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
- **Bank Assessment for Non-point source Consequences of Sediment (BANCS)**
- Meander Width Ratio (MWR)

**Geomorphic Functions Assessed**

- **Lateral Stability**
  - Bank Assessment for Non-point source Consequences of Sediment (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
<table>
<thead>
<tr>
<th>Level and Category</th>
<th>Parameter</th>
<th>Measurement Method</th>
<th>Pre-Restoration Condition</th>
<th>Post-Restoration Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td>Value</td>
<td>Rating</td>
</tr>
<tr>
<td>1 - Hydrology</td>
<td>Channel-Forming Discharge</td>
<td>Regional Curves</td>
<td>N/A</td>
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<tr>
<td>2 - Hydraulics</td>
<td>Floodplain Connectivity</td>
<td>Bank Height Ratio</td>
<td>1.5</td>
<td>Not Functioning</td>
</tr>
<tr>
<td></td>
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<td>Entrenchment Ratio</td>
<td>1.73</td>
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<td>HEC-RAS</td>
<td>n/a</td>
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<tr>
<td>3 - Geomorphology</td>
<td>Bed Form diversity</td>
<td>Pool-to-pool spacing</td>
<td>1.5 to 9</td>
<td>Not Functioning</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pool Depth Variability</td>
<td>2.0 to 3.0</td>
<td>Functioning</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ripple Length to Ripple Width</td>
<td>2.9 to 4.3</td>
<td>Functioning</td>
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<tr>
<td></td>
<td></td>
<td>Ripple Slope to Reach Slope</td>
<td>1.2 to 3.9</td>
<td>FAR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pool Slope to Reach Slope</td>
<td>0.3 to 0.6</td>
<td>FAR</td>
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<tr>
<td></td>
<td></td>
<td>Rosgen</td>
<td>F → C → E</td>
<td>FAR</td>
</tr>
<tr>
<td></td>
<td>Channel Evolution</td>
<td>PFC</td>
<td>Not Functional</td>
<td>Not Functioning</td>
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<tr>
<td></td>
<td>Riparian Vegetation</td>
<td>Buffer Width based on Beltwidth</td>
<td>0</td>
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<tr>
<td></td>
<td></td>
<td>BEHI/NBS</td>
<td>Mod / Low</td>
<td>FAR</td>
</tr>
<tr>
<td></td>
<td>Lateral Stability</td>
<td>Lateral Erosion Rate</td>
<td>0.09 yr/ft</td>
<td>Functioning</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Confinement</td>
<td>0.69 to 1.14</td>
<td>Functioning</td>
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<tr>
<td></td>
<td></td>
<td>MWR</td>
<td>2.4 to 4.0</td>
<td>Functioning</td>
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<tr>
<td></td>
<td></td>
<td>W/Dproj /W/Dref</td>
<td>1.4</td>
<td>FAR</td>
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<tr>
<td></td>
<td></td>
<td>Wavelength to Ruffle Width</td>
<td>9 to 14</td>
<td>Functioning</td>
</tr>
</tbody>
</table>
Darnell Reach

Floodplain Connectivity

Bank Height Ratio

Not Functioning
Functioning - At-Risk
Functioning

Monitoring Years

Baker, 2008
Bank Assessment for Non-point source Consequences of Sediment (BANCS)
Bank Assessment for Non-point source Consequences of Sediment (BANCS)

- Model to predict streambank erosion rates
- Methods based on Rosgen (2006)
- Two measurements
  - Bank Erosion Hazard Index (BEHI)
  - Near Bank Stress (NBS)
- Erosion rates estimated using bank erodibility curves
### Methods for Estimating Near-Bank Stress (NBS)

1. Channel pattern, transverse bar or split channel/central bar creating NBS  
   - Level I: Reconnaissance
2. Ratio of radius of curvature to bankfull width (\( R_b / W_{bkf} \))  
   - 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 (\( \tau_{nb} / \tau_{bkf} \))  
   - Level III: Detailed prediction
7. Velocity profiles / Isovels / Velocity gradient
   - Level IV: Validation

### 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)
- Silt/Clay (Add 10 points)
- Stratification Adjustment (Add 5–10 points, depending on position of unstable layers in relationship to bankfull stage)

### Surface Protection
- Root Density as % of Bank Material

### Measures
- Vertical distance (ft)
- Horizontal distance (ft)
- Bankfull Height (ft)
- Bank Sketch
- Bank Angle (H)
- Root Depth (ft)
- Study Bank Height (ft)
- Weighted Root Density (G)
- Bankfull Height (ft)
- Bankfull Width (W_{bkf} (ft))
- Bankfull Shear Stress \( \tau_{bkf} \) (lb/ft²)
- Bankfull Mean Depth (d_{bkf} (ft))
- Bankfull Slope (S_{bkf})
- Bankfull Size (R_{bkf} (ft))
- Bankfull Stress (NBS)

