15. Field Trip Exercise

Introduction

The first site on the field trip will provide an opportunity to characterize site conditions, collect preliminary channel and road-stream crossing structure measurements, discuss the process of performing the site assessment to design a replacement structure, discuss the feasibility of using the stream simulation method at the site in designing the replacement structure, and discuss various construction approaches and concerns at the site when the structure is replaced. Although it is not feasible to do the actual survey needed for a site assessment and culvert replacement design, collecting preliminary field measurements and discussing channel and road-stream characteristics as an interdisciplinary team will help reinforce the topics discussed in the classroom.

Please work together in your respective interdisciplinary teams to address the various topics and questions listed below.

Please address the questions listed below in the instructions. Two blank pages are included at the end of the document so that you can take notes and construct a sketch map, cross sections, and longitudinal profile of the site.

Attached at the end of the document are selected handouts (Montgomery and Buffington channel classification, Rosgen channel classification, channel/bank stability indicator assessment, grade control stability rating table) to help you with your observations of channel features and understanding of fluvial processes.

Time permitting, we will go to other sites to evaluate recent replacement structures and discuss the merits of the designs as they relate to stream simulation and geomorphic processes.

SITE A

In your assigned groups, conduct a reconnaissance of the site by walking 20-30 channel widths upstream and downstream of the crossing. Each person should construct a sketch map of the site document the prominent geomorphic and road features observed during your reconnaissance. To help focus your observations and documentation, address the various items listed in the following categories:

Road and Existing Structure Characteristics

- What are the type, dimensions, and length of the existing culvert?
- Is there sediment in the culvert?
- Is the culvert perched? If perched, what is the height of the perch?
- What is the skew of the channel and culvert (both upstream and downstream)?
- What is the skew of the road and culvert?
- What is the height of the fill?
- What are the slopes of the fill?
- What is the curvature of the road?

Planform Characteristics

- Channel and valley planform pattern.
- Channel bedforms: pools, riffles, steps, bar deposits, large woody debris.
- Valley bottom features: floodplain, terraces, valley walls, side channels or floodplain swales.
- Bank characteristics and erosion.
- Exposed bedrock.
- Relative channel alignment to the road/culvert and the curvature of the road.
- Assess whether the road is crossing the stream at a straight segment of the channel or at a channel.
- Assess the alignment of the channel with the structure.

Longitudinal Profile

In addition to the sketch map, construct a longitudinal profile (20-30 channel widths upstream and downstream from the crossing) to document and record the key features identified on the sketch map.

- Key grade control features and bedforms, habitat features.
- Distinct changes in channel gradient.
- Maximum points of scour, residual pool depths, etc.
- At a few of the key grade controls and channel-bed features, determine the height, length, and width of features such as steps, riffles, and pools.
- Also determine the width and spacing between pools.
- Describe and sketch the arrangement of rocks that make up a given grade control feature (are they embedded, tightly or loosely packed, buried into the banks, etc.).
- ***Assess the relative stability of the key grade control features.***
- Is the channel gradient and variability similar both upstream and downstream from the crossing?
- Where do the maximum points of scour occur?
- Describe the geomorphic controls on scour depth?
- Are key grade control features similar both upstream and downstream from the crossing?

Cross Sections

Locate cross sections both upstream and downstream from the influence of the road-stream crossing that best characterize and represent channel conditions. On the attached blank paper, draw at least four representative cross sections (two upstream and two downstream) and show the:

- Relationship between ordinary high water, bankfull flow, and flood-prone width.
- Assess bank characteristics and overall bank stability at the different cross sections.
- Is the channel confined or unconfined (entrenched, moderately entrenched, or slightly entrenched)?
- Are channel characteristics similar both upstream and downstream from the crossing?
- Label the cross section locations on the sketch map and longitudinal profile.
- Draw a cross section about 5 – 15 upstream from the culvert and a cross section at the maximum width of the plunge pool. Compare those cross sections with those constructed outside of the culvert influence.

Channel-Bed Sediments

- At key grade controls and cross sections, discuss the process and reasons for conducting the pebble counts.
- Compare differences in particle sizes between channel units and key grade control features.
- How variable are channel bed sediment sizes longitudinally and laterally along the channel?
- Demonstrate and determine the degree of channel-bed armoring. If you are not familiar with pebble counts, pick up several particles and identify the intermediate axis of the particle.

Subsurface Information

- At exposed bank areas, describe the composition and character of the material. Be sure to examine bank sediments at the plunge pool.
- Is the material soft, have a high clay content, stratified, variable vertically and laterally, or show evidence of groundwater seepage?
- Do your observations indicate that a more detailed subsurface geotechnical investigation is needed at the site?

Channel Responses and Stability

Based on your observations at the site, address the following channel responses:

1) Channel Stability:
Is the overall channel stable or is it unstable because of local or system-wide degradation and aggradation?

2) Vertical Adjustment Potential:
What are the potential ranges that the channel-bed surface will vertically fluctuate or adjust its elevation (potential aggradation and degradation or scour)?

What geomorphic evidence was used to identify potential aggradation surfaces?

