Upper Turtle River Watershed Dam #9, Larimore Dam

Appendix D-8: Stream Classification and Riparian Area Assessment

Grand Forks County Water Resource District
USDA - NRCS

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Introduction

Background

Larimore Dam (also known as Upper Turtle River Dam No. 9) is located on the South Branch of the Turtle River in Grand Forks County, North Dakota, approximately 3½ miles northeast of the city of Larimore in Section 32, T152N, R54W. It was constructed in 1979 under the Watershed Protection Program (PL 83-566) of the USDA-NRCS (formerly known as the USDA-SCS) as a multi-purpose structure with the primary functions of flood risk reduction and recreation. Larimore Dam is one of eight (8) PL 83-566 flood risk reduction structures in the Upper Turtle River Watershed and is in series with three (3) of those structures separately. Those three structures are Upper Turtle River Dams 6 (Kolding Dam), 7, and 8.

As part of the Watershed Plan and rehabilitation effort, an assessment of the Turtle River and riparian areas near the dam is required. The purpose of the analysis completed in this technical memorandum is to supplement the development of a conceptual design for an alternative where the dam is decommissioned, or for a no-action alternative where a breach of the dam is possible.

The Rosgen Stream Classification System was used to provide a morphological description of the Turtle River both upstream and downstream of Larimore Dam. Through this effort, the stream was classified using a Level II assessment out of the River Stability Field Guide (Rosgen, 2014a). The Level II assessment typically involves field measurements to describe the morphology of the river and used to classify the stream being analyzed. The Rosgen Stream Classification System has been widely used in the Midwest to describe the geomorphic condition of rivers. Stream classification is dependent on various field measurements. Experience with fluvial geomorphology, engineering, and hydrology is required for the staff conducting the field measurements and observations.

In addition to the stream classification and visual-based habitat assessment, a Level III river stability assessment that involves the collection and analysis of specific channel stability variables was completed to predict river stability. More information on the Level III assessment is available in the River Stability Field Guide (Rosgen, 2014a).

A Stream Visual Assessment Protocol (second version – SVAP2) was also conducted using the same upstream and downstream locations as the Rosgen assessments. The protocol was developed by the NRCS in the 1990s and updated in 2009, and it relies on visual observations of channel, water, and aquatic habitat conditions.

Rapid Bioassessment Protocols (RBP) (Barbour, Gerritsen, Snyder, & Stribling, 1999) were used to assess the biological condition of riparian areas for the Turtle River in a cost-effective manner. For the purposes of the Larimore Dam rehabilitation effort, the condition of riparian areas was evaluated by using the visual- based habitat assessment in Section 5.2 of Rapid Bioassessment Protocols for Use in Stream and Wadeable Rivers (Barbour, Gerritsen, Snyder, & Stribling, 1999). The visual-based habitat assessment provides a qualitative rating for aquatic

habitat. The different elements of aquatic habitat to be evaluated include channel substrate, channel morphology, bank structure, and vegetation.

Data Acquisition

Locations

Seasonal (winter) restrictions prohibited field data collection at this stage of the analyses. Locations selected for analysis were partially driven by the availability of off-site tools for use in the analyses. The sites chosen for both the upstream and downstream locations are representative of the stream conditions in those reaches on the basis of landform, soils, climate, slope, adjacent land use, and other criteria.

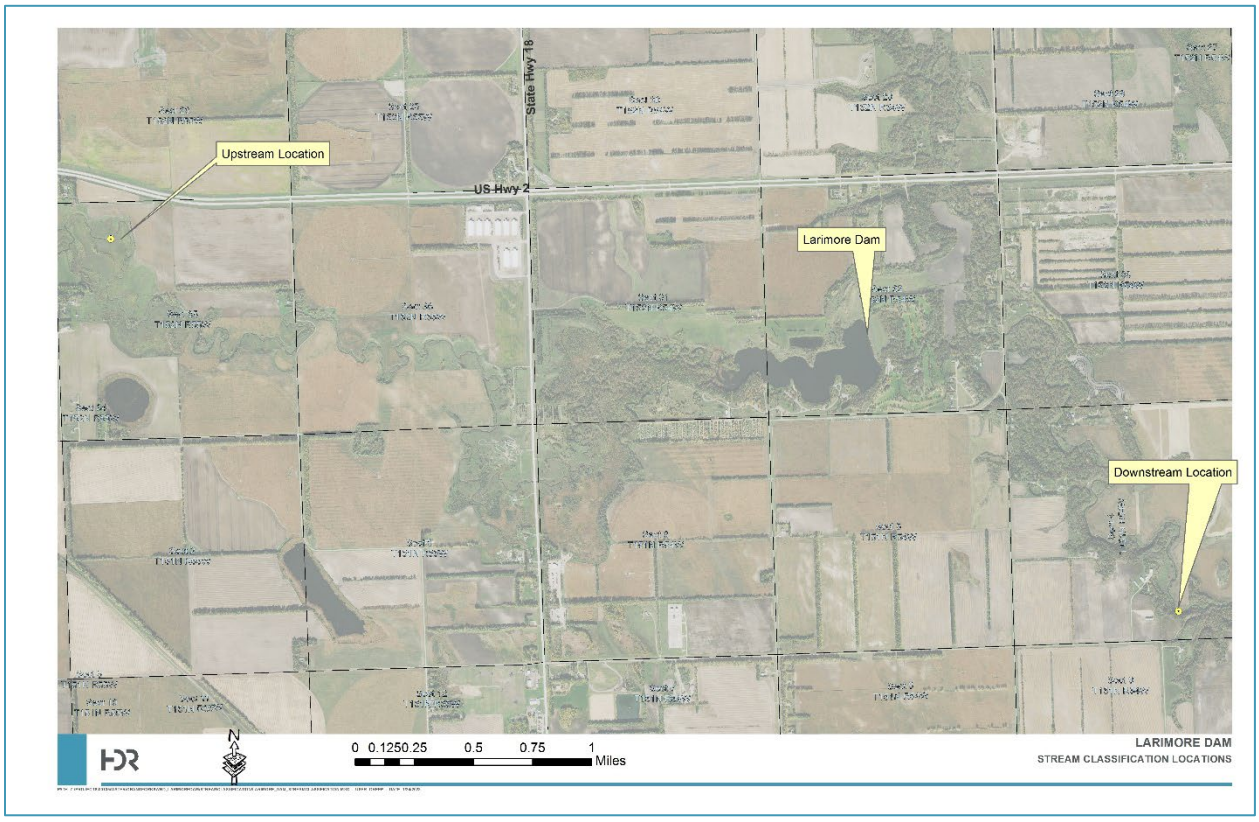


Figure 1 – Stream Classification Locations

Both locations analyzed had primary artificial factors in their geomorphological settings, namely each were downstream of a dam or dams. The downstream location is obviously below Larimore Dam and the upstream location downstream of three dams (in parallel); Upper Turtle River Dam 6 (Kolding Dam), Upper Turtle River Dam 7, and Upper Turtle River Dam 8. The downstream location is approximately 17,900 feet, or 3.4 miles (channel distance) downstream of Larimore Dam and the upstream location is approximately 37,800 feet, or 7.2 miles (channel distance) upstream of the Larimore Dam reservoir. A surveyed channel and floodplain cross section was available at the downstream location. LiDAR data was utilized at the upstream

location. The parameters upstream of Larimore Dam were analyzed to determine the stream classification where Larimore Dam would presumably have little to no effect on the stream

These locations and the reaches in the vicinity of them were used for each of the three analysis methods (Rosgen, SVAP2, and RPB).

Data Collection Highlights

Various channel and floodplain metrics are needed to complete the analyses. Numerous channel and floodplain photos, surveyed channel and floodplain cross-sections, LiDAR data, aerial photography, USGS gage data, Web Soil Survey, and other data tools were utilized to replicate field data collection. Below is a more detailed list of data collected for the analyses:

- Ground photos
    - Downstream x-section and floodplain survey, 2020 and 2022
    - Field reconnaissance, 2020
    - Wetland field delineation, 2022
- Channel and floodplain field survey, 2020 and 2021
- LiDAR data, James River Basin, Phase 8, Block C, Quality Level 2 (1-meter horizontal resolution, 2.7cm – 3.8cm vertical accuracy)
- Aerial photography, National Agriculture Imagery Program (NAIP), 2021
- Aerial photography, Google Earth, various years
- USGS Gaging Station 05082625, Turtle River at Turtle River State Park
- USGS StreamStats website
- NWS Normal Depth Calculator website
- Upper Turtle River HEC-RAS model, USDA-NRCS, 2022
- Upper Turtle River HEC-HMS model, USDA-NRCS, 2022

Data Analyses

After all necessary data was acquired from the offsite review, the data analysis was conducted for the stream classification (Level II assessment), the RBP assessment, the SVAP2 assessment, and the river stability prediction (Level III assessment).

Level II Stream Classification Analysis

Site specific data is populated in the Rosgen Level II worksheets and the stream is classified according to the categories. This category is compared to regional curves developed in comparable watersheds in northeastern North Dakota. The elevation of bankfull discharge is the single most important parameter used in Level II classifications. The stage of bankfull discharge is related to important channel dimensions such as width. Moreover, the bankfull channel width is required to estimate two of the five primary Level II criteria (i.e., entrenchment ratio and width/depth ratio). For this reason, bankfull verification analysis was completed which involved comparing bankfull metrics to the predicted values informed by regional curves established in comparable northeastern North Dakota watersheds.

Regional Data Analysis

Regional data for northeastern North Dakota was obtained from the NRCS. Figure 2, Figure 3, Figure 4, and Figure 5 show the regional data and the Turtle River data plotted on logarithmic axes with drainage area on the x-axis. The y-axis represents key parameters used with the Rosgen Stream Classification.