### Total Score
- BEHI Score (Fig. 3-7)

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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

Photo Credit: USFWS
### Bank Erosion Hazard Rating Guide

<table>
<thead>
<tr>
<th>Stream Potential</th>
<th>Reach</th>
<th>Date</th>
<th>Crew</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Very Low</strong></td>
<td>1.0-1.1</td>
<td>1.0-1.9</td>
<td>1.0-0.9</td>
</tr>
<tr>
<td></td>
<td><strong>Index</strong></td>
<td><strong>Choice</strong></td>
<td><strong>V: I:</strong></td>
</tr>
<tr>
<td><strong>Low</strong></td>
<td>1.11-1.19</td>
<td>2.0-3.9</td>
<td>0.89-0.5</td>
</tr>
<tr>
<td></td>
<td><strong>Index</strong></td>
<td><strong>Choice</strong></td>
<td><strong>V: I:</strong></td>
</tr>
<tr>
<td><strong>Moderate</strong></td>
<td>1.2-1.5</td>
<td>4.0-5.9</td>
<td>0.49-0.3</td>
</tr>
<tr>
<td></td>
<td><strong>Index</strong></td>
<td><strong>Choice</strong></td>
<td><strong>V: I:</strong></td>
</tr>
<tr>
<td><strong>High</strong></td>
<td>1.6-2.0</td>
<td>6.0-7.9</td>
<td>0.29-0.15</td>
</tr>
<tr>
<td></td>
<td><strong>Index</strong></td>
<td><strong>Choice</strong></td>
<td><strong>V: I:</strong></td>
</tr>
<tr>
<td><strong>Very High</strong></td>
<td>2.1-2.8</td>
<td>8.0-9.0</td>
<td>0.14-0.05</td>
</tr>
<tr>
<td></td>
<td><strong>Index</strong></td>
<td><strong>Choice</strong></td>
<td><strong>V: I:</strong></td>
</tr>
<tr>
<td><strong>Extreme</strong></td>
<td>&gt;2.8</td>
<td>10</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td></td>
<td><strong>Index</strong></td>
<td><strong>Choice</strong></td>
<td><strong>V: I:</strong></td>
</tr>
</tbody>
</table>

**SUB-TOTAL** (Sum one index from each column)

**Rosgen, 1996**
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
Select a Representative or Typical Bank Condition for Prediction

- Measure Bank Height (A)
- Measure Bankfull Height (B)
- Measure Root Depth (C)
- Measure Root Density (D)
- 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
CHESAPEAKE BAY FIELD OFFICE
COASTAL PROGRAM

BEHI

Select a Representative or Typical Bank Condition for Prediction

Measure Bank Height (A)

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

Rooting Depth = Bank Height

Photo Credit: USFWS
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

Total Rooting Depth = 4.0 ft
Select a Representative or Typical Bank Condition for Prediction

- Measure Bank Height (A)
- 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
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COASTAL PROGRAM

Select a Representative or Typical Bank Condition for Prediction

Measure Bank Height (A)
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

Bank Angle = 130°

Photo Credit: USFWS
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
Where to Measure Bank Angle

Rosgen, 2003
Select a Representative or Typical Bank Condition for Prediction

- Measure Bank Height (A)
- Measure Bankfull Height (B)
- Measure Root Depth (C)
- Measure Root Density (D)

Measure

- 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

Photo Credit: USFWS
Select a Representative or Typical Bank Condition for Prediction

- Measure Bank Height (A)
- Measure Bankfull Height (B)
- Measure Root Depth (C)
- Measure Root Density (D)
- 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

Photo Credit: USFWS
Determining Bank Material Adjustment

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

• Determine general bank composition

• Adjust BEHI score
Select a Representative or Typical Bank Condition for Prediction

- Measure Bank Height (A)
- Measure Bankfull Height (B)
- Measure Root Depth (C)
- Measure Root Density (D)
- Measure Bank Angle
- Measure Surface Protection

A/B
C/A
D*(C/A)

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
BEHI

Select a Representative or Typical Bank Condition for Prediction

Measure Bank Height (A)
Measure Bankfull Height (B)
Measure Root Depth (C)
Measure Root Density (D)
Measure Bank Angle
Measure Surface Protection

A/B
C/A
D*(C/A)

Adjust Index for Bank Materials
Adjust Index for Stratification
Obtain a Total Score