What are the ranges of scour depths in the channel and where does maximum scour occur (e.g., channel bends, obstructions, steps, large woody debris, etc.)?

Are there scour depth concerns at the crossing?

3) Headcut Potential:
Is the channel susceptible to headcutting and what are the implications for allowing it to occur?

4) Lateral Adjustment Potential:
Can channel migration or lateral shifting affect the stream/culvert alignment?

5) Floodplain inundation/connectivity:
Is floodplain function and connectivity important in the channel system?

How will channel topping floods affect channel-bed stability at and through the crossing?

Reference Reach

- Can a suitable reference reach (es) be identified at the site and used to construct channel characteristics through the replacement structure?
- Identify a potential reference reach for the site and document its location on your map and longitudinal profile.

Stream Simulation and Replacement Structure Recommendations

- Recommend the type of replacement structure (round pipe, squash pipe, bottomless structure, bridge, etc.) for the site?
- What is the recommended width of the replacement structure?
- Discuss whether regrade and/or grade control measures will be necessary at the site?
- Discuss stream simulation objectives and feasibility at the site.

Construction Considerations

- Are there any on-site materials (trees, rocks, etc.) that could be used for in-stream structures?
- Identify potential sources on the sketch map. Is the existing roadway embankment material suitable for reuse as embankment material?
- Are there any equipment access issues or material storage limitations at the site?
- Is road traffic a concern? If yes, where can the bypass road be located? Will a bypass road need to be constructed?
- How will the site be dewatered for construction?
- Can “dirty” water be treated with natural filtration?

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15. Field Trip Exercise

project:	
sampling date:	sampling ID:
channel unit sampled:	sampling location:
pebble count method:	sampling interval (mm):
orientation of transect:	length of transects (m):
general description of sediment sampled (embeddedness, imbrication, particle shape, particle roundness, etc.):	

particle size (phi units)	particle size (mm)	transect 1	transect 2	transect 3	transect 4	transect 5	total count
> -11.0	> 2048						
-10.5 to -11.0	1448 to 2048						
-10.0 to -10.5	1024 to 1448						
-9.5 to -10.0	724 to 1024						
-9.0 to -9.5	512 to 724						
-8.5 to -9.0	362 to 512						
-8.0 to -8.5	256 to 362						
-7.5 to -8.0	181 to 256						
-7.0 to -7.5	128 to 181						
-6.5 to -7.0	90.5 to 128						
-6.0 to -6.5	64.0 to 90.5						
-5.5 to -6.0	45.2 to 64.0						
-5.0 to -5.5	32.0 to 45.2						
-4.5 to -5.0	22.6 to 32.0						
-4.0 to -4.5	16.0 to 22.6						
-3.5 to -4.0	11.3 to 16.0						
-3.0 to -3.5	8.0 to 11.3						
-2.5 to -3.0	5.7 to 8.0						
-2.0 to -2.5	4.0 to 5.7						
-1.5 to -2.0	2.8 to 4.0						
-1.0 to -1.5	2.0 to 2.8						
< -1	< 2						
sample size total							

largest particles sampled	long-axis (mm)	intermediate-axis (mm)	short-axis (mm)	particle roundness	particle shape

15. Field Trip Exercise

project:	
sampling date:	sampling ID:
channel unit sampled:	sampling location:
pebble count method:	sampling interval (mm):
orientation of transect:	length of transects (m):
general description of sediment sampled (embeddedness, imbrication, particle shape, particle roundness, etc.):	

