, 2006

- Estimates bank stress associated with bankfull flows
- Seven methods can be used
- Method must incorporate understanding of stream processes
- Select method that best represents site conditions
- Average of methods is not recommended

Factors to Consider



Rosgen, 2003

- Uses stream pattern, shape and depositional areas
- Maximum depth location influences rating
- Chute cutoff return flows and split channels converging against study banks cause disproportionate energy distribution
- Depositional features cause disproportionate energy distribution
- Evaluate individual channels of a braided reach separately
- If the stream slope directly upstream of a study bank is steeper than the average reach slope adjust NBS upwards

NBS Method 1

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

Rosgen, 2006

- Rapid visual assessment
- Based on channel pattern and depositional features

NBS Method 2

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

Rosgen, 2006

- Can be completed rapidly
- Use this method if a tight radius in a bend is having the greatest influence

Photo Credit: USFWS

NBS Methods 3 and 4

(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)

Rosgen, 2006

- Use when the stream slope is having the greatest impact
- Steep pool slopes accelerate streambank erosion

NBS Methods 5 and 6

(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)

Rosgen, 2006

- Depth at the bank related to overall depth
- Due to complexity, Method 5 is more often used

NBS Method 7

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

Rosgen, 2006

- Most detailed method
- Collecting velocity data at bankfull
- Not likely to use

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

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)

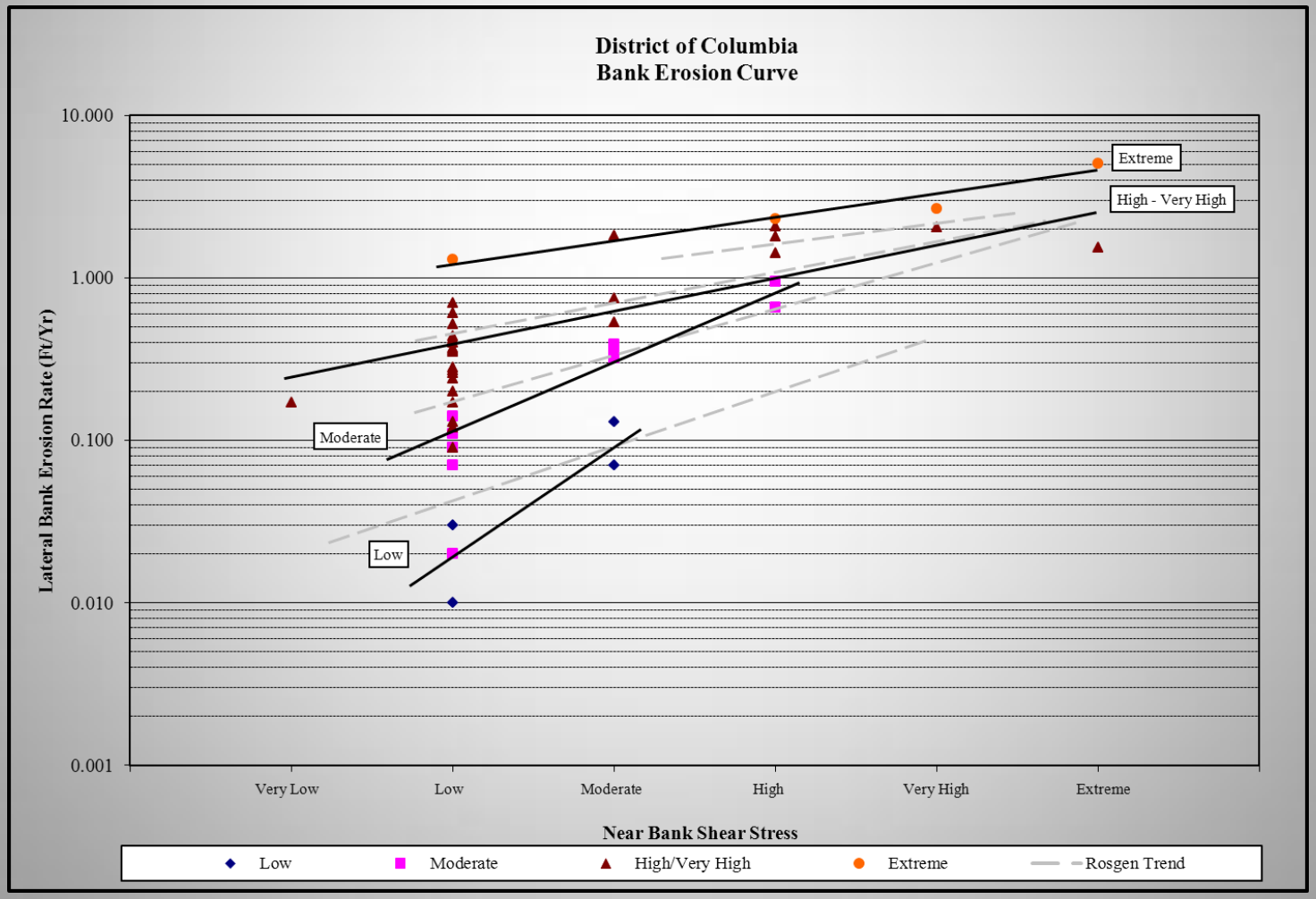
Level IV

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

Rosgen, 2006

- Most likely to use Methods 2 and 5
- Slope is a factor use Methods 3 and 4
- Method 7 will rarely be used

Bank Erosion Curves



USFWS, 2005

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