Rosgen 2006
## BEHI Form and Index

**Stream:**
- Location:

**Station:**
- Stream Type:
- Valley Type:

### Study Bank Height / Bankfull Height (C)

<table>
<thead>
<tr>
<th>Study Bank Height (ft)</th>
<th>Bankfull Height (ft)</th>
<th>(A) / (B) = (C)</th>
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</table>

**Root Depth / Study Bank Height (E)**

<table>
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<th>Root Depth (ft)</th>
<th>Study Bank Height (ft)</th>
<th>(D) / (A) = (E)</th>
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</thead>
</table>

**Weighted Root Density (G)**

<table>
<thead>
<tr>
<th>Root Density as % =</th>
</tr>
</thead>
</table>

**Bank Angle (H)**

<table>
<thead>
<tr>
<th>Bank Angle as Degrees =</th>
</tr>
</thead>
</table>

**Surface Protection (I)**

<table>
<thead>
<tr>
<th>Surface Protection as % =</th>
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</thead>
</table>

**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)

**Stratification Adjustment**

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

**Bank Sketch**

- Vertical distance (ft)
- Horizontal distance (ft)

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### Bank Erosion Hazard Rating Guide

**Bank Height (ft):**

<table>
<thead>
<tr>
<th>Bank Height (ft):</th>
<th>Bank Height/ Bankfull Ht</th>
<th>Root Depth/ Bank Ht</th>
<th>Root Density %</th>
<th>Bank Angle (Degrees)</th>
<th>Surface Protection%</th>
</tr>
</thead>
<tbody>
<tr>
<td>VERY LOW</td>
<td>1.0-1.9</td>
<td>1.0-0.9</td>
<td>100-80</td>
<td>0-20</td>
<td>100-80</td>
</tr>
<tr>
<td>LOW</td>
<td>1.11-1.19</td>
<td>0.89-0.5</td>
<td>79-55</td>
<td>21-60</td>
<td>79-55</td>
</tr>
<tr>
<td>MODERATE</td>
<td>2.0-3.9</td>
<td>2.0-3.9</td>
<td>2.0-3.9</td>
<td>2.0-3.9</td>
<td>2.0-3.9</td>
</tr>
<tr>
<td>HIGH</td>
<td>4.0-5.9</td>
<td>4.0-5.9</td>
<td>4.0-5.9</td>
<td>4.0-5.9</td>
<td>4.0-5.9</td>
</tr>
<tr>
<td>VERY HIGH</td>
<td>6.0-7.9</td>
<td>6.0-7.9</td>
<td>6.0-7.9</td>
<td>6.0-7.9</td>
<td>6.0-7.9</td>
</tr>
<tr>
<td>EXTREME</td>
<td>8.0-9.0</td>
<td>8.0-9.0</td>
<td>8.0-9.0</td>
<td>8.0-9.0</td>
<td>8.0-9.0</td>
</tr>
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</table>

**Bank Erosion Potential**

<table>
<thead>
<tr>
<th>Bank Height (ft):</th>
<th>Bank Height/ Bankfull Ht</th>
<th>Root Depth/ Bank Ht</th>
<th>Root Density %</th>
<th>Bank Angle (Degrees)</th>
<th>Surface Protection%</th>
</tr>
</thead>
<tbody>
<tr>
<td>VERY LOW</td>
<td>1.0-1.9</td>
<td>1.0-0.9</td>
<td>100-80</td>
<td>0-20</td>
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<tr>
<td>LOW</td>
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<td>21-60</td>
<td>79-55</td>
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<tr>
<td>MODERATE</td>
<td>2.0-3.9</td>
<td>2.0-3.9</td>
<td>2.0-3.9</td>
<td>2.0-3.9</td>
<td>2.0-3.9</td>
</tr>
<tr>
<td>HIGH</td>
<td>4.0-5.9</td>
<td>4.0-5.9</td>
<td>4.0-5.9</td>
<td>4.0-5.9</td>
<td>4.0-5.9</td>
</tr>
<tr>
<td>VERY HIGH</td>
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<td>6.0-7.9</td>
<td>6.0-7.9</td>
</tr>
<tr>
<td>EXTREME</td>
<td>8.0-9.0</td>
<td>8.0-9.0</td>
<td>8.0-9.0</td>
<td>8.0-9.0</td>
<td>8.0-9.0</td>
</tr>
</tbody>
</table>