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-10.0 to -10.5	1024 to 1448						
-9.5 to -10.0	724 to 1024						
-9.0 to -9.5	512 to 724						
-8.5 to -9.0	362 to 512						
-8.0 to -8.5	256 to 362						
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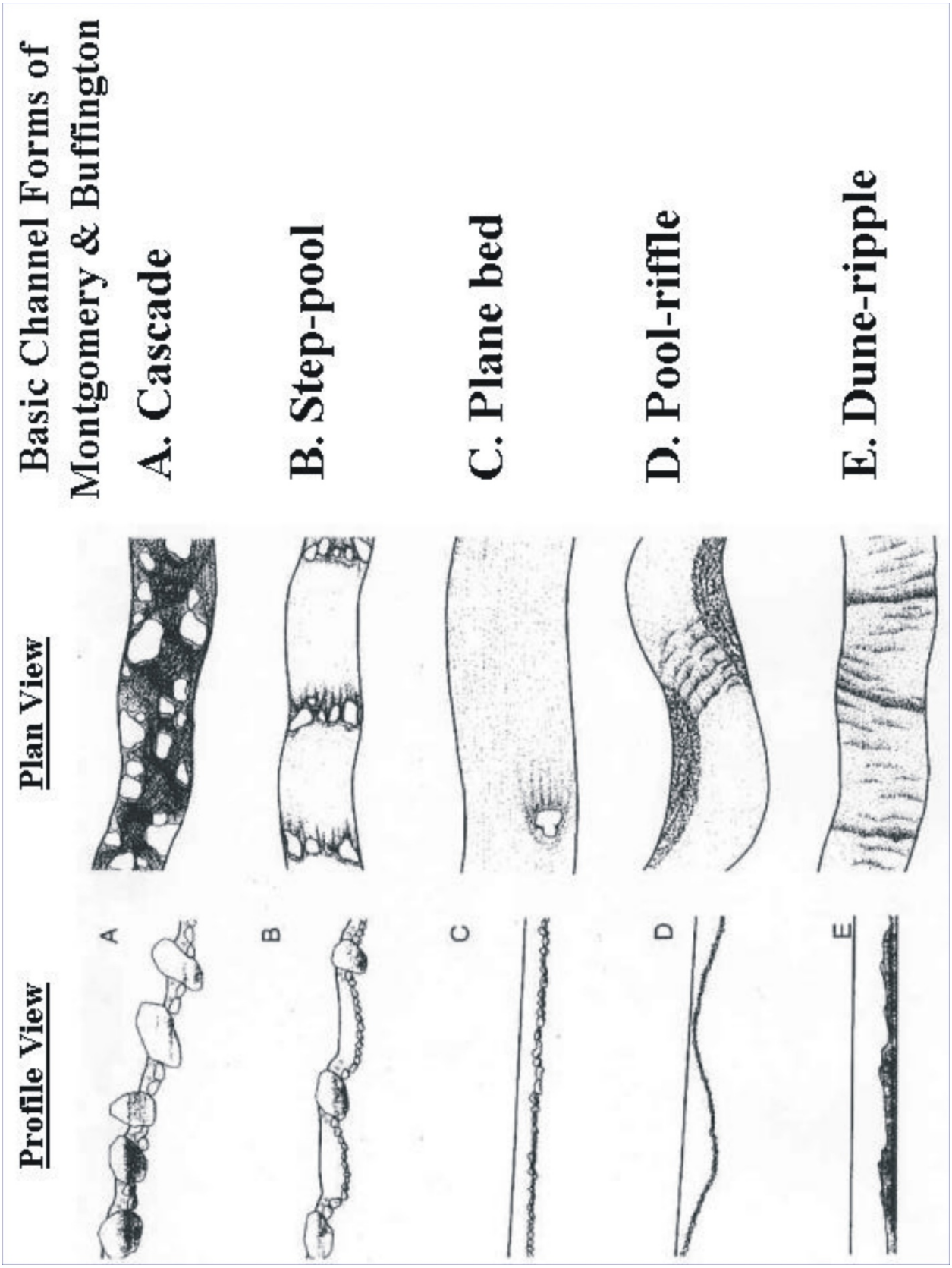
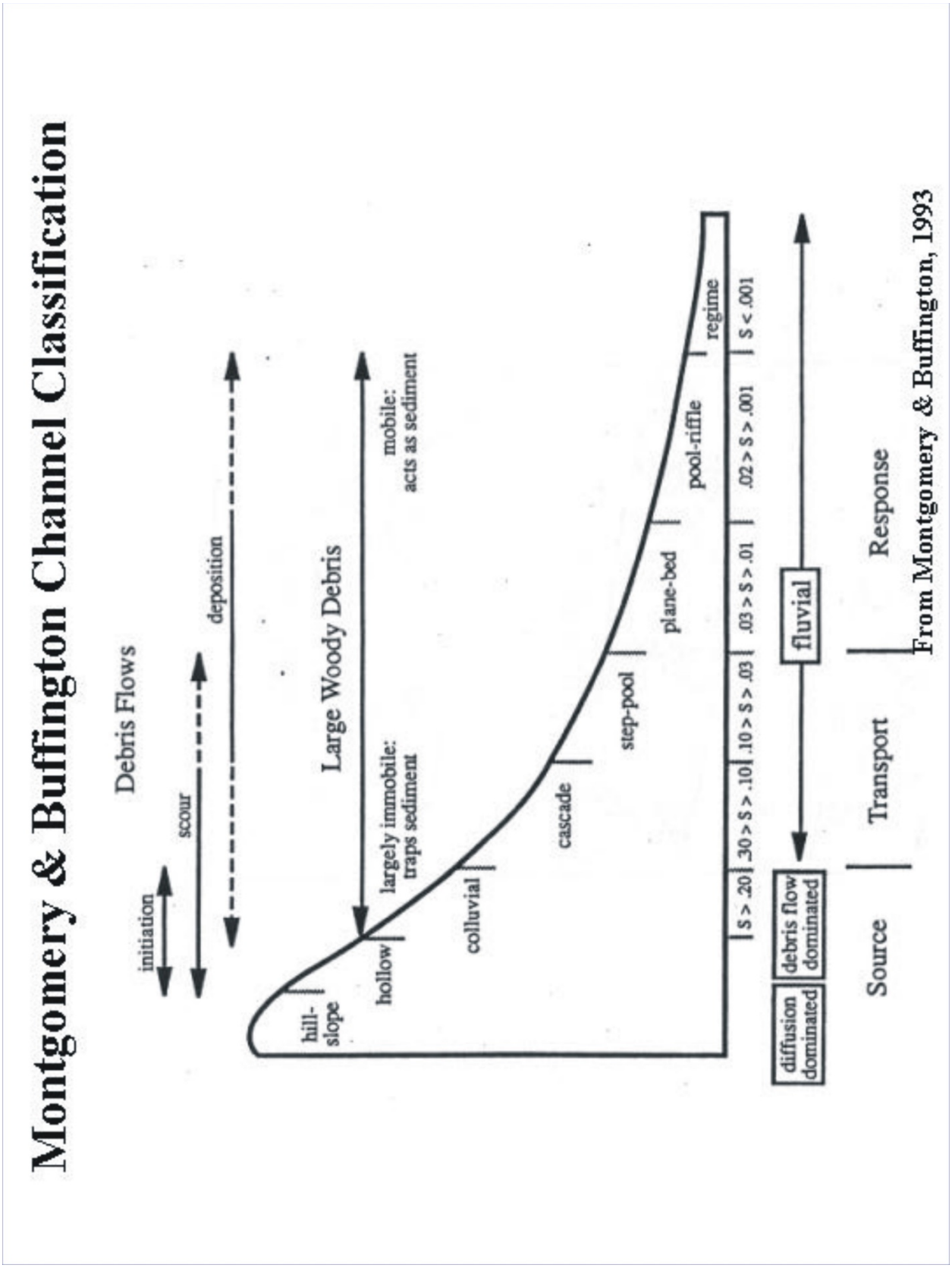
-7.0 to -7.5	128 to 181						
-6.5 to -7.0	90.5 to 128						
-6.0 to -6.5	64.0 to 90.5						
-5.5 to -6.0	45.2 to 64.0						
-5.0 to -5.5	32.0 to 45.2						
-4.5 to -5.0	22.6 to 32.0						
-4.0 to -4.5	16.0 to 22.6						
-3.5 to -4.0	11.3 to 16.0						
-3.0 to -3.5	8.0 to 11.3						
-2.5 to -3.0	5.7 to 8.0						
-2.0 to -2.5	4.0 to 5.7						
-1.5 to -2.0	2.8 to 4.0						
-1.0 to -1.5	2.0 to 2.8						
< -1	< 2						
sample size total							