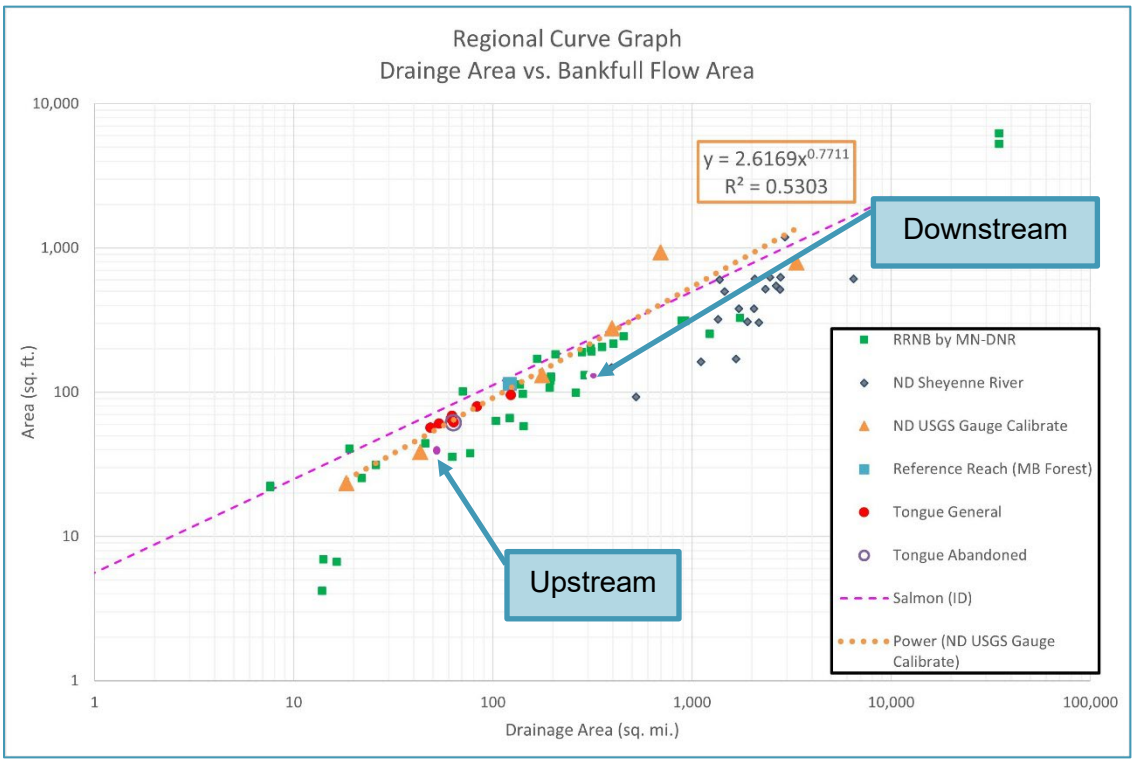


Figure 2 – Regional Curves – Drainage Area vs. Bankfull Flow Area

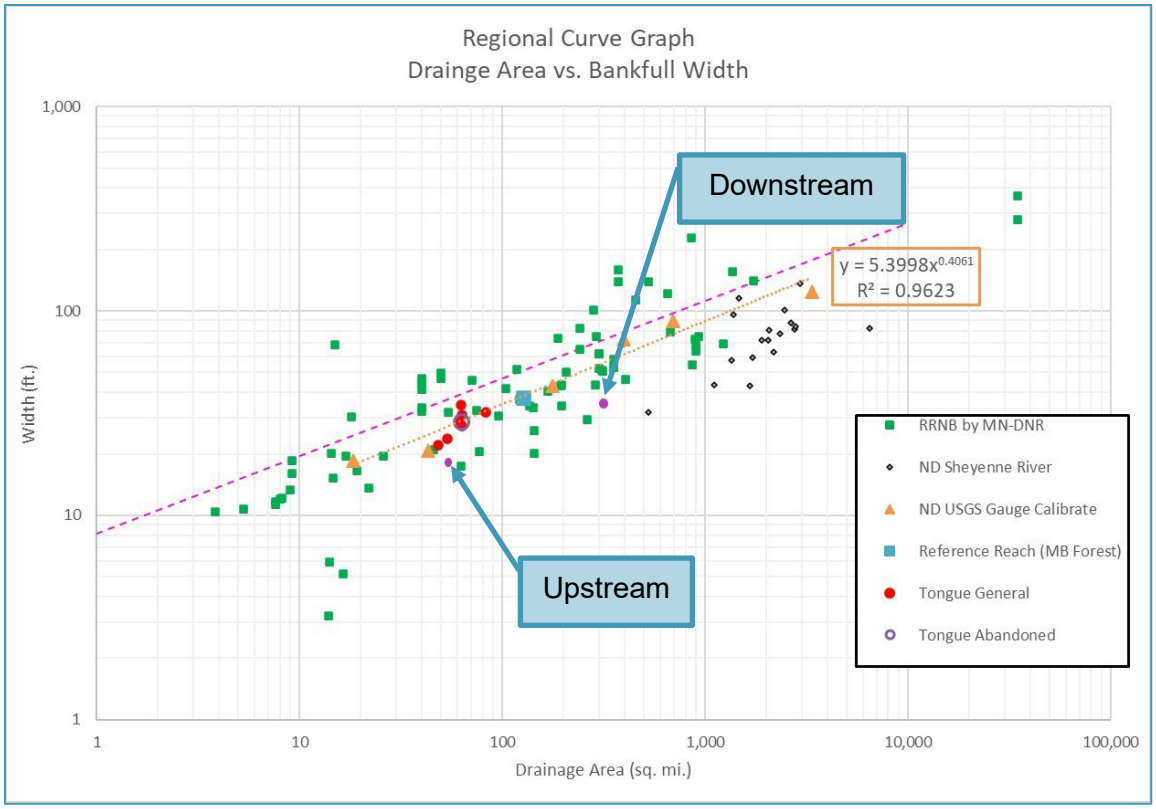


Figure 3 - Regional Curves – Drainage Area vs. Bankfull Width

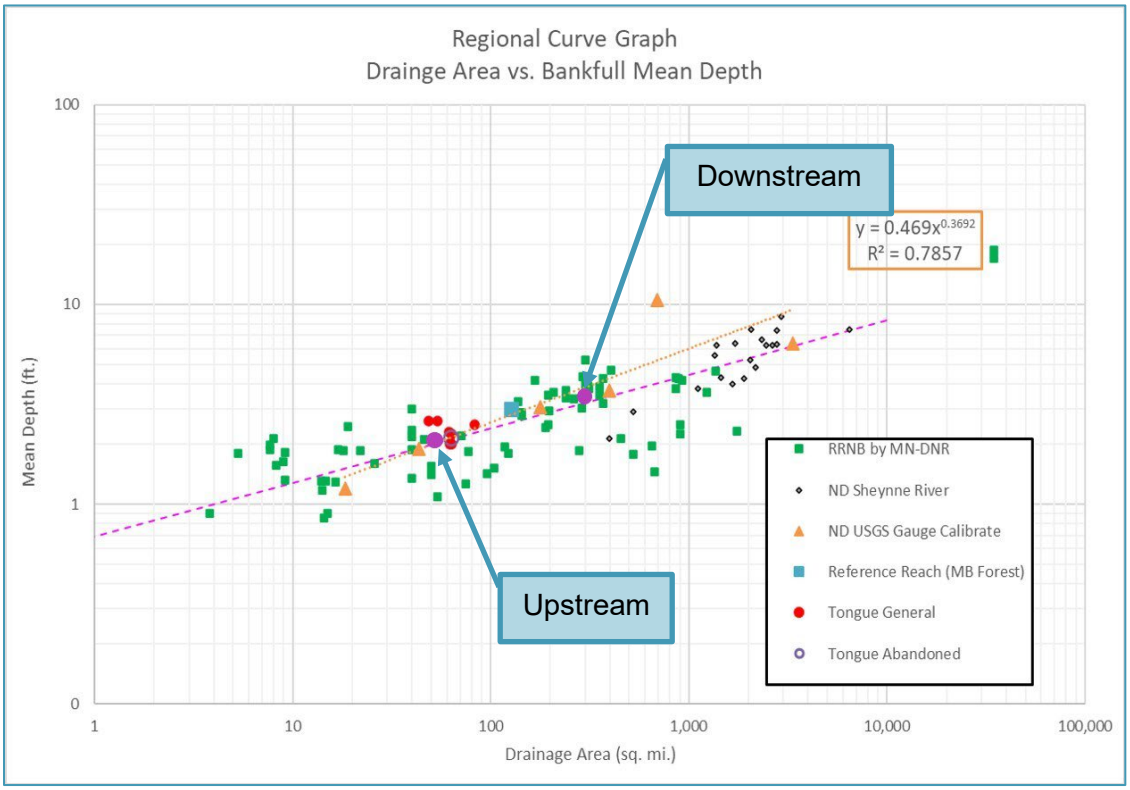


Figure 4 - Regional Curves – Drainage Area vs. Bankfull Mean Depth

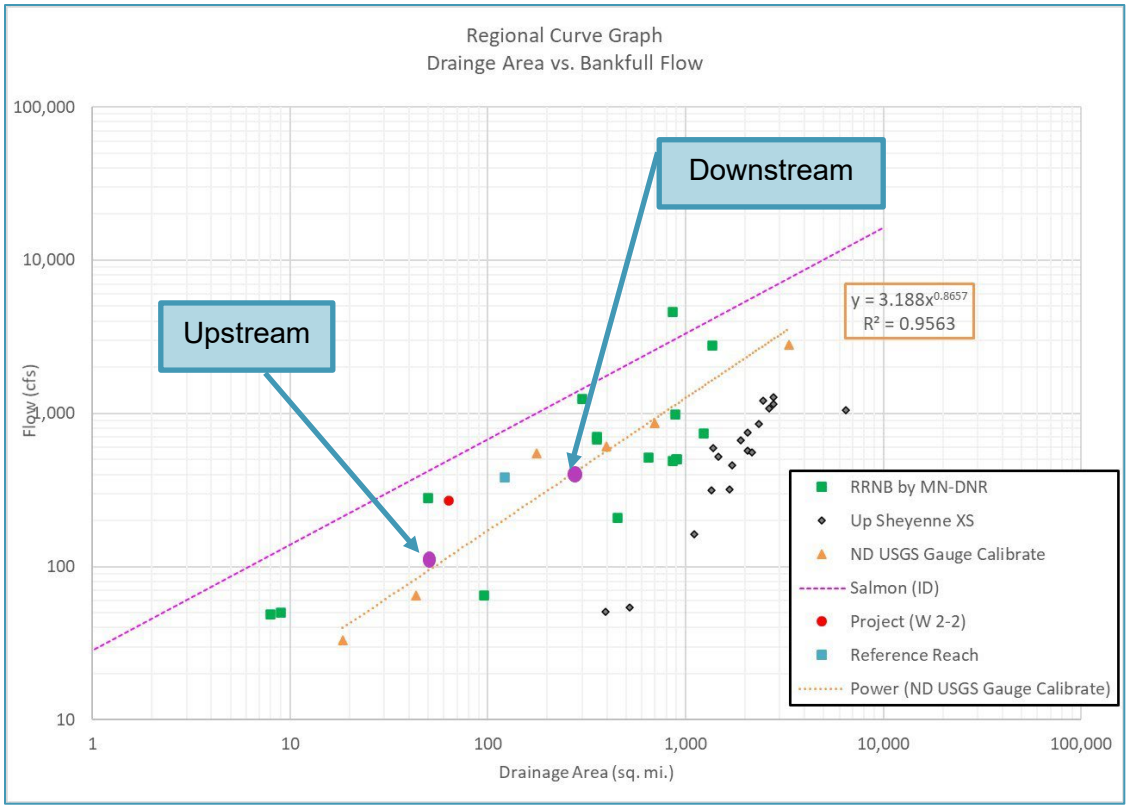


Figure 5 - Regional Curves – Drainage Area vs. Bankfull Flow

In general, the data from the Turtle River is slightly below the trendlines plotted for the regional data. The data are not significantly distant from the plotted trendline and are considered acceptable for this analysis.

Stream Classification

The parameters determined upstream and downstream of Larimore Dam are shown in Table 1. For definitions or further clarification on each of the parameters listed in the table, refer to the River Stability Field Guide (Rosgen, 2014a). Results shown in Table 1 are used along with the Rosgen Stream Classification key shown in Figure 6.

Starting at the top of Figure 6, the Turtle River is a single thread channel with an entrenchment ratio of about 3.42. The width-to-depth ratio is 9.4, which falls in the category of a very low width-to-depth ratio. The sinuosity of the channel is 1.92. The data indicates that the Turtle River upstream of Larimore Dam is an E type stream. Further refinement based on the makeup of the bed material, which would be considered sandy, results in a stream classification of E5 for the Turtle River upstream of Larimore Dam.

Similarly, the parameters downstream of Larimore Dam were analyzed to determine the stream classification where Larimore Dam would presumably have little to no effect on the stream. Starting at the top of Figure 6, the Turtle River is a single thread channel with an entrenchment ratio of about 6.67. The width-to-depth ratio is 9.7, which falls in the category of a very low width-to-depth ratio. The sinuosity of the channel is 1.54. The data indicates that the Turtle River downstream of Larimore Dam is an E type stream. Further refinement based on the

makeup of the bed material, which would be considered sandy, results in a stream classification of E5 for the Turtle River downstream of Larimore Dam.

Table 1 – Rosgen Classification Parameters

Parameter	Upstream of Larimore Dam	Downstream of Larimore Dam
Bankfull Width (W_{bkf})	19 ft	35 ft
Bankfull Mean Depth (d_{bkf})	2.02 ft	3.60 ft
Bankfull Cross-Sectional Area (A_{bkf})	38.3 ft^2	127.7 ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf})	9.4 ft/ft	9.7 ft/ft
Bankfull Maximum Depth (d_{max})	3.12 ft	5.82 ft
Flood-Prone Area Width (W_{fpa})	65 ft	233 ft
Entrenchment Ratio (ER)	3.42 ft/ft	6.67 ft/ft
Channel Materials (Particle Size Index D_{50})	5 mm	5 mm
Average Water Surface Slope (S)	0.0037 ft/ft	0.0012 ft/ft
Channel Sinuosity (k)	1.92 ft/ft	1.54 ft/ft

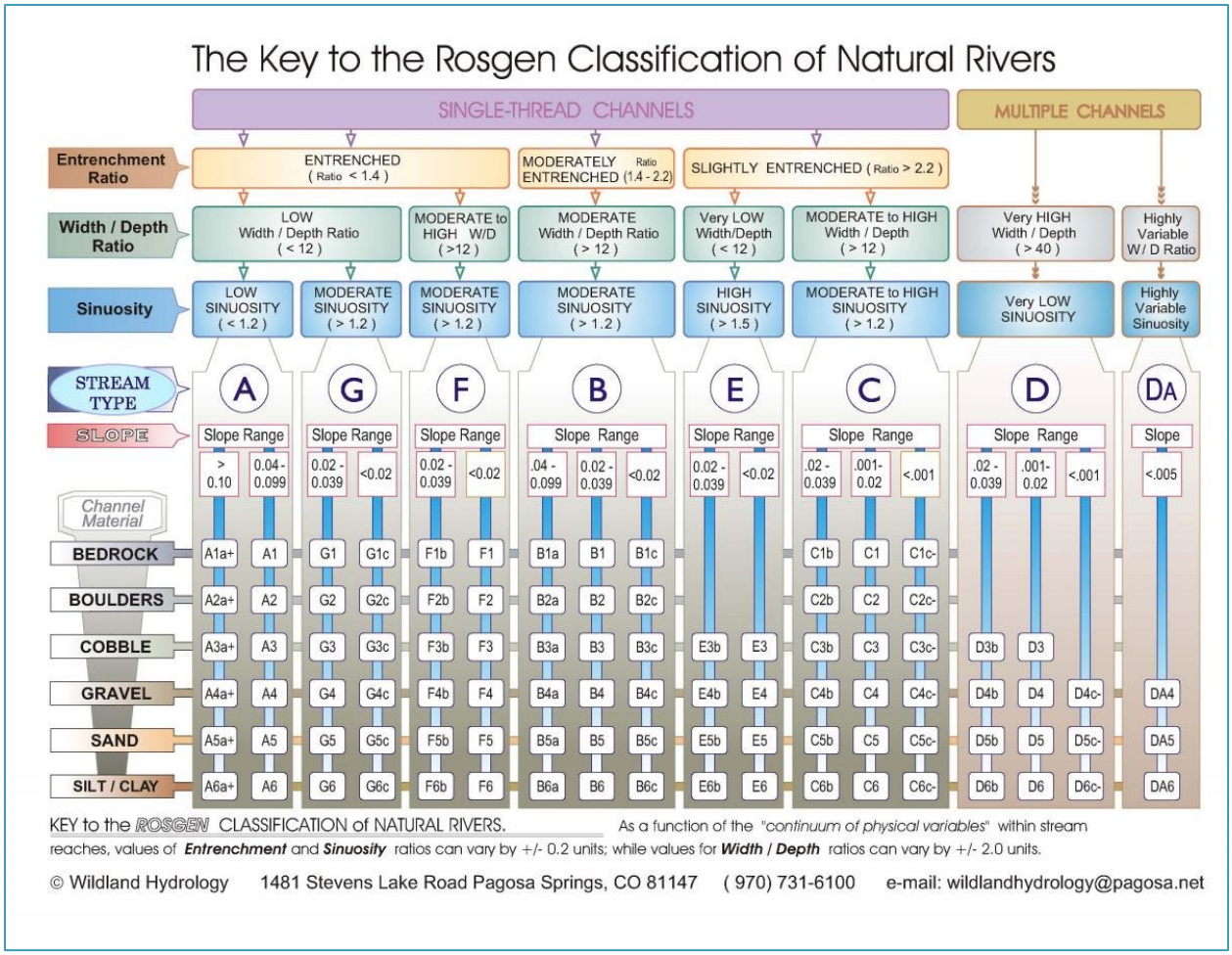


Figure 6 – Rosgen Stream Classification Key for Natural Rivers (Rosgen, 2014a)

River Stability Prediction – Level III Analysis

For this effort, a Level III analysis was completed using the data described previously.

Stream Stability Indices

Stream stability indices – such as depositional patterns within the stream, and channel blockages – were evaluated both upstream and downstream of Larimore Dam. The results of the stream stability indices are shown on Worksheets 3-2 through 3-10 shown in Appendix D-8-D. Additionally, Worksheet 2-3 from the Level II analysis is included for reference. These worksheets were extracted from River Stability – Forms and Worksheets (Rosgen, 2014b).