**V = value, I = index**

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Rosgen, 2006

Rosgen, 1996
# Near Bank Stress

- 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

## Methods for Estimating Near-Bank Stress (NBS)

<table>
<thead>
<tr>
<th>Level</th>
<th>Method</th>
<th>Estimation Level</th>
<th>Validation Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Channel pattern, transverse bar or split channel/central bar creating NBS</td>
<td>Level I</td>
<td>Reconnaissance</td>
</tr>
<tr>
<td>II</td>
<td>Ratio of radius of curvature to bankfull width (Rc / Wbf)</td>
<td>Level II</td>
<td>General prediction</td>
</tr>
<tr>
<td>II</td>
<td>Ratio of pool slope to average water surface slope (Sp / S)</td>
<td>Level II</td>
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<tr>
<td>III</td>
<td>Ratio of near-bank maximum depth to bankfull mean depth (dmb / dbkf)</td>
<td>Level III</td>
<td>Detailed prediction</td>
</tr>
<tr>
<td>III</td>
<td>Ratio of near-bank shear stress to bankfull shear stress (τmb / τbf)</td>
<td>Level III</td>
<td>Detailed prediction</td>
</tr>
<tr>
<td>IV</td>
<td>Velocity profiles / Isovels / Velocity gradient</td>
<td>Level IV</td>
<td>Validation</td>
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</tbody>
</table>

## Level II

<table>
<thead>
<tr>
<th>Method</th>
<th>Estimation Level</th>
<th>Validation Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2)</td>
<td>Radius of Curvature (Rc)</td>
<td>Bankfull Width Wbf (ft)</td>
</tr>
<tr>
<td>(3)</td>
<td>Pool Slope Sp</td>
<td>Average Slope S</td>
</tr>
<tr>
<td>(4)</td>
<td>Pool Slope Sp</td>
<td>Riffle Slope Srif</td>
</tr>
<tr>
<td>(5)</td>
<td>Near-Bank Max Depth dmb (ft)</td>
<td>Mean Depth dbf (ft)</td>
</tr>
</tbody>
</table>

## Level III

<table>
<thead>
<tr>
<th>Method</th>
<th>Estimation Level</th>
<th>Validation Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>(6)</td>
<td>Near-Bank Max Depth dmb (ft)</td>
<td>Near-Bank Slope Smb</td>
</tr>
</tbody>
</table>

## Level IV

<table>
<thead>
<tr>
<th>Method</th>
<th>Estimation Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>(7)</td>
<td>Velocity Gradient (ft/sec/ft)</td>
</tr>
</tbody>
</table>

*Rosgen, 2006*
Factors to Consider

- 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

Rosgen, 2003
NBS Method 1

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

| 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
# NBS Method 2

<table>
<thead>
<tr>
<th></th>
<th>Bankfull Width ( W_{bkf} ) (ft)</th>
<th>( \text{Ratio} \ R_c / W_{bkf} )</th>
<th>Near-Bank Stress (NBS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2) Radius of Curvature ( R_c ) (ft)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 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

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

<table>
<thead>
<tr>
<th>Method</th>
<th>Pool Slope $S_p$</th>
<th>Average Slope $S$</th>
<th>Ratio $S_p / S$</th>
<th>Near-Bank Stress (NBS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Riffle Slope $S_{rif}$</td>
<td>Ratio $S_p / S_{rif}$</td>
<td>Near-Bank Stress (NBS)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Rosgen, 2006
NBS Methods 5 and 6

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

| Method | Near-Bank Max Depth \( d_{\text{nb}} \) (ft) | Mean Depth \( d_{\text{bf}} \) (ft) | Ratio \( \frac{d_{\text{nb}}}{d_{\text{bf}}} \) | Near-Bank Stress (NBS) | Near-Bank Max Depth \( d_{\text{nb}} \) (ft) | Near-Bank Slope \( S_{\text{nb}} \) | Near-Bank Shear Stress \( \tau_{\text{nb}} \) (lb/ft\(^2\)) | Mean Depth \( d_{\text{bf}} \) (ft) | Average Slope S | Bankfull Shear Stress \( \tau_{\text{bf}} \) (lb/ft\(^2\)) | Ratio \( \frac{\tau_{\text{nb}}}{\tau_{\text{bf}}} \) | Near-Bank Stress (NBS) |
|--------|---------------------------------|---------------------------------|----------------|---------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| (5)    |                                 |                                 |                |                     |                                 |                                 |                                 |                                 |                                 |                                 |                                 |                                 |                                 |
| (6)    |                                 |                                 |                |                     |                                 |                                 |                                 |                                 |                                 |                                 |                                 |                                 |                                 |

Rosgen, 2006
NBS Method 7

- Most detailed method
- Collecting velocity data at bankfull
- Not likely to use
- Most likely to use Methods 2 and 5
- Slope is a factor use Methods 3 and 4
- Method 7 will rarely be used
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