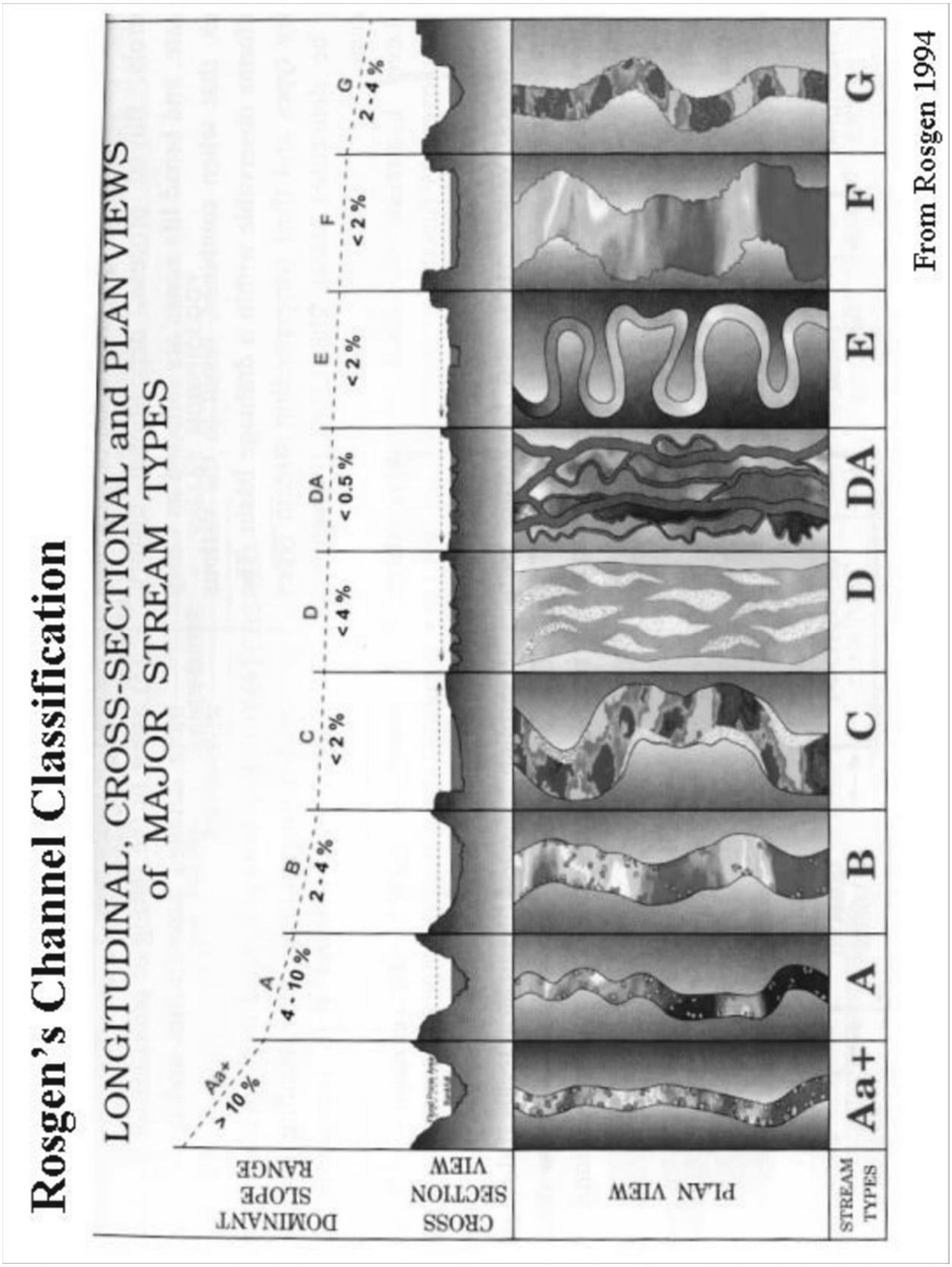
largest particles sampled	long-axis (mm)	intermediate-axis (mm)	short-axis (mm)	particle roundness	particle shape