The channel flow regime is considered perennial for both the upstream and downstream locations. Runoff is generated by snowmelt, rainfall, and rain on snow scenarios. The flow regime of the downstream location, approximately 17,900 channel feet downstream of Larimore Dam, has had nearly 50 years of regulated flow from upstream dams (Upper Turtle River Dam 6

(Kolding Dam), Upper Turtle River Dam 7, Upper Turtle River Dam 8, and Upper Turtle River Dam 9 (Larimore Dam)). Similarly, the upstream location, approximately 37,800 channel feet upstream of the Larimore Dam reservoir is impacted by a trio of dams upstream of it in parallel – Upper Turtle River Dam 6 (Kolding Dam), Upper Turtle River Dam 7, and Upper Turtle River Dam 8.

The observation location downstream of the dam has irregular meanders, and the same can be said for the upstream observation location. The downstream observation location appeared to have a few additional mid-channel bars compared to the upstream location. A higher amount of channel blockages was noted at the downstream observation location when compared to the upstream location due to a greater availability of larger tree branches in the reach to fall into channel.

The degree of channel incision is slightly higher for the location upstream of Larimore Dam. The width-to-depth ratio state is considered moderately unstable for both observation locations. The meander width ratio, which is a measure of confinement, indicates little to no departure from reference conditions for both the downstream and upstream locations. To summarize the stream stability indices, the Pfankuch channel stability rating (1975) was used. Both observation locations produced a good stability rating for an E5 stream type.

Channel Stability

Worksheets 3-11 through 3-21 from River Stability – Forms and Worksheets (Rosgen, 2014b) are used to assess the stability of the channel. The stability of the channels is dependent on bank height and angle, root depth and density, bank substrate, and bank surface protection offered by vegetation. Observations and data from Web Soil Survey and other sources were utilized for both observation locations. The completed worksheets are shown in Appendix D-8-D.

The results from the data upstream of Larimore Dam show that the channel is stable with a slight tendency toward being vertically incised. There is also a slight tendency toward channel enlargement, and it is showing the ability to supply a moderate amount of sediment in the reach. The lack of point bar sediment along with the stream stability indices upstream of the dam indicate that deposition and incision are not expected to occur in significant magnitudes.

The results from the data downstream of Larimore Dam show that the channel is stable in the lateral direction and shows a tendency toward being vertically incised. There is a slight tendency toward channel enlargement, and it is showing the ability to supply a moderate amount of sediment in the reach. The lack of point bar sediment along with the stream stability indices upstream of the dam indicate that deposition and incision are not expected to occur in significant magnitudes.

Rapid Bioassessment Protocols

Observations were made utilizing available data for the 10 categories involved in the riparian area assessment using Rapid Bioassessment Protocols (RBP). The categories are given in Table 2.

Table 2 - Rapid Bioassessment Protocol Categories

Category No.	Category Name
1	Epifaunal Substrate / Available Cover
2	Pool Substrate Characterization
3	Pool Variability
4	Sediment Deposition
5	Channel Flow Status
6	Channel Alteration
7	Channel Sinuosity
8	Bank Stability (scored separately for left and right banks)
9	Vegetative Protection (scored separately for left and right banks)
10	Riparian Vegetative Zone Width (scored separately for left and right banks)

After the 10 categories were rated for the observation locations upstream and downstream of the dam, the data was compiled and is shown in Table 3. The downstream assessment location resulted in a higher rating than the upstream location. Photos taken during the RBP assessment are provided in Appendix D-8-A and the RBP scoring sheets in Appendix D-8-B at the end of this document.

Table 3 – Rapid Bioassessment Protocol Totals

	Category Rating Number										
Location	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Upstream of Dam	8	13	13	18	18	20	16	16	16	16	154
Downstream of Dam	11	15	16	18	19	20	15	18	16	18	166

Stream Visual Assessment Protocol

The Stream Visual Assessment Protocol, Version 2 (SVAP2) is similar to the RBP discussed earlier and was developed by the USDA-NRCS. The same data sources and site locations utilized for the Rosgen and RBP exercises were also used here.

There are also 10 categories in SVAP2, with an additional 5 categories to be scored if they are applicable. Those are presented in Table 4.

Table 4 - Stream Visual Assessment Protocol, Version 2 Categories

Category No.	Category Name
1	Channel Condition
2	Hydrologic Alteration
3	Riparian Zone
4	Bank Stability
5	Water Appearance
6	Nutrient Enrichment
7	Barriers to Fish Movement
8	Instream Fish Cover
9	Pools
10	Invertebrate Habitat
11	Canopy Cover (scored if applicable)
12	Manure Presence (scored if applicable)
13	Salinity (scored if applicable)
14	Riffle Embeddedness (scored if applicable)
15	Macroinvertebrates Observed (scored if applicable)

After the ratings were assigned for the observation locations upstream and downstream of the dam, the data was compiled and is shown in Table 5. The habitat assessment for the Turtle River resulted in less-than-optimal ratings for both locations. The downstream assessment location resulted in a higher rating ("fair") with the upstream location at a lower rating ("poor"). Photos taken during the SVAP2 assessment are provided in Appendix D-8-A and the RBP scoring sheets in Appendix D-8-C at the end of this document.

Table 5 - Stream Visual Assessment Protocol, Version 2 Ratings

	Category Rating Number								
Location	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Upstream of Dam	8	5	8	8	6	7	5	5	6
Downstream of Dam	8	5	8	8	6	8	5	6	6

	Category Rating Number								
Location	**10**	**11**	**12**	**13**	**14**	**15**	**Total**	**Score**	**Rating**
Upstream of Dam	4	NA	NA	NA	NA	NA	62	6.2	***Fair***
Downstream of Dam	7	6	NA	NA	NA	NA	73	6.6	***Fair***

Conclusion

Data was collected upstream and downstream of Larimore Dam. The data was used for a Level II stream classification, which results in a Rosgen Stream Classification of type E5 upstream of the dam and a stream type E5 downstream of the dam.

A Level III river stability analysis was also completed for both observation locations. This analysis indicates that the upstream channel has some lateral and vertical instability when compared to the downstream channel. Other than the increased channel incision and lateral instability, the upstream channel seems to be stable when compared to the downstream observation location. Based on the results, minimal lateral movement or vertical aggradation is expected if Larimore Dam were decommissioned.

A qualitative assessment of the Turtle River was completed using a visual-based habitat assessment with Rapid Bioassessment Protocols (Barbour, Gerritsen, Snyder, & Stribling, 1999). The results of the assessment show that the habitat for the Turtle River near Larimore Dam is sub-optimal to optimal.

A Stream Visual Assessment Protocol (SVAP2) was conducted at both the upstream and downstream sites. Both assessments resulted in a “Fair” rating, which includes hydrologic effects of the dams upstream of each location whereas the RBP does not.

References

Barbour, M. T., Gerritsen, J., Snyder, B. D., & Stribling, J. B. (1999). Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers. Washington, D.C.: US Environmental Protection Agency.

Pfankuch, D. J. (1975). Stream Reach Inventory and Channel Stability Evaluation. U.S. Department of Agriculture, Forest Service No. R1-75-002, GPO No. 696-260/200. Washington, D.C.: U.S. Government Printing Office.

Rosgen, D. (1996). Applied River Morphology. Pagosa Springs, Colorado, United States of America: Wildland Hydrology.

Rosgen, D. (2014a). River Stability Field Guide (2nd ed.). (D. Geenen, Ed.) Fort Collins, Colorado: Wildland Hydrology.

Rosgen, D. (2014b). River Stability Forms & Worksheets (2nd ed.). (D. Geenen, Ed.) Fort Collins, Colorado: Wildland Hydrology.

National Biology Handbook, Part 614, Stream Visual Assessment Protocol Version 2 (2009), U.S. Department of Agriculture, Natural Resources Conservation Service.

APPENDIX D-8-A
Photos for Rosgen, RBP, and SVAP2 Assessments

U.S. Location: NW ¼ Section 35, T152N, R55W, Approx Lat/Long: 47º 56’ 42”; 97º 39’ 42”

D.S. Location: SE ¼ Section 4, T151N, R54W, Approx Lat/Long: 47º 55’ 12”; 97º 33’ 57”

D.S. Location: SE ¼ Section 4, T151N, R54W, Approx Lat/Long: 47º 55’ 12”; 97º 33’ 57”

D.S. Location: SE ¼ Section 4, T151N, R54W, Approx Lat/Long: 47º 55’ 12”; 97º 33’ 57”

D.S. Location: SE ¼ Section 4, T151N, R54W, Approx Lat/Long: 47º 55’ 12”; 97º 33’ 57”

APPENDIX D-8-B
Rapid Bioassessment Protocol Worksheets

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (FRONT)

STREAM NAME Turtle River	LOCATION NW¼, Sect 35, T152N, R55W	
STATION #_____ RIVERMILE_____	STREAM CLASS Rosgen E5, S-4(3)	
LAT 47 56' 42" LONG 97 39' 42"	RIVER BASIN Upper Turtle River	
STORET #	AGENCY	
INVESTIGATORS D. Reep		
FORM COMPLETED BY D. Reep	DATE _____ TIME _____ AM PM	REASON FOR SURVEY Larimore Dam Rehabilitation

WEATHER CONDITIONS

N/A

Now		Past 24 hours
❑	storm (heavy rain)	❑
❑	rain (steady rain)	❑
❑	showers (intermittent)	❑
____%	%cloud cover	❑____%
❑	clear/sunny	❑

Has there been a heavy rain in the last 7 days? ❑ Yes ❑ No

Air Temperature_____^{0} C

Other_____

SITE LOCATION/MAP

Draw a map of the site and indicate the areas sampled (or attach a photograph)

STREAM CHARACTERIZATION

Stream Subsystem
☑ Perennial ❑ Intermittent ❑ Tidal

Stream Origin
❑ Glacial
❑ Non-glacial montane
❑ Swamp and bog
❑ Spring-fed
❑ Mixture of origins
❑ Other_____

Stream Type
❑ Coldwater ❑ Warmwater

Catchment Area 134 km^2

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

WATERSHED FEATURES

Predominant Surrounding Landuse
❑ Forest ❑ Commercial
❑ Field/Pasture ❑ Industrial
☑ Agricultural ❑ Other _____
❑ Residential

Local Watershed NPS Pollution
❑ No evidence ☑ Some potential sources
❑ Obvious sources

Local Watershed Erosion
❑ None ☑ Moderate ❑ Heavy

RIPARIAN VEGETATION (18 meter buffer)

Indicate the dominant type and record the dominant species present
❑ Trees ❑ Shrubs ☑ Grasses ❑ Herbaceous

dominant species present _____

INSTREAM FEATURES

Estimated Reach Length _____m

Estimated Stream Width _____m

Sampling Reach Area _____m^2

Area in km^2 (m^2x1000) _____km^2

Estimated Stream Depth _____m

Surface Velocity (at thalweg) _____m/sec

Canopy Cover
☑ Partly open ❑ Partly shaded ❑ Shaded

High Water Mark _____m

Proportion of Reach Represented by Stream Morphology Types
❑ Riffle_____% ❑ Run_____%
❑ Pool_____%

Channelized ❑ Yes ☑ No

Dam Present ☑ Yes ❑ No

LARGE WOODY DEBRIS

LWD _____m^2

Density of LWD _____m^2/km^2 **(LWD/ reach area)**

AQUATIC VEGETATION

Indicate the dominant type and record the dominant species present
☑ Rooted emergent ❑ Rooted submergent ❑ Rooted floating ❑ Free floating
❑ Floating Algae ❑ Attached Algae

dominant species present _____

Portion of the reach with aquatic vegetation _____%

WATER QUALITY

Temperature_____^{0} C

Specific Conductance_____

Dissolved Oxygen _____

pH _____

Turbidity _____

WQ Instrument Used _____

Water Odors
☑ Normal/None ❑ Sewage
❑ Petroleum ❑ Chemical
❑ Fishy ❑ Other_____

Water Surface Oils
❑ Slick ❑ Sheen ❑ Globs ❑ Flecks
☑ None ❑ Other_____

Turbidity (if not measured)
❑ Clear ☑ Slightly turbid ❑ Turbid
❑ Opaque ❑ Stained ❑ Other_____

SEDIMENT/ SUBSTRATE

Odors
☑ Normal ❑ Sewage ❑ Petroleum
❑ Chemical ❑ Anaerobic ❑ None
❑ Other_____

Oils
☑ Absent ❑ Slight ❑ Moderate ❑ Profuse

Deposits
❑ Sludge ❑ Sawdust ❑ Paper fiber ❑ Sand
❑ Relict shells ❑ Other_____

Looking at stones which are not deeply embedded, are the undersides black in color?
❑ Yes ❑ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			**ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)**		
Substrate Type	**Diameter**	**% Composition in Sampling Reach**	**Substrate Type**	**Characteristic**	**% Composition in Sampling Area**
Bedrock			Detritus	sticks, wood, coarse plant materials (CPOM)	
Boulder	> 256 mm (10")				
Cobble	64-256 mm (2.5"-10")		Muck-Mud	black, very fine organic (FPOM)	
Gravel	2-64 mm (0.1"-2.5")				
Sand	0.06-2mm (gritty)		Marl	grey, shell fragments	
Silt	0.004-0.06 mm				
Clay	< 0.004 mm (slick)				

HABITAT ASSESSMENT FIELD DATA SHEET—LOW GRADIENT STREAMS (FRONT)

STREAM NAME Turtle River	LOCATION NW¼, Sect 35, T152N, R55W	
STATION #_____ RIVERMILE_____	STREAM CLASS Rosgen E5, S-4(3)	
LAT 47 56' 42" LONG 97 39' 42"	RIVER BASIN Upper Turtle River	
STORET #	AGENCY	
INVESTIGATORS D. Reep		
FORM COMPLETED BY D. Reep	DATE _____ TIME _____ AM PM	REASON FOR SURVEY Larimore Dam Rehabilitation

	Habitat Parameter	Condition Category			
		Optimal	**Suboptimal**	**Marginal**	**Poor**
Parameters to be evaluated in sampling reach	**1. Epifaunal Substrate/ Available Cover**	Greater than 50% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 **[8]** 7 6	5 4 3 2 1 0
	2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
	SCORE	20 19 18 17 16	15 14 **[13]** 12 11	10 9 8 7 6	5 4 3 2 1 0
	3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
	SCORE	20 19 18 17 16	15 14 **[13]** 12 11	10 9 8 7 6	5 4 3 2 1 0
	4. Sediment Deposition	Little or no enlargement of islands or point bars and less than <20% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
	SCORE	20 19 **[18]** 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
	5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
	SCORE	20 19 **[18]** 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—LOW GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	[20] 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE	20 19 18 17 [16]	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 8 (LB)	Left Bank 10 9	[8] 7 6	5 4 3	2 1 0
SCORE 8 (RB)	Right Bank 10 9	[8] 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 8 (LB)	Left Bank 10 9	[8] 7 6	5 4 3	2 1 0
SCORE 8 (RB)	Right Bank 10 9	[8] 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE 8 (LB)	Left Bank 10 9	[8] 7 6	5 4 3	2 1 0
SCORE 8 (RB)	Right Bank 10 9	[8] 7 6	5 4 3	2 1 0