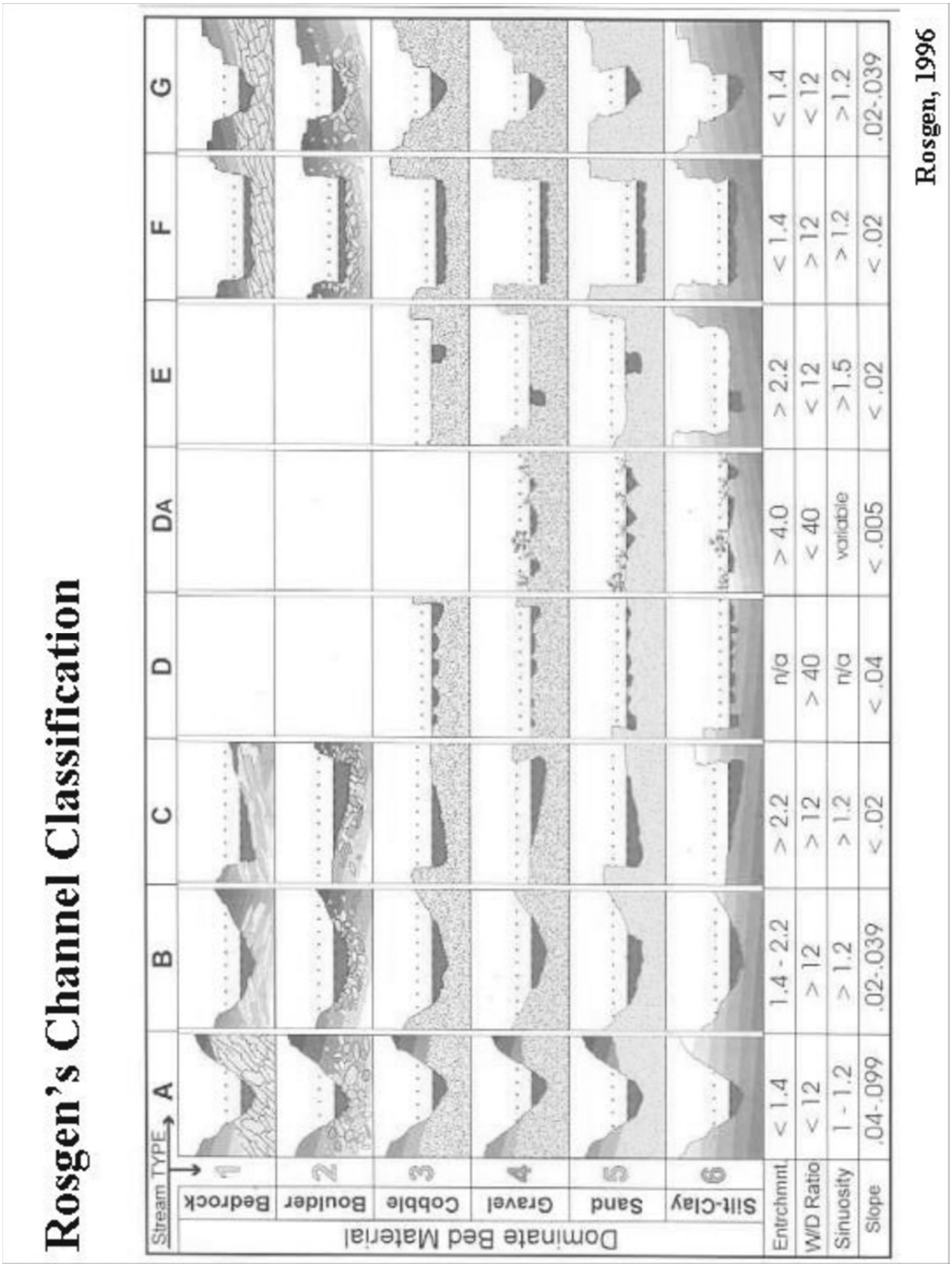

Profile View
Plan View
Basic Channel Forms of Montgomery & Buffington
A
A. Cascade
B
B. Step-pool
C
C. Plane bed
D
D. Pool-riffle
E
E. Dune-ripple


Montgomery & Buffington Channel Classification
Debris Flows
initiation
scour
deposition
Large Woody Debris
largely immobile: traps sediment
mobile: acts as sediment
hill-slope
hollow
colluvial
cascade
step-pool
plane-bed
pool-riffle
regime
S > .20
.30 > S > .10
.10 > S > .03
.03 > S > .01
.02 > S > .001
S < .001
diffusion dominated
debris flow dominated
fluvial
Source
Transport
Response
From Montgomery & Buffington, 1993

General Channel Characteristics for Channel Types of Montgomery and Buffington

Type of channel	Typical bed material	Typical slope	Typical sediment supply conditions	Typical transport capacity of stream	Typical reach type	Frequency of effective bedload transport (mobile bed)	Dominant roughness elements	Pool spacing (channel widths)
nonalluvial								
-colluvial	variable	> 0.20	high	high	source	infrequent	grains, LWD	variable
-bedrock	bedrock	variable	low	high	transport	not applicable	not applicable	variable
alluvial								
-cascade	boulder	0.10 to 0.30	low	high	transport	infrequent	grains, banks	< 1
-step-pool	cobble, boulder	0.03 to 0.10	low	high	transport	infrequent	bedforms, grains, LWD, banks	1 to 4
-plane bed 1	cobble	0.01 to 0.03	low	high	transport	infrequent	grains, banks	none
-plane bed 2	gravel	0.01 to 0.03	moderate	moderate	response	frequent	grains, banks	none
-pool-riffle	gravel	0.001 to 0.02	moderate	moderate	response	frequent	bedforms, grains, LWD, sinuosity, banks	5 to 7
-regime	sand	< 0.001	high	low	response	very frequent	sinuosity, bedforms	5 to 7
-braided	sand, gravel, cobble	< 0.030	high	low	response	frequent	bedforms	variable


Rosgen's Channel Classification
LONGITUDINAL, CROSS-SECTIONAL and PLAN VIEWS
of MAJOR STREAM TYPES
DOMINANT SLOPE RANGE
CROSS SECTION VIEW
PLAN VIEW
STREAM TYPES
Aa+
> 10 %
A
4 - 10 %
B
2 - 4 %
C
< 2 %
D
< 4 %
DA
< 0.5 %
E
< 2 %
F
< 2 %
G
2 - 4 %
Aa+
A
B
C
D
DA
E
F
G
From Rosgen 1994


Rosgen's Channel Classification
Stream TYPE
A
B
C
D
DA
E
F
G
Dominate Bed Material
Bedrock
Boulder
Cobble
Gravel
Sand
Silt-Clay
1
2
3
4
5
6
Entrchmnt
< 1.4
1.4 - 2.2
> 2.2
n/a
> 4.0
> 2.2
< 1.4
< 1.4
W/D Ratio
< 12
> 12
> 12
> 40
< 40
< 12
> 12
< 12
Sinuosity
1 - 1.2
> 1.2
> 1.2
n/a
variable
> 1.5
> 1.2
> 1.2
Slope
.04-.099
.02-.039
< .02
< .04
< .005
< .02
< .02
.02-.039
Rosgen, 1996

Channel characteristics of major Rosgen stream types

Stream Type	Channel characteristics
A	**Step-pool, or cascading:** plunge and scour pools, high energy, low sediment storage, stable;
B	**Riffles and rapids:** some scour pools, bars rare, stable;
C	**Pool-riffle sequences:** meandering, point bars, well-developed floodplain, banks stable or unstable;
D	**Braided:** multiple channels, shifting bars, scour, deposition, high sediment supply, eroding banks;
DA	**Anastomosing:** multiple channels, pool-riffle, vegetated floodplain, adjacent wetlands, stable banks;
E	**Meadow meanders:** well-developed floodplain, riffle-pool, relative high sediment conveyance;
F	**Valley meanders:** incised into valleys, poor floodplain, pool-riffle, banks stable or unstable;
G	**Gullies:** incised into hillslopes and meadows, high sediment supply, unstable banks, step-pool.