Total Score 154

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (FRONT)

STREAM NAME Turtle River	LOCATION SE¼, Sect 4, T151N, R54W	
STATION #_____ RIVERMILE_____	STREAM CLASS Rosgen E5, S-5(3)	
LAT 47 55' 12" LONG 97 33' 57"	RIVER BASIN Upper Turtle River	
STORET #	AGENCY	
INVESTIGATORS D. Reep		
FORM COMPLETED BY D. Reep	DATE _____ TIME _____ AM PM	REASON FOR SURVEY Larimore Dam Rehabilitation

WEATHER CONDITIONS

N/A

Now		Past 24 hours
❑	storm (heavy rain)	❑
❑	rain (steady rain)	❑
❑	showers (intermittent)	❑
____% ❑	%cloud cover	❑ ____%
❑	clear/sunny	❑

Has there been a heavy rain in the last 7 days? ❑ Yes ❑ No

Air Temperature_____ ^{0} C

Other_____

SITE LOCATION/MAP

Draw a map of the site and indicate the areas sampled (or attach a photograph)

STREAM CHARACTERIZATION

Stream Subsystem
☑ Perennial ❑ Intermittent ❑ Tidal

Stream Origin
❑ Glacial
❑ Non-glacial montane
❑ Swamp and bog
❑ Spring-fed
❑ Mixture of origins
❑ Other_____

Stream Type
❑ Coldwater ❑ Warmwater

Catchment Area 805 km^2

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

WATERSHED FEATURES

Predominant Surrounding Landuse
❑ Forest ❑ Commercial
❑ Field/Pasture ❑ Industrial
☑ Agricultural ❑ Other _____
❑ Residential

Local Watershed NPS Pollution
❑ No evidence ☑ Some potential sources
❑ Obvious sources

Local Watershed Erosion
❑ None ☑ Moderate ❑ Heavy

RIPARIAN VEGETATION (18 meter buffer)

Indicate the dominant type and record the dominant species present
❑ Trees ❑ Shrubs ☑ Grasses ❑ Herbaceous

dominant species present _____

INSTREAM FEATURES

Estimated Reach Length _____m

Estimated Stream Width _____m

Sampling Reach Area _____m^2

Area in km^2 (m^2x1000) _____km^2

Estimated Stream Depth _____m

Surface Velocity (at thalweg) _____m/sec

Canopy Cover
☑ Partly open ❑ Partly shaded ❑ Shaded

High Water Mark _____m

Proportion of Reach Represented by Stream Morphology Types
❑ Riffle_____% ❑ Run_____%
❑ Pool_____%

Channelized ❑ Yes ☑ No

Dam Present ☑ Yes ❑ No

LARGE WOODY DEBRIS

LWD _____m^2

Density of LWD _____m^2/km^2 **(LWD/ reach area)**

AQUATIC VEGETATION

Indicate the dominant type and record the dominant species present
☑ Rooted emergent ❑ Rooted submergent ❑ Rooted floating ❑ Free floating
❑ Floating Algae ❑ Attached Algae

dominant species present _____

Portion of the reach with aquatic vegetation _____%

WATER QUALITY

Temperature_____^{0} C

Specific Conductance_____

Dissolved Oxygen _____

pH _____

Turbidity _____

WQ Instrument Used _____

Water Odors
☑ Normal/None ❑ Sewage
❑ Petroleum ❑ Chemical
❑ Fishy ❑ Other_____

Water Surface Oils
❑ Slick ❑ Sheen ❑ Globs ❑ Flecks
☑ None ❑ Other_____

Turbidity (if not measured)
❑ Clear ☑ Slightly turbid ❑ Turbid
❑ Opaque ❑ Stained ❑ Other_____

SEDIMENT/ SUBSTRATE

Odors
☑ Normal ❑ Sewage ❑ Petroleum
❑ Chemical ❑ Anaerobic ❑ None
❑ Other_____

Oils
☑ Absent ❑ Slight ❑ Moderate ❑ Profuse

Deposits
❑ Sludge ❑ Sawdust ❑ Paper fiber ❑ Sand
❑ Relict shells ❑ Other_____

Looking at stones which are not deeply embedded, are the undersides black in color?
❑ Yes ❑ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			**ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)**		
Substrate Type	**Diameter**	**% Composition in Sampling Reach**	**Substrate Type**	**Characteristic**	**% Composition in Sampling Area**
Bedrock			Detritus	sticks, wood, coarse plant materials (CPOM)	
Boulder	> 256 mm (10")				
Cobble	64-256 mm (2.5"-10")		Muck-Mud	black, very fine organic (FPOM)	
Gravel	2-64 mm (0.1"-2.5")				
Sand	0.06-2mm (gritty)		Marl	grey, shell fragments	
Silt	0.004-0.06 mm				
Clay	< 0.004 mm (slick)				

HABITAT ASSESSMENT FIELD DATA SHEET—LOW GRADIENT STREAMS (FRONT)

STREAM NAME Turtle River	LOCATION SE¼, Sect 4, T151N, R54W	
STATION #_____ RIVERMILE_____	STREAM CLASS Rosgen E5, S-5(3)	
LAT 47 55' 12" LONG 97 33' 57"	RIVER BASIN Upper Turtle River	
STORET #	AGENCY	
INVESTIGATORS D. Reep		
FORM COMPLETED BY D. Reep	DATE _____ TIME _____ AM PM	REASON FOR SURVEY Larimore Dam Rehabilitation

	Habitat Parameter	Condition Category			
		Optimal	**Suboptimal**	**Marginal**	**Poor**
Parameters to be evaluated in sampling reach	**1. Epifaunal Substrate/ Available Cover**	Greater than 50% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
	SCORE	20 19 18 17 16	15 14 13 12 **[11]**	10 9 8 7 6	5 4 3 2 1 0
	2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
	SCORE	20 19 18 17 16	**[15]** 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
	3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
	SCORE	20 19 18 17 **[16]**	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
	4. Sediment Deposition	Little or no enlargement of islands or point bars and less than <20% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
	SCORE	20 19 **[18]** 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
	5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
	SCORE	20 **[19]** 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—LOW GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	[20] 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE	20 19 18 17 16	[15] 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 9 (LB)	Left Bank 10 [9]	8 7 6	5 4 3	2 1 0
SCORE 9 (RB)	Right Bank 10 [9]	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 8 (LB)	Left Bank 10 9	[8] 7 6	5 4 3	2 1 0
SCORE 8 (RB)	Right Bank 10 9	[8] 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE 8 (LB)	Left Bank 10 9	[8] 7 6	5 4 3	2 1 0
SCORE 10 (RB)	Right Bank [10] 9	8 7 6	5 4 3	2 1 0

Total Score 166

APPENDIX D-8-C
Stream Visual Assessment Protocol Worksheets

Stream Visual Assessment Protocol

Owners name _____ Evaluator's name Dennis Reep Date Jan-2023

Stream name Turtle River Waterbody ID number _____

Reach location NW, Section 35, T152N, R55W - Approximately 37,800 feet upstream of Larimore Reservoir

_____

Ecoregion _____ Drainage area 51.8 sq. mi. Gradient 0.37%

Applicable reference site _____

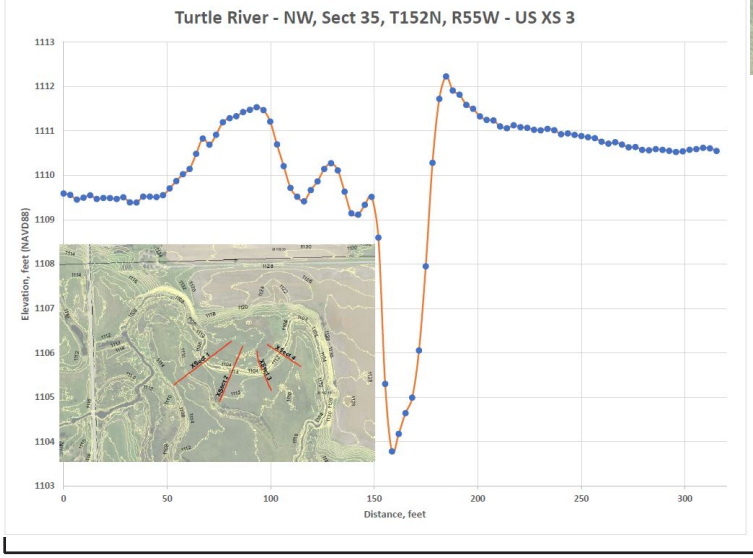
Land use within drainage (%): row crop _____ hayland _____ grazing/pasture _____ forest _____ residential _____

confined animal feeding operations _____ Cons. Reserve _____ industrial _____ Other: _____

Weather conditions-today _____ Past 2-5 days _____

Active channel width _____ Dominant substrate: boulder _____ gravel _____ sand _____ silt _____ mud _____

Site Diagram



Assessment Scores

Channel condition	8
Hydrologic alteration	5
Riparian zone	8
Bank stability	8
Water appearance	6
Nutrient enrichment	7
Barriers to fish movement	5
Instream fish cover	5

Pools	6
Invertebrate habitat	4

Score only if applicable

Canopy cover	
Manure presence	
Salinity	
Riffle embeddedness	
Marcroinvertebrates Observed (optional)	

Overall score
(Total divided by number scored) 6.2

<6.0	**Poor**
6.1-7.4	**Fair**
7.5-8.9	**Good**
>9.0	**Excellent**

Suspected causes of observed problems_____

Recommendations_____

Stream Visual Assessment Protocol

Owners name _____ Evaluator's name Dennis Reep Date Jan-2023

Stream name Turtle River Waterbody ID number _____

Reach location SW of SE, Section 4, T151N, R54W - Approximately 17,900 feet downstream of Larimore Dam.

Ecoregion _____ Drainage area _____ Gradient 0.124% (surveyed XS)

Applicable reference site _____

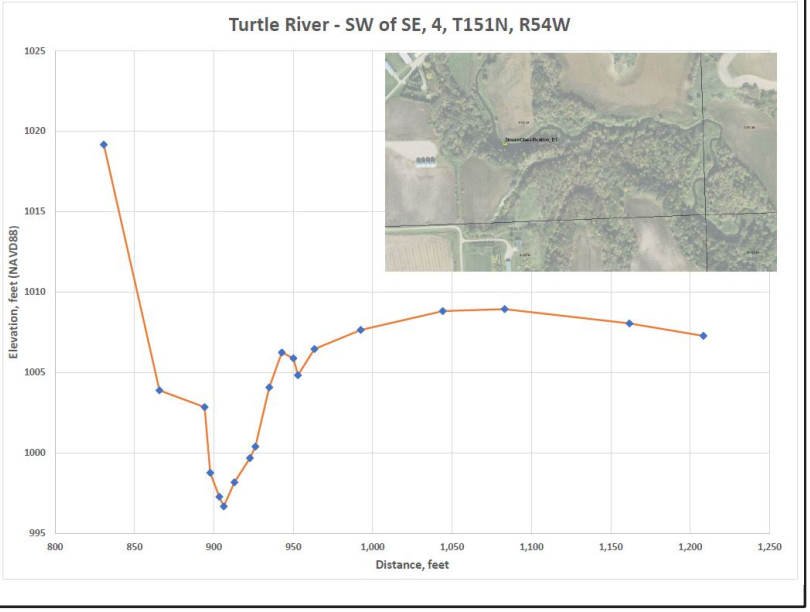
Land use within drainage (%): row crop _____ hayland _____ grazing/pasture _____ forest _____ residential _____

confined animal feeding operations _____ Cons. Reserve _____ industrial _____ Other: _____

Weather conditions-today _____ Past 2-5 days _____

Active channel width _____ Dominant substrate: boulder _____ gravel _____ sand _____ silt _____ mud _____

Site Diagram



Assessment Scores

Channel condition	8
Hydrologic alteration	5
Riparian zone	8
Bank stability	8
Water appearance	6
Nutrient enrichment	8
Barriers to fish movement	5
Instream fish cover	6

Pools	6
Invertebrate habitat	7

Score only if applicable

Canopy cover	6
Manure presence	
Salinity	
Riffle embeddedness	
Marcroinvertebrates Observed (optional)	

Overall score
(Total divided by number scored) 6.6

<6.0	**Poor**
6.1-7.4	**Fair**
7.5-8.9	**Good**
>9.0	**Excellent**

Suspected causes of observed problems_____

Recommendations_____

APPENDIX D-8-D
River Stability Worksheets

Worksheet 2-3. Field form for *Level II* stream classification.