Recognizing Channel Instability: Johnson et al. (1999)

TABLE 1. Stability Indicators, Descriptions, and Ratings

Stability indicator (1)	Ratings: Excellent (1–3) (2)	Good (4–6) (3)	Fair (7–9) (4)	Poor (10–12) (5)
1. Bank soil texture and coherence	Clay and silty clay; cohesive material	Clay loam to sandy clay loam	Sandy clay to sandy loam	Loamy sand to sand; noncohesive material
2. Average bank slope angle (Pfankuch 1978)	Bank slopes <3H:1V (18° or 33%) on both sides.	Bank slopes up to 2H:1V (27° or 50%) on one or occasionally both banks.	Bank slopes to 1.7H:1V (31° or 60%) common on one or both banks.	Bank slopes over 60% common on one or both banks.
3. Vegetative bank protection (Pfankuch 1978; Thorne et al. 1996)	Wide band of woody vegetation with at least 90% density and cover. Primarily hard wood, leafy, deciduous trees with mature, healthy, and diverse vegetation located on the bank. Woody vegetation oriented vertically.	Medium band of woody vegetation with 70–90% plant density and cover. A majority of hard wood, leafy, deciduous trees with maturing, diverse vegetation located on the bank. Woody vegetation oriented 80–90° from horizontal with minimal root exposure.	Small band of woody vegetation with 50–70% plant density and cover. A majority of soft wood, piney, coniferous trees with young or old vegetation lacking in diversity located on or near the top of bank. Woody vegetation oriented at 70–80° from horizontal often with evident root exposure.	Woody vegetation band may vary depending on age and health with less than 50% plant density and cover. Primarily soft wood, piney, coniferous trees with very young, old and dying, and/or monostand vegetation located off of the bank. Woody vegetation oriented at less than 70° from horizontal with extensive root exposure.
4. Bank cutting (Pfankuch 1978)	Little or none evident. Infrequent raw banks less than 15 cm high generally.	Some intermittently along channel bends and at prominent constrictions. Raw banks may be up to 30 cm.	Significant and frequent. Cuts 30–60 cm high. Root mat overhangs.	Almost continuous cuts, some over 60 cm high. Undercutting, sod-root overhangs, and side failures frequent.
5. Mass wasting or bank failure (Pfankuch 1978)	No or little evidence of potential or very small amounts of mass wasting. Uniform channel width over the entire reach.	Evidence of infrequent and/or minor mass wasting. Mostly healed over with vegetation. Relatively constant channel width and minimal scalloping of banks.	Evidence of frequent and/or significant occurrences of mass wasting that can be aggravated by higher flows, which may cause undercutting and mass wasting of unstable banks. Channel width quite irregular and scalloping of banks is evident.	Frequent and extensive mass wasting. The potential for bank failure, as evidenced by tension cracks, massive undercuttings, and bank slumping, is considerable. Channel width is highly irregular and banks are scalloped.
6. Bar development (Lagasse et al. 1995)	Bars are mature, narrow relative to stream width at low flow, well vegetated, and composed of coarse gravel to cobbles.	Bars may have vegetation and/or be composed of coarse gravel to cobbles, but minimal recent growth of bar evident by lack of vegetation on portions of the bar.	Bar widths tend to be wide and composed of newly deposited coarse sand to small cobbles and/or may be sparsely vegetated.	Bar widths are generally greater than 1/2 the stream width at low flow. Bars are composed of extensive deposits of fine particles up to coarse gravel with little to no vegetation.
7. Debris jam potential (Pfankuch 1978)	Debris or potential for debris in channel is negligible.	Small amounts of debris present. Small jams could be formed.	Noticeable accumulation of all sizes. Moderate downstream debris jam potential possible.	Moderate to heavy accumulations of various size debris present. Debris jam potential significant.
8. Obstructions, flow deflectors, and sediment traps (Pfankuch 1978)	Rare or not present.	Present, causing cross currents and minor bank and bottom erosion.	Moderately frequent and occasionally unstable obstructions, cause noticeable erosion of the channel. Considerable sediment accumulation behind obstructions.	Frequent and often unstable causing a continual shift of sediment and flow. Traps are easily filled causing channel to migrate and/or widen.
9. Channel bed material consolidation and armoring (Pfankuch 1978)	assorted sizes tightly packed, overlapping, and possibly imbricated. Most material >4 mm	Moderately packed with some overlapping. Very small amounts of material <4 mm	Loose assortment with no apparent overlap. Small to medium amounts of material <4 mm	Very loose assortment with no packing. Large amounts of material <4 mm
10. Shear stress ratio [Eqs. (3)–(4)]	$\tau_o/\tau_c < 1.0$	$1.0 \le \tau_o/\tau_c < 1.5$	$1.5 \le \tau_o/\tau_c < 2.5$	$\tau_o/\tau_c \ge 2.5$
11. High flow angle of approach to bridge or culvert (Simon and Downs 1995)[a]	$0° \le \alpha \le 5°$	$5° < \alpha \le 10°$	$10° < \alpha \le 30°$	$\alpha > 30°$
12. Bridge or culvert distance from meander impact point (Simon and Downs 1995)[b]	$D_m > 35$ m	$20 < D_m \le 35$ m	$10 < D_m \le 20$ m	$0 < D_m \le 10$ m
13. Percentage of channel constriction (Simon and Downs 1995)	0–5%	6–25%	26–50%	>50%

Note: Ranges of values in ratings columns provide possible rating values for each factor.
[a]α = approach flow angle to bridge or culvert.
[b]D_m = distance from bridge or culvert upstream to meander impact point.

TABLE 2. Stability Indicators and Weights for Stability Assessment Scheme

Stability indicator (1)	Weight (2)
1. Bank soil texture and coherence	0.6
2. Average bank slope angle	0.6
3. Vegetative bank protection	0.8
4. Bank cutting	0.4
5. Mass wasting or bank failure	0.8
6. Bar development	0.6
7. Debris jam potential	0.2
8. Obstructions, deflectors, and sediment traps	0.2
9. Bed material consolidation and armoring	0.8
10. Shear stress ratios	1.0
11. High flow angle of approach to bridge	0.8
12. Distance from meander impact point	0.8
13. Percentage of channel constriction	0.8

TABLE 3. Overall Rating Ranges

Description (1)	Rating, R (2)
Excellent	$R < 32$
Good	$32 \le R < 55$
Fair	$55 \le R < 78$
Poor	$R \ge 78$

15. Field Trip Exercise

A qualitative descriptive method for determining the relative stability of channel bedforms and features.

Bedform	**Material Type and Size**	**Stability Rating**	**Bedform Characteristics**
Steps	*Boulder-Cobble*	High	Boulder-cobble steps that span the width of the active channel and are keyed into the banks. Particles are tightly packed. Keyed-in particles extend below the maximum depth of the pool below the step.
Steps	*Boulder-Cobble, Cobble-Gravel*	Mod-erate	Boulder-cobble or cobble-gravel steps that do not span the width of the active channel or are loosely keyed into the banks. Particles are moderately packed or key pieces are not in contact with each other. Keyed-in particles extend below the maximum depth of the pool below the step.
Steps	*Cobble-Gravel*	Low	Boulder-cobble or cobble-gravel steps that do not span the width of the active channel. Evidence of lateral scour along flanks of structure. Particles are poorly packed and key pieces are not in contact with each other. Keyed-in particles do not extend below the maximum depth of the pool below the step.
Riffles with Ribs	*Cobble-Boulder, Cobble-Gravel*	High	Typically steep riffles composed of cobble-boulder or cobble-gravel material that are tightly packed and embedded in the channel bed. Pool tail crests and/or coarse transverse ribs (microsteps) within the riffle span the width of the active channel. Pool tail crests and transverse rib particles are tightly packed and embedded in the channel bed, and coarser than the surrounding riffle material.
Riffles	*Cobble-Boulder, Cobble-Gravel*	Mod-erate	Riffles composed of cobble-boulder or cobble-gravel material that are moderately packed and embedded in the channel bed.
Riffles	*Cobble-Gravel*	Low	Riffles composed of cobble-gravel material that are loosely packed and embedded in the channel bed.
Steps and Riffles	*Bedrock*	High	Steps and riffles composed of bedrock (exposed at surface or just below a thin veneer of alluvial material) that spans the width of the active channel.
Steps and Riffles	*Wood and Rock*	High	Wood and rock (boulder-cobble) that form a composite structure. Combination of wood and rock span the width of the active channel and is keyed into the banks. Wood is sound and competent, and partially anchored by the channel bed and banks. Boulder-cobble particles are tightly packed and embedded in the channel bed. For steps, keyed-in particles extend below the maximum depth of the pool below the step.
Steps and Riffles	*Wood and Rock*	Mod-erate	Wood and rock (boulder-cobble) that form a composite structure. Combination of wood and rock that span the span the width of the active channel, but is not well keyed into the banks. Evidence of lateral scour along flanks of structure. Wood is beginning to soften and decay, and is partially anchored by the channel bed and banks. Boulder-cobble particles are moderately packed and embedded in the channel bed. For steps, keyed-in particles extend below the maximum depth of the pool below the step.
Steps and Riffles	*Wood and Rock*	Low	Wood and rock (boulder-cobble) that form a composite structure. Combination of wood and rock that do not span the width of the active channel. Evidence of lateral scour along flanks of structure. Wood is rotten and punky, and not anchored by the channel bed and banks. Boulder-cobble particles are loosely packed and embedded in the channel bed. For steps, keyed-in particles do not extend below the maximum depth of the pool below the step.
Steps and Riffles	*Wood*	High	Wood is sound and competent. The wood piece or pieces span the width of the active channel and are well anchored by the channel bed and banks.
Steps and Riffles	*Wood*	Mod-erate	Wood is beginning to soften and decay. The wood piece or pieces do not completely span the width of the active channel and are poor to moderately anchored by the channel bed and banks.
Steps and Riffles	*Wood*	Low	Wood is rotten and punky. The wood piece or pieces do not completely span the width of the active channel and are not or poorly anchored by the channel bed and banks.
Beaver Dams	Wood, Sticks, Mud	Mod-erate	Beaver dam is well constructed with a good distribution of large wood, small sticks, and mud. Beaver are actively utilizing and maintaining the dam. Abundant beaver food resources in vicinity of dam for long-term sustainability. Consider consequences of failure from large flood over the service-life of the crossing structure.
Beaver Dams	Wood, Sticks, Mud	Low	Beaver dam is poorly constructed and inactive (i.e., not maintained}. Large wood pieces are not present. Evidence of lateral scour along flanks of structure. Also, construction of beaver dams on large streams during drought conditions. High likelihood that these structures will fail during large floods or when flow conditions return to normal.