Stream:	**Turtle River**			
Basin:		Drainage Area:	acres **51.8**	mi^2
Location:	**NW¼, Section 35, T152N, R55W**			
Twp.&Rge:		Sec.&Qtr.:		
Cross-Section Monuments (Lat./Long.):			Date:	
Observers:	**DWR**		Landscape Type:	

Bankfull Width (W_{bkf}) The surface width of the stream at bankfull stage elevation, in a riffle section.	**19.0**	ft
Bankfull Mean Depth (d_{bkf}) Mean depth of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A_{bkf} / W_{bkf}$).	**2.02**	ft
Bankfull Cross-Sectional Area (A_{bkf}) Area of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**38.3**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) *Bankfull Width* divided by *Bankfull Mean Depth*, in a riffle section.	**9.4**	ft/ft
Bankfull Maximum Depth (d_{max}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**3.12**	ft
Flood-Prone Area Width (W_{fpa}) Width of the channel at an elevation that is twice the *Bankfull Maximum Depth*, measured perpendicular to the fall line of the valley in a riffle section.	**65.00**	ft
Entrenchment Ratio (ER) The *Flood-Prone Area Width* divided by *Bankfull Width* (W_{fpa} / W_{bkf}), in a riffle section.	**3.42**	ft/ft
Channel Materials (Particle Size Index D_{50}) The D_{50} particle size index represents the median or dominant diameter of channel materials, as sampled proportionately from the channel surface between the bankfull stage and Thalweg elevations.	**5**	mm
Average Water Surface Slope (S) The elevation difference of water surface measurements over the stream length between two similar bed features (e.g., start of riffle to start of last riffle) for several riffle–pool or step–pool sequences, representing channel gradient.	**0.0037**	ft/ft
Channel Sinuosity (k) An index of channel pattern determined from stream length divided by valley length (SL / VL), or from valley slope divided by average water surface slope (S_{val} / S).	**1.92**	ft/ft

Stream Type **E5** **See Classification Key (Figure 2-35)**

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

Flow Regime

Stream: **Turtle River**						Stream Type: **E5**		
Location: **NW¼, Section 35, T152N, R55W**						Landscape Type:		
Observers: **DWR**						Date:		
List ALL COMBINATIONS that APPLY.....☞	**P1**	**P2**	**P7**	**P9**				

General Category

E	***Ephemeral stream channel:*** 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 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:	**Turtle River**		
Location:	**NW¼, Section 35, T152N, R55W**		
Observers:	**DWR**	Stream Type:	**E5**
Landscape Type:		Date:	

Stream Size Category and Order ☞ **S-4(3)**

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 – 9.0	15 – 30	☑
S-5	9.0 – 15.0	30 – 50	☐
S-6	15.0 – 22.8	50 – 75	☐
S-7	22.8 – 30.5	75 – 100	☐
S-8	30.5 – 46.0	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).

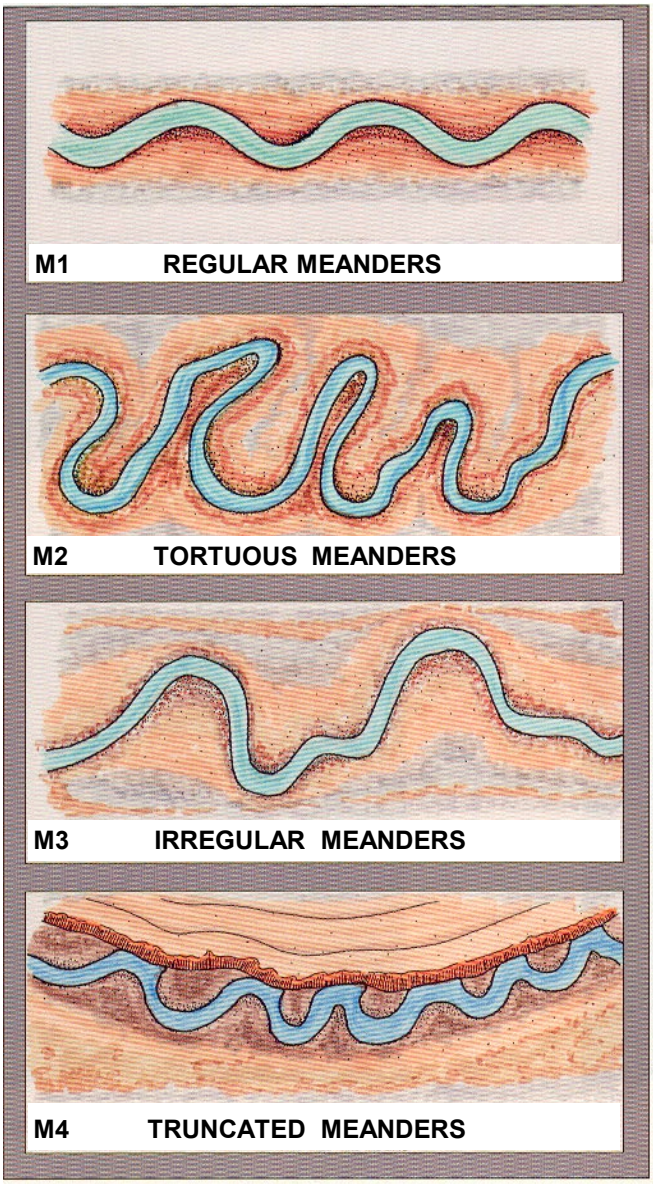
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Turtle River**	Stream Type:	**E5**
Location:	**NW¼, Section 35, T152N, R55W**	Landscape Type:	
Observers:	**DWR**	Date:	

List ALL CATEGORIES that APPLY ☞	M3	M7			

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

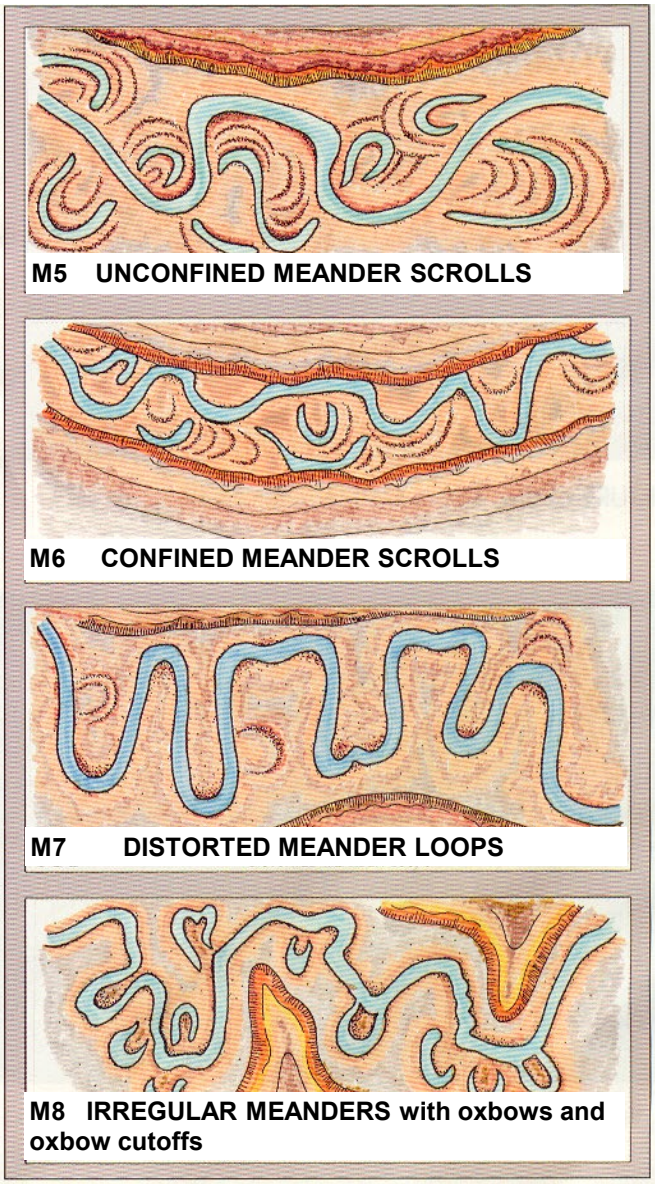


M1 REGULAR MEANDERS

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 oxbow cutoffs

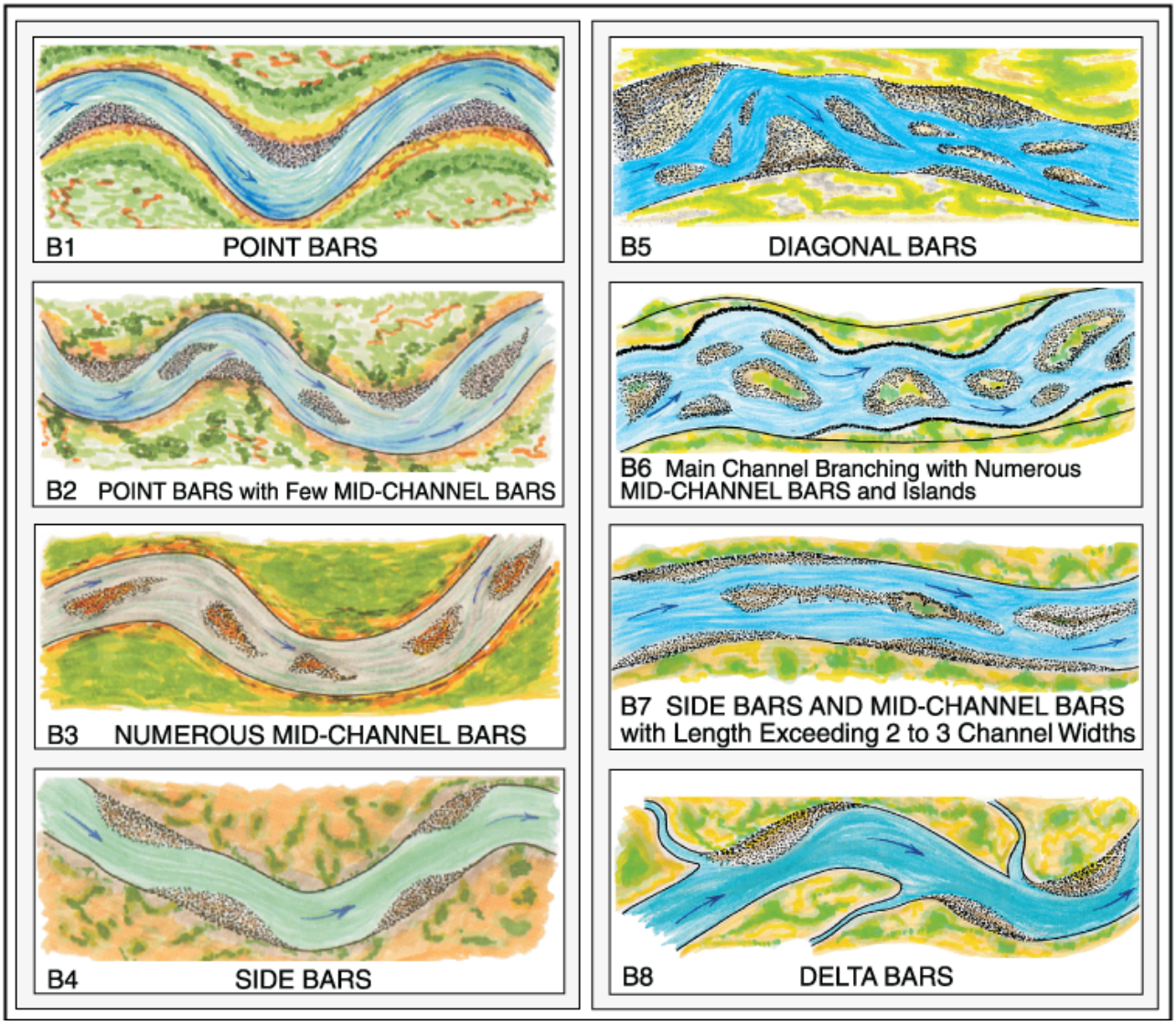
Worksheet 3-5. Depositional patterns used for stabiilty assessments.

Depositional Patterns

Stream:	**Turtle River**	Stream Type:	**E5**
Location:	**NW¼, Section 35, T152N, R55W**	Landscape Type:	
Observers:	**DWR**	Date:	

List ALL CATEGORIES that APPLY ☞	B1				

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:	**Turtle River**	Stream Type:	**E5**
Location:	**NW¼, Section 35, T152N, R55W**	Landscape Type:	
Observers:	**DWR**	Date:	

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-sectional area.	☐
D4	Numerous	Significant build-up of medium- to large-sized materials, e.g., large limbs, branches, small logs, or portions of trees, occupying 10–30% of the active channel cross-sectional area.	☐
D5	Extensive	Debris "dams" of predominantly larger materials, e.g., branches, logs, and trees, occupying 30–50% of the active channel cross-sectional 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-sectional 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 or breached, initiating a series of channel adjustments, such as streambank erosion, lateral migration, avulsion, aggradation, or 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.

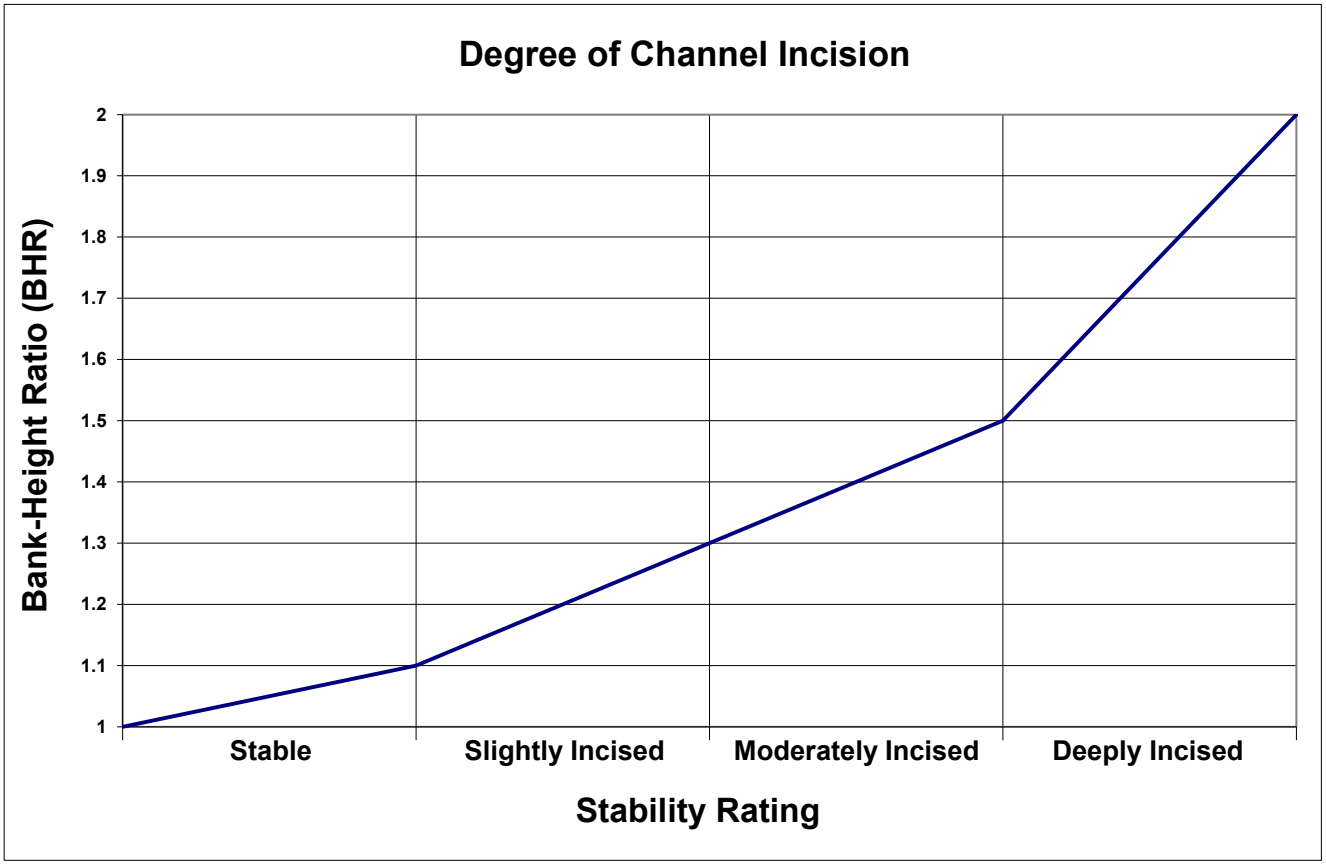
Degree of Channel Incision

Stream:	**Turtle River**	Stream Type:	**E5**
Location:	**NW¼, Section 35, T152N, R55W**	Landscape Type:	
Observers:	**DWR**	Date:	

Low Bank Height:	**4.5**
Bankfull Max Depth:	**3.12**

Bank-Height Ratio (BHR):	**1.44**

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



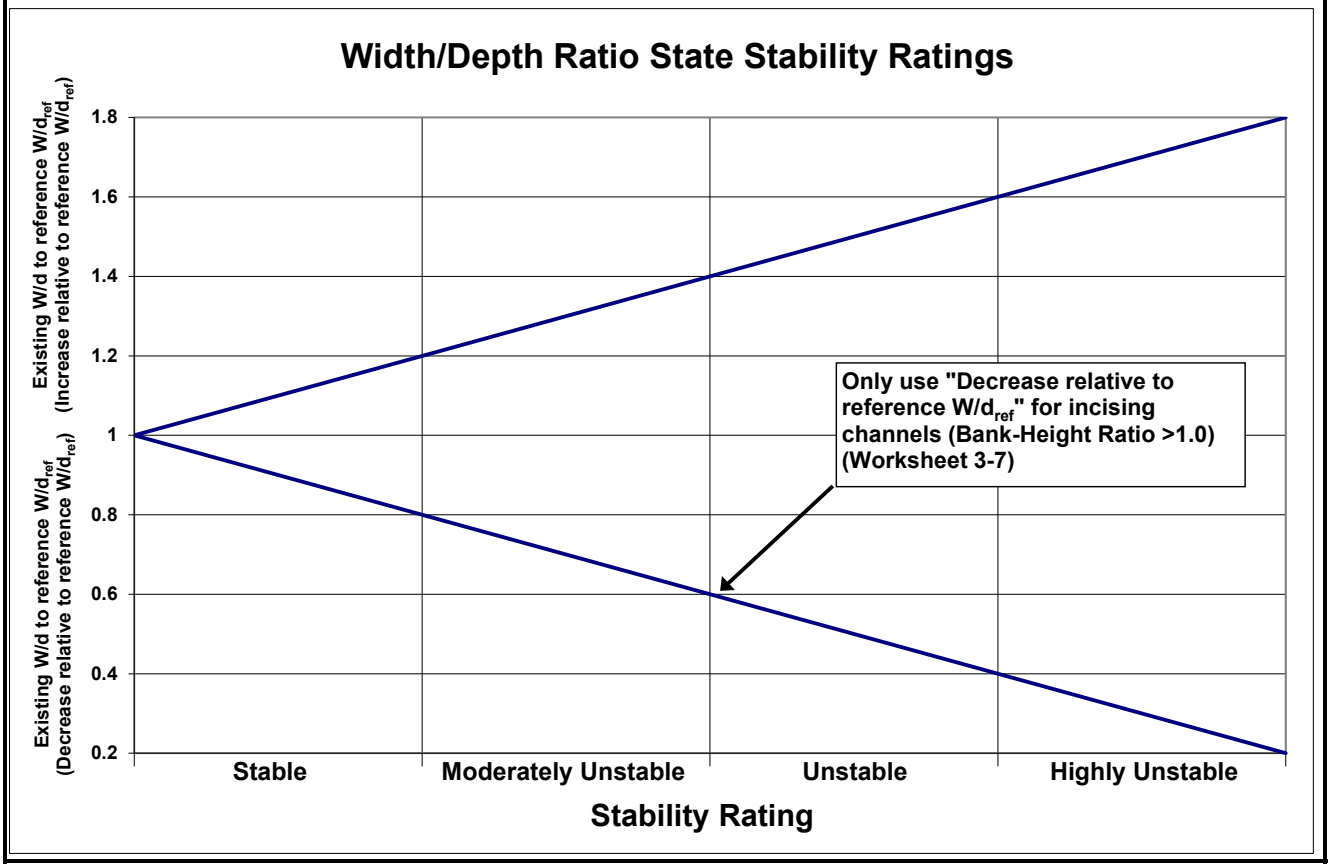
Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State

Stream:	**Turtle River**	Stream Type:	**E5**
Location:	**NW¼, Section 35, T152N, R55W**	Landscape Type:	
Observers:	**DWR**	Date:	

Existing Width/Depth Ratio (W/d):	**9.4**	Existing W/d to Reference W/d_{ref} :	**0.71**
Reference Width/Depth Ratio (W/d_{ref}):	**13.3**		

Width/Depth Ratio State Stability Rating ☞ **Moderately Unstable**



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

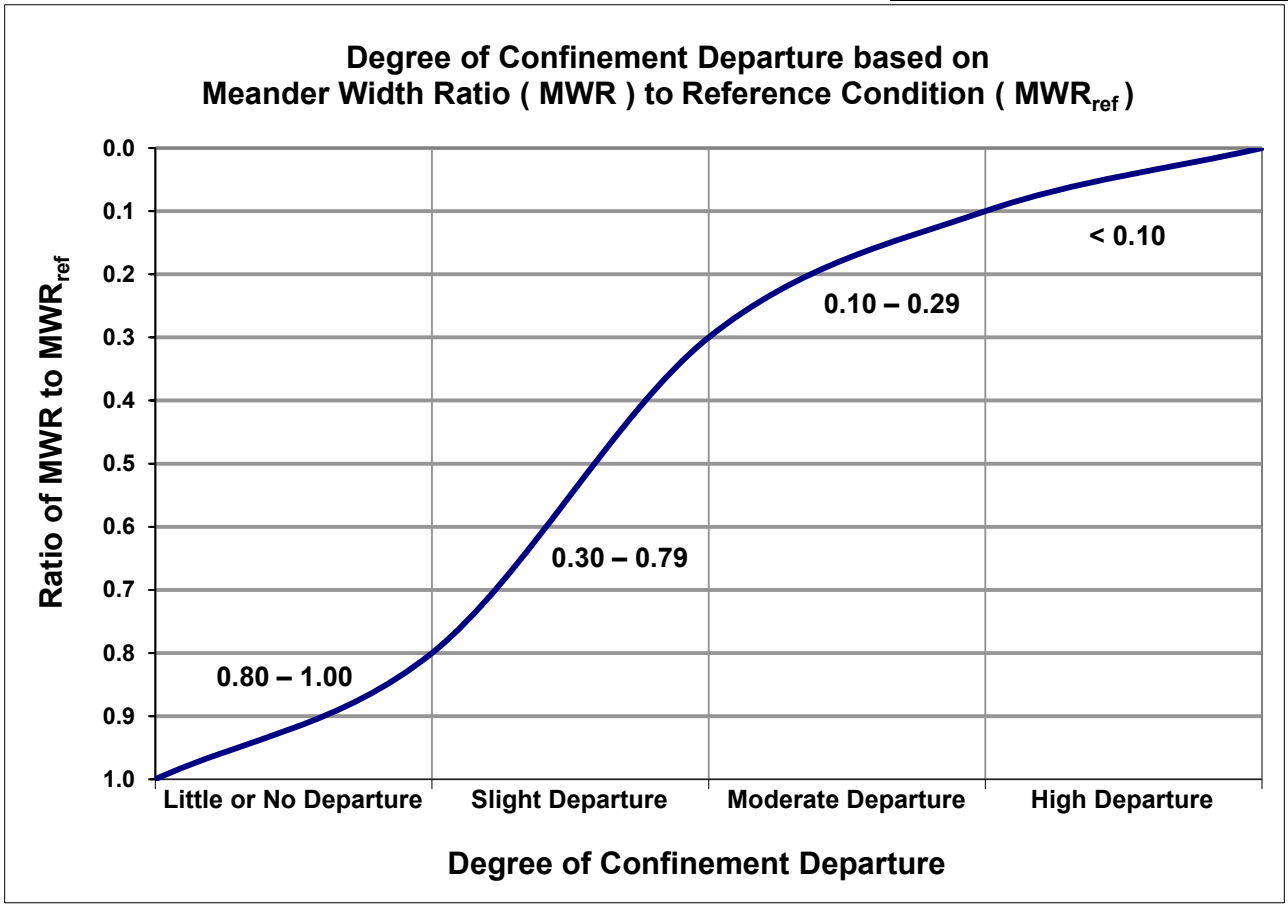
Degree of Confinement

Stream:	**Turtle River**	Stream Type:	**E5**
Location:	**NW¼, Section 35, T152N, R55W**	Landscape Type:	
Observers:	**DWR**	Date:	

Existing Meander Width Ratio (MWR):	**20**
Reference Meander Width Ratio (MWR_{ref}):	**24.2**

Ratio of MWR to MWR_{ref} : **0.83**

Degree of Confinement Stability Rating ☞ **Little or No Departure**



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

Stream: Turtle River **Location:** NW¼, Section 35, T152N **Landscape Type:** **Observers:** DWR **Date:**

Location	Key	Category	Excellent		Good		Fair		Poor	
			Description	Rating	Description	Rating	Description	Rating	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 two 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 =	**18**	**Good Total =**	**28**	**Fair Total =**	**0**	**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 =	**E5**
***Potential Stream Type =**	**E5**
Modified channel stability rating =	**Good**

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

Worksheet 3-11. Form to calculate an overall Bank Erosion Hazard Index (BEHI) rating. Use **Figure 3-7** to determine individual BEHI scores.

Bank Erosion Hazard Index (BEHI)

Stream: **Turtle River** Location: **NW¼, Section 35, T152N, R55W**

Station: Observers: **DWR**

Date: Stream Type: **E5** Landscape Type:

						BEHI Score (Fig. 3-7)
Study Bank Height to Bankfull Height (C)						
Study Bank Height (ft) =	5.00 (A)	Bankfull Height (ft) =	2.60 (B)	(A) / (B) =	1.92 (C)	7.5
Root Depth to Study Bank Height (E)						
Root Depth (ft) =	3.00 (D)	Study Bank Height (ft) =	5.00 (A)	(D) / (A) =	0.60 (E)	3.5
Weighted Root Density (G)						
Root Density as % =	40.00 (F)			(F) × (E) =	24 (G)	6.2
Bank Angle (H)						
Bank Angle as *Degrees* =	35 (H)					2.5
Surface Protection (I)						
Surface Protection as % =	95% (I)					0.8

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)

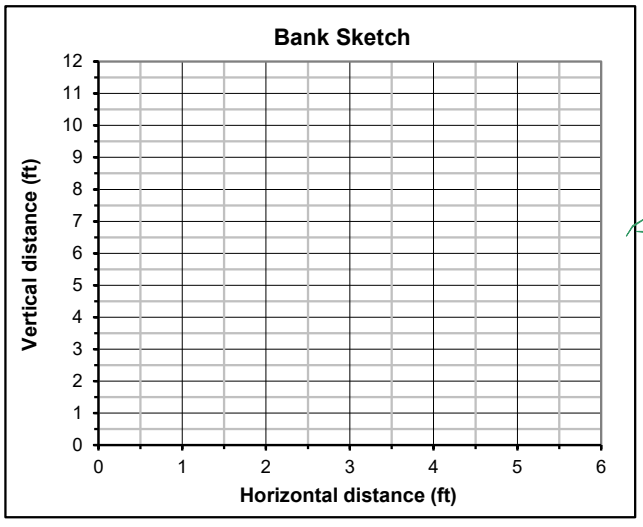
Silt/Clay (Add 10 points if uniform silt; No adjustment if silt with a mixture of clay; Subtract 10 points if silt/clay mixture with high % of clay; Subtract 20 points if clay)

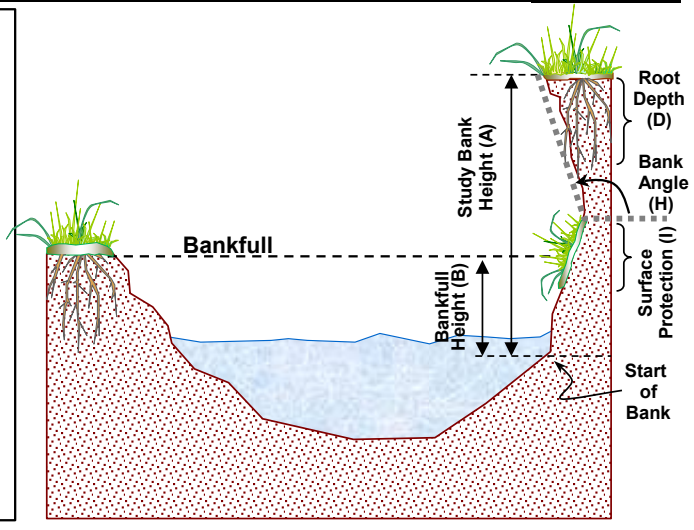
Bank Material Adjustment 7

Stratification Adjustment

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

Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*	**Adjective Rating** and **Total Score**	**Moderate** 27.5
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50		





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

Estimating Near-Bank Stress (NBS)

Stream: **Turtle River** Location: **NW¼, Section 35, T152N, R55W**

Station: Stream Type: **E5** Landscape Type:

Observers: **DWR** Date:

Methods for Estimating Near-Bank Stress (NBS)

(1)	Channel pattern, transverse bar, or central bar creating NBS	Level I	Reconaissance
(2)	Radius of curvature to bankfull width (R_c / W_{bkf})	Level II	General Prediction
(3)	Pool slope to average water surface slope (S_p / S)	Level II	General Prediction
(4)	Pool slope to riffle slope (S_p / S_{rif})	Level II	General Prediction
(5)	Near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})	Level III	Detailed Prediction
(6)	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 or central bars - short 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)**
210	**19**	**11.052632**	**Very Low**

(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)**

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

Worksheet 3-13. Annual streambank erosion estimates for various study reaches.

Streambank Erosion Prediction

Stream: **Turtle River** Location: **NW¼, Section 35, T152N, R55W**

Graph Used: Total Stream Length (ft): Date:

Observers: **DWR** Landscape Type: Stream Type: **E5**

(1) Station (ft)	(2) BEHI Rating (Worksheet 3-11) (adjective)	(3) NBS Rating (Worksheet 3-12) (adjective)	(4) Bank Erosion Rate (Figure 3-9 or 3-10) (ft/yr)	(5) Length of Bank (ft)	(6) Study Bank Height (ft)	(7) Erosion Subtotal [(4)×(5)×(6)] (ft^3/yr)	(8) Unit Erosion Rate (tons/yr/ft) {[(7)/27] × 1.3 / (5)}
1.	**Moderate**	**Very Low**	**0.090**	**1.00**	**5.00**	**0.45**	**0.02167**
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							
11.							
12.							
13.							
14.							
15.							
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**0.45**	
Convert erosion in ft^3/yr to yds^3/yr {divide *Total Erosion (ft^3/yr)* by 27}					**Total Erosion (yds^3/yr)**	**0.02**	
Convert erosion in yds^3/yr to tons/yr {multiply *Total Erosion (yds^3/yr)* by 1.3}					**Total Erosion (tons/yr)**	**0.02**	
Calculate erosion per unit length of channel {divide *Total Erosion (tons/yr)* by *Total Stream Length (ft)* surveyed}					**Unit Erosion Rate (tons/yr/ft)**		

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

Sediment Competence using Dimensional and Dimensionless Shear Stress Methods

Stream:	**Turtle River**		Stream Type: **E5**		
Location:	**NW¼, Section 35, T152N, R55W**		Landscape Type:		
Observers:	**DWR**		Date:		

Enter Required Information for Existing Condition

5.0	D_{50}	Median particle size of riffle bed material (mm)			
	$\hat{D}_{50}$	Median particle size of bar or sub-pavement sample (mm)			
0.00	D_{max}	Largest particle from bar sample (ft)	**0**	**(mm)**	304.8 mm/ft
0.0037	S	Existing average water surface slope (ft/ft)			
2.02	d	Existing bankfull mean depth (ft)			
1.65	γ_s-γ/γ	Immersed specific gravity of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\ (\ D_{50}/\hat{D}_{50})^{-0.872}$
0.00	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:	

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

	d	Required bankfull mean depth (ft) $d = \frac{\tau^*(\gamma_s - 1)D_{max}}{S}$	(use D_{max} in ft)

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

	S	Required average water surface slope (ft/ft) $S = \frac{\tau^*(\gamma_s - 1)D_{max}}{d}$	(use D_{max} in ft)

Check: ☑ Stable ☐ Aggrading ☐ Degrading

Sediment Competence Using Dimensional Shear Stress

0.466		Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.43, d = existing depth, S = existing slope
Shields **35**	CO **87**	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**
Shields **0.000**	CO **0.000**	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**
Shields **0.00**	CO **0.00**	Predicted mean depth required to initiate movement of measured D_{max} (mm) $d = \frac{\tau}{\gamma S}$ τ = predicted shear stress, γ = 62.43, S = existing slope
Shields **0.0000**	CO **0.0000**	Predicted slope required to initiate movement of measured D_{max} (mm) $S = \frac{\tau}{\gamma d}$ τ = predicted shear stress, γ = 62.43, d = existing depth

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Worksheet 3-15. Stability ratings for stream type stage shifts.

Stream Succession Stage Shifts	
Stream: **Turtle River**	Stream Type: **E5**
Location: **NW¼, Section 35, T152N, R55W**	Landscape Type:
Observers: **DWR**	Date:
Stream Type Stage Shifts (Figure 3-14)	**Stability Rating (Check ✓ Appropriate Rating)**
Stream Type at Potential, (C→E), (F_b→B), (F→B_c), (F→C), (G→B), (D→C)	☐ Stable
(E→C), (B→High W/d B), (C→High W/d C)	☑ Moderately Unstable
(G_c→F), (G→F_b), (F→D), (C→F)	☐ Unstable
(C→D), (A→G), (B→G), (D→G), (C→G), (E→G), (E→A)	☐ Highly Unstable

Worksheet 3-16. Lateral stability prediction summary.

Lateral Stability Prediction					
Stream: **Turtle River**			Stream Type: **E5**		
Location: **NW¼, Section 35, T152N, R55W**			Landscape Type:		
Observers: **DWR**			Date:		
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	1.2 – 1.4	1.4 – 1.6	> 1.6	**2**
	(2)	**(4)**	**(6)**	**(8)**	
2 Depositional Patterns (Worksheet 3-5)	B1, B2	B4, B8	B3	B5, B6, B7	**1**
	(1)	**(2)**	**(3)**	**(4)**	
3 Meander Patterns (Worksheet 3-4)	M1, M3, M4		M2, M5, M6, M7, M8		**1**
	(1)		**(3)**		
4 Streambank Erosion: Unit Rate (Worksheet 3-13)	< 0.006	0.006 – 0.04	0.041 – 0.07	> 0.07	**4**
	(2)	**(4)**	**(6)**	**(8)**	
5 Degree of Confinement (MWR / MWR_{ref}) (Worksheet 3-9)	> 0.8	0.3 – 0.79	0.1 – 0.29	< 0.1	**1**
	(1)	**(2)**	**(3)**	**(4)**	
				Total Points	**9**
	Lateral Stability Category Point Range				
Overall Lateral Stability Category (use total points and check ✓ stability rating)	***Stable*** **< 10** ☑	***Moderately Unstable*** **10 – 12** ☐	***Unstable*** **13 – 21** ☐	***Highly Unstable*** **> 21** ☐	

Worksheet 3-17. Vertical stability prediction for excess deposition and aggradation.

Vertical Stability Prediction for Excess Deposition and Aggradation					
Stream: **Turtle River**			Stream Type: **E5**		
Location: **NW¼, Section 35, T152N, R55W**			Landscape Type:		
Observers: **DWR**			Date:		
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 slope to transport largest size available	Trend toward insufficient depth 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 or suspended sand	Reduction over 25% of annual sediment yield for bedload or suspended sand	**2**
	(2)	**(4)**	**(6)**	**(8)**	
3 W/d Ratio State (Worksheet 3-8)	< 1.2	1.2 – 1.4	1.4 – 1.6	> 1.6	**2**
	(2)	**(4)**	**(6)**	**(8)**	
4 Stream Succession Stage Shifts (Worksheet 3-15)	Current stream type at potential or does not indicate deposition/ aggradation	(E→C)	(B→High W/d B), (C→High W/d C), (C→F), (G_c→F), (G→F_b)	(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 and Aggradation				
Vertical Stability for Excess Deposition / Aggradation (use total points and check ✓ stability rating)	***No Deposition*** **< 15** ☑	***Moderate Deposition*** **15 – 20** ☐	***Excess Deposition*** **21 – 30** ☐	***Aggradation*** **> 30** ☐	

Worksheet 3-18. Vertical stability prediction for channel incision and degradation.

Vertical Stability Prediction for Channel Incision and Degradation					
Stream: **Turtle River**			Stream Type: **E5**		
Location: **NW¼, Section 35, T152N, R55W**			Landscape Type:		
Observers: **DWR**			Date:		
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	Trend to move larger sizes than D_{100} of bar or D_{84} of bed	D_{100} of bed moved	Particles much larger than D_{100} of bed moved	**2**
	(2)	**(4)**	**(6)**	**(8)**	
2 Sediment Capacity (POWERSED)	Does not indicate excess capacity	Slight excess energy: up to 10% increase above reference	Excess energy sufficient to increase load up to 50% of annual load	Excess energy transporting more than 50% of annual load	**2**
	(2)	**(4)**	**(6)**	**(8)**	
3 Degree of Channel Incision (BHR) (Worksheet 3-7)	1.00 – 1.10	1.11 – 1.30	1.31 – 1.50	> 1.50	**6**
	(2)	**(4)**	**(6)**	**(8)**	
4 Stream Succession States (Worksheets 3-15 and 3-7)	Does not indicate incision or degradation	If BHR > 1.1 and stream type has W/d between 5–10	If BHR > 1.1 and stream type has W/d less than 5	(B→G), (C→G), (E→G), (D→G), (A→G), (E→A)	**4**
	(2)	**(4)**	**(6)**	**(8)**	
5 Confinement (MWR / MWR_{ref}) (Worksheet 3-9)	0.80 – 1.00	0.30 – 0.79	0.10 – 0.29	< 0.10	**1**
	(1)	**(2)**	**(3)**	**(4)**	
				Total Points	**15**
	Vertical Stability Category Point Range for Channel Incision and Degradation				
Vertical Stability for Channel Incision/ Degradation (use total points and check ✓ stability rating)	***Not Incised*** **< 12** ☐	***Slightly Incised*** **12 – 18** ☑	***Moderately Incised*** **19 – 27** ☐	***Degradation*** **> 27** ☐	

Worksheet 3-19. Channel enlargement prediction summary.

Channel Enlargement Prediction					
Stream: **Turtle River**			Stream Type: **E5**		
Location: **NW¼, Section 35, T152N, R55W**			Landscape Type:		
Observers: **DWR**			Date:		
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 Stream Succession Stage Shifts (Worksheet 3-15)	Stream Type at Potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C)	(B→High W/d B), (C→High W/d C), (E→C)	(G→F), (F→D)	(C→D), (A→G), (B→G), (D→G), (C→G), (E→G), (E→A), (C→F)	**4**
	(2)	**(4)**	**(6)**	**(8)**	
2 Lateral Stability (Worksheet 3-16)	*Stable*	*Moderately Unstable*	*Unstable*	*Highly Unstable*	**2**
	(2)	**(4)**	**(6)**	**(8)**	
3 Vertical Stability Excess Deposition and Aggradation (Worksheet 3-17)	*No Deposition*	*Moderate Deposition*	*Excess Deposition*	*Aggradation*	**2**
	(2)	**(4)**	**(6)**	**(8)**	
4 Vertical Stability Channel Incision and Degradation (Worksheet 3-18)	*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*** **< 11** ☐	***Slight Increase*** **11 – 16** ☑	***Moderate Increase*** **17 – 24** ☐	***Extensive*** **> 24** ☐	

Worksheet 3-20. Overall sediment supply rating determined from individual stability rating categories.

Overall Sediment Supply Prediction			
Stream: **Turtle River**		Stream Type: **E5**	
Location: **NW¼, Section 35, T152N, R55W**		Landscape Type:	
Observers: **DWR**		Date:	
Overall Sediment Supply Prediction Criteria (choose corresponding points for each criterion 1–5)	**Stability Rating**	**Points**	**Selected Points**
1 Lateral Stability (Worksheet 3-16)	***Stable***	**1**	**1**
	Mod. Unstable	**2**	
	Unstable	**3**	
	Highly Unstable	**4**	
2 Vertical Stability Excess Deposition or Aggradation (Worksheet 3-17)	***No Deposition***	**1**	**1**
	Mod. Deposition	**2**	
	Excess Deposition	**3**	
	Aggradation	**4**	
3 Vertical Stability Channel Incision or Degradation (Worksheet 3-18)	***Not Incised***	**1**	**2**
	Slightly Incised	**2**	
	Mod. Incised	**3**	
	Degradation	**4**	
4 Channel Enlargement Prediction (Worksheet 3-19)	***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	**7**

	Category Point Range			
Overall Sediment Supply Rating (use total points and check ✓ stability rating)	***Low*** **< 6** ☐	***Moderate*** **6 – 10** ☑	***High*** **11 – 15** ☐	***Very High*** **> 15** ☐

Worksheet 3-21. Summary of stability condition categories.

Summary of Stability Conditions

Stream:	**Turtle River**					Location: **NW¼, Section 35, T152N, R55W**					
Observers:	**DWR**		Date:			Stream Type: **E5**			Landscape Type:		
Channel Dimension	Bankfull Mean Depth (ft): **2**		Bankfull Width (ft): **19**			Cross-Sectional Area (ft^2): **38.3**		Width/Depth Ratio: **9.4**		Entrenchment Ratio: **3.4**	
Channel Pattern	Mean: Range:	λ/W_{bkf}:		L_m/W_{bkf}:		R_c/W_{bkf}:		MWR:		Sinuosity:	
Streamflow	Bankfull Mean Velocity ($\bar{u}_{bkf}$) (ft/sec):			Bankfull Discharge (Q_{bkf}):			Estimation Method:			Drainage Area (mi^2):	
River Profile & Bed Features	Check: ☑ Riffle/Pool ☐ Step/Pool ☐ Plane Bed ☐ Convergence/Divergence ☐ Dunes/Antidunes/Smooth Bed										
	Bankfull Max Depth (ft):	Riffle: **3.1**	Pool:	Depth Ratio (max to mean):	Riffle: **1.55**	Pool:	Pool-to-Pool Spacing:	Ratio:	Slope: Valley:	Water Surface: **0.0037**	
Level III Stream Stability Indices	Riparian Vegetation	Current Composition/Density:		Potential Composition/Density:			Remarks: Condition, Vigor & Usage of Existing Reach:				
	Flow Regime: **P1**	Stream Size & Order: **S4(3)**		Meander Patterns: **M3, M7**			Depositional Patterns: **B1**		Debris/Channel Blockages: **D1, D2**		
	Degree of Incision (Bank-Height Ratio): **1.44**	Degree of Incision Stability Rating: **Moderately Incised**		Modified Pfankuch Stability Rating (Numeric & Adjective Rating): **66, Good**							
	W/d Ratio State $(W/d)/(W/d_{ref})$: **0.71**	W/d Ratio State Stability Rating: **Moderately Unstable**		Degree of Confinement (MWR/MWR_{ref}):			MWR/MWR_{ref} Stability Rating: **0.83, Little to No Departure**				
Bank Erosion Summary	Length of Reach Studied (ft): **1**	Annual Streambank Erosion Rate: **0.02** (tons/yr)	**0.02** (tons/yr/ft)	Curve Used: **Very Low**	Remarks:						
Sediment Capacity (POWERSED)	☑ *Sufficient Capacity* ☐ *Insufficient Capacity* ☐ *Excess Capacity*						Remarks:				
Entrainment/ Competence	Largest Particle from Bar Sample (mm):	$\tau =$ **0.27**	$\tau^* =$ **0**	Existing Depth:	Required Depth:	Existing Slope:	Required Slope:				
Stream Succession	→	→	→	→	→	Existing Stream State (Type):	Potential Stream State (Type):				
Lateral Stability	☑ *Stable*	☐ *Mod. Unstable*	☐ *Unstable*	☐ *Highly Unstable*	Remarks:						
Vertical Stability (Aggradation)	☑ *No Deposition*	☐ *Mod. Deposition*	☐ *Ex. Deposition*	☐ *Aggradation*	Remarks:						
Vertical Stability (Degradation)	☐ *Not Incised*	☑ *Slightly Incised*	☐ *Mod. Incised*	☐ *Degradation*	Remarks:						
Channel Enlargement	☐ *No Increase*	☑ *Slight Increase*	☐ *Mod. Increase*	☐ *Extensive*	Remarks:						
Sediment Supply (Channel Source)	☐ *Low*	☑ *Moderate*	☐ *High*	☐ *Very High*	Remarks:						

Worksheet 2-3. Field form for *Level II* stream classification.

Stream:	**Turtle River**			
Basin:		Drainage Area:	acres **311**	mi^2
Location:	**SE¼, Section 4, T151N, R54W**			
Twp.&Rge:		Sec.&Qtr.:		
Cross-Section Monuments (Lat./Long.):			Date:	
Observers:	**DWR**		Landscape Type:	

Bankfull Width (W_{bkf}) The surface width of the stream at bankfull stage elevation, in a riffle section.	**35.0**	ft
Bankfull Mean Depth (d_{bkf}) Mean depth of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A_{bkf} / W_{bkf}$).	**3.60**	ft
Bankfull Cross-Sectional Area (A_{bkf}) Area of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**127.7**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) *Bankfull Width* divided by *Bankfull Mean Depth*, in a riffle section.	**9.7**	ft/ft
Bankfull Maximum Depth (d_{max}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**4.50**	ft
Flood-Prone Area Width (W_{fpa}) Width of the channel at an elevation that is twice the *Bankfull Maximum Depth*, measured perpendicular to the fall line of the valley in a riffle section.	**233.00**	ft
Entrenchment Ratio (ER) The *Flood-Prone Area Width* divided by *Bankfull Width* (W_{fpa} / W_{bkf}), in a riffle section.	**6.66**	ft/ft
Channel Materials (Particle Size Index D_{50}) The D_{50} particle size index represents the median or dominant diameter of channel materials, as sampled proportionately from the channel surface between the bankfull stage and Thalweg elevations.	**5**	mm
Average Water Surface Slope (S) The elevation difference of water surface measurements over the stream length between two similar bed features (e.g., start of riffle to start of last riffle) for several riffle–pool or step–pool sequences, representing channel gradient.	**0.0012**	ft/ft
Channel Sinuosity (k) An index of channel pattern determined from stream length divided by valley length (SL / VL), or from valley slope divided by average water surface slope (S_{val} / S).	**1.54**	ft/ft

Stream Type **E5** **See Classification Key (Figure 2-35)**

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

Flow Regime

Stream:	**Turtle River**	Stream Type:	**E5**
Location:	**SE¼, Section 4, T151N, R54W**	Landscape Type:	
Observers:	**DWR**	Date:	

List ALL COMBINATIONS that APPLY.....☞	**P1**	**P2**	**P7**	**P9**				

General Category

E	***Ephemeral stream channel:*** 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 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:	**Turtle River**		
Location:	**SE¼, Section 4, T151N, R54W**		
Observers:	**DWR**	Stream Type:	**E5**
Landscape Type:		Date:	

Stream Size Category and Order ☞ **S-5(3)**

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 – 9.0	15 – 30	☐
S-5	9.0 – 15.0	30 – 50	☑
S-6	15.0 – 22.8	50 – 75	☐
S-7	22.8 – 30.5	75 – 100	☐
S-8	30.5 – 46.0	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).

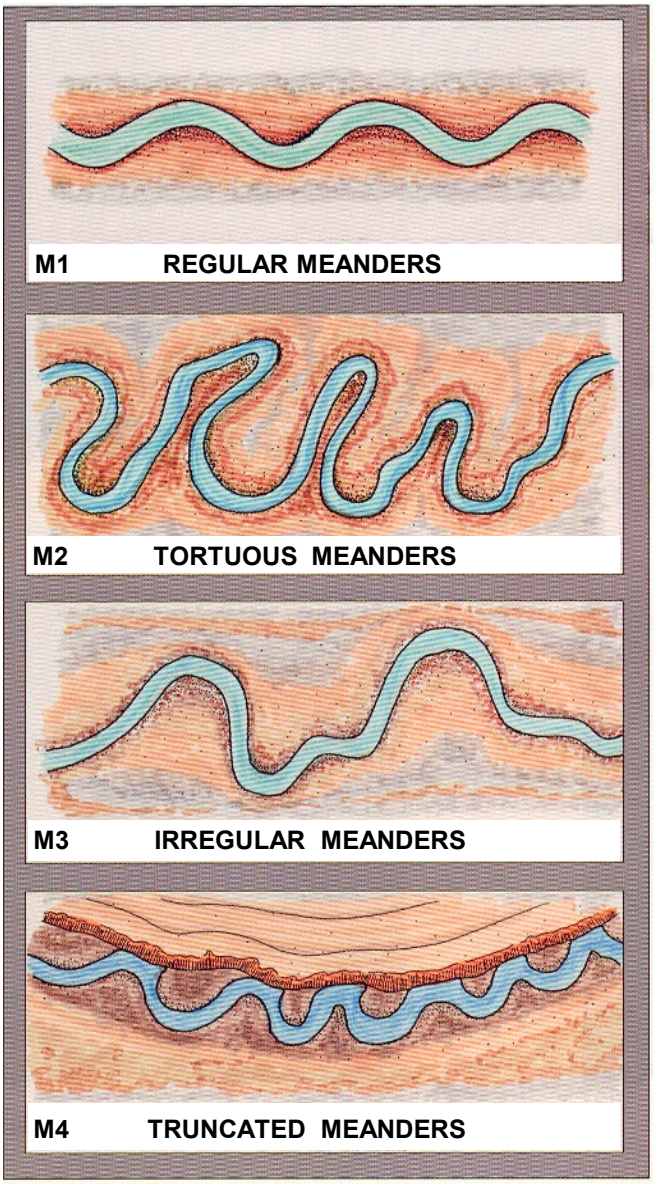
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Turtle River**	Stream Type:	**E5**
Location:	**SE¼, Section 4, T151N, R54W**	Landscape Type:	
Observers:	**DWR**	Date:	

List ALL CATEGORIES that APPLY ☞	M3	M7			

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

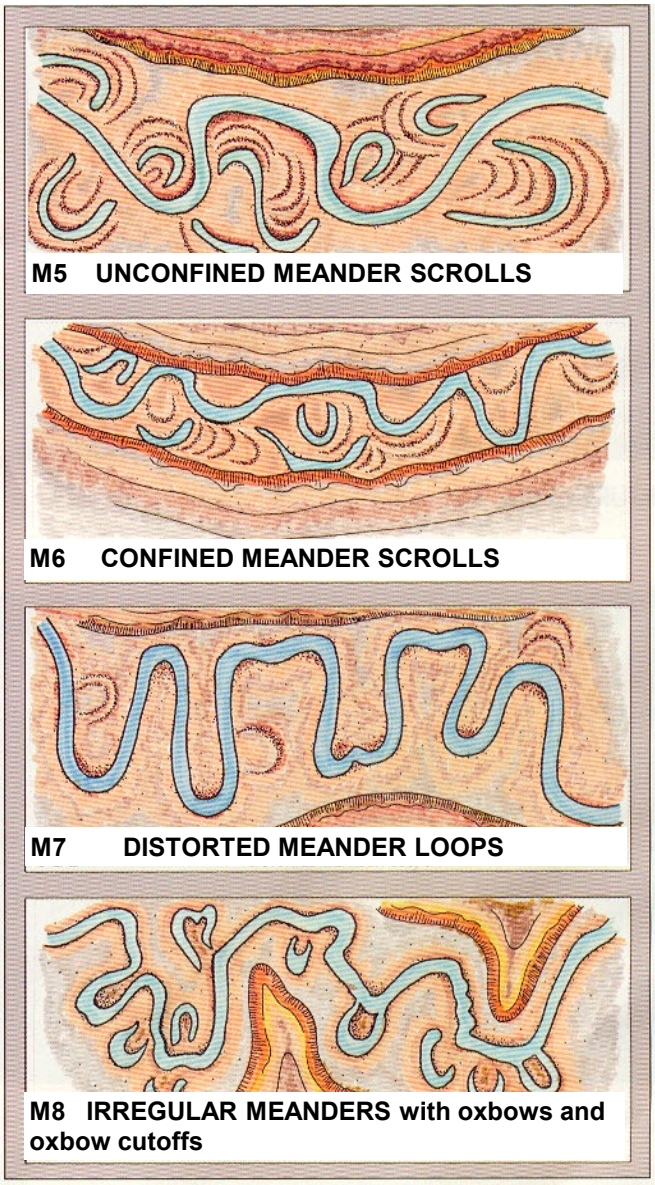


M1 REGULAR MEANDERS

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 oxbow cutoffs

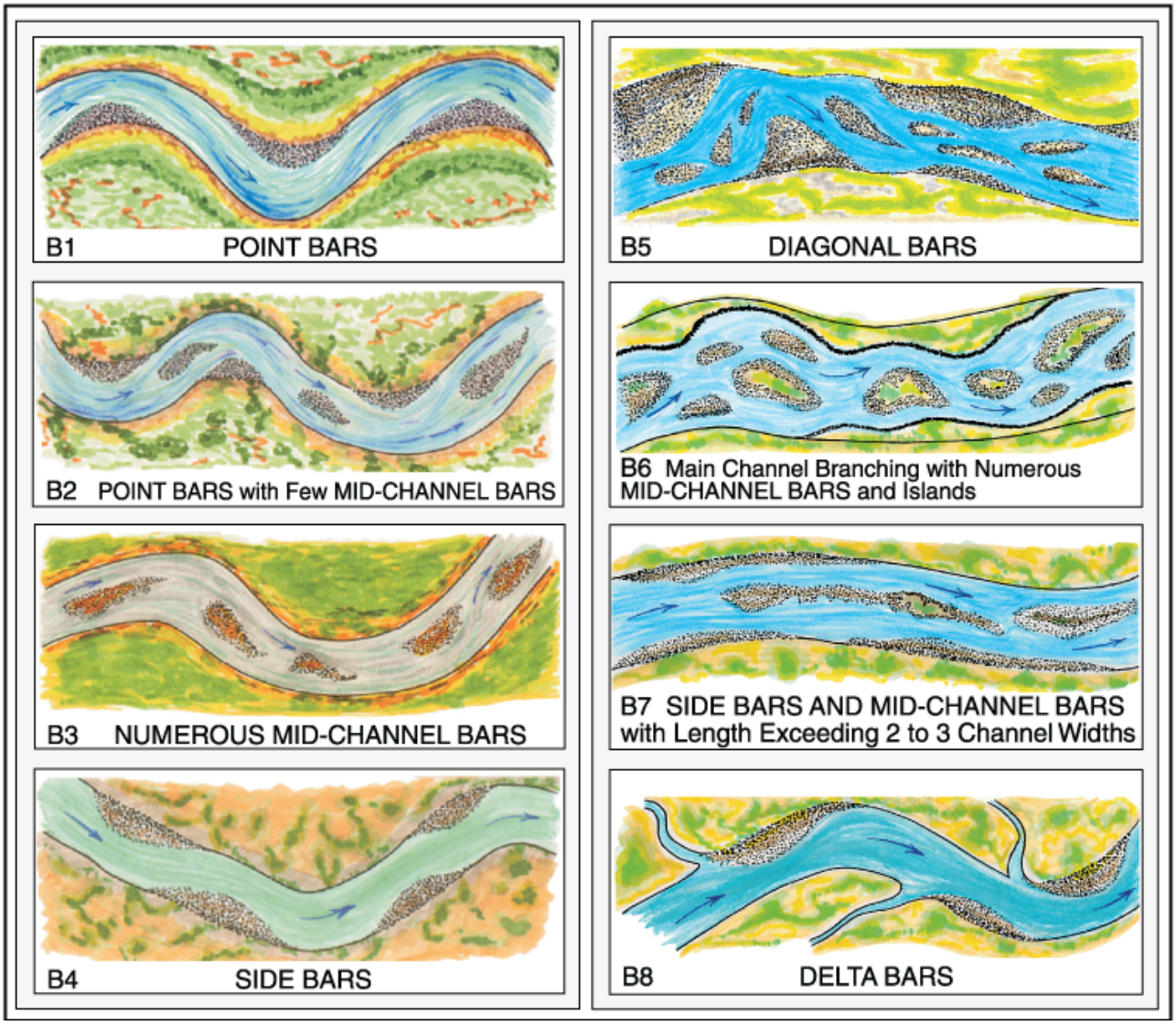
Worksheet 3-5. Depositional patterns used for stabiilty assessments.

Depositional Patterns

Stream:	**Turtle River**	Stream Type:	**E5**
Location:	**SE¼, Section 4, T151N, R54W**	Landscape Type:	
Observers:	**DWR**	Date:	

List ALL CATEGORIES that APPLY ☞	B1	B2			

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:	**Turtle River**	Stream Type:	**E5**
Location:	**SE¼, Section 4, T151N, R54W**	Landscape Type:	
Observers:	**DWR**	Date:	

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-sectional area.	☑
D4	Numerous	Significant build-up of medium- to large-sized materials, e.g., large limbs, branches, small logs, or portions of trees, occupying 10–30% of the active channel cross-sectional area.	☐
D5	Extensive	Debris "dams" of predominantly larger materials, e.g., branches, logs, and trees, occupying 30–50% of the active channel cross-sectional 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-sectional 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 or breached, initiating a series of channel adjustments, such as streambank erosion, lateral migration, avulsion, aggradation, or 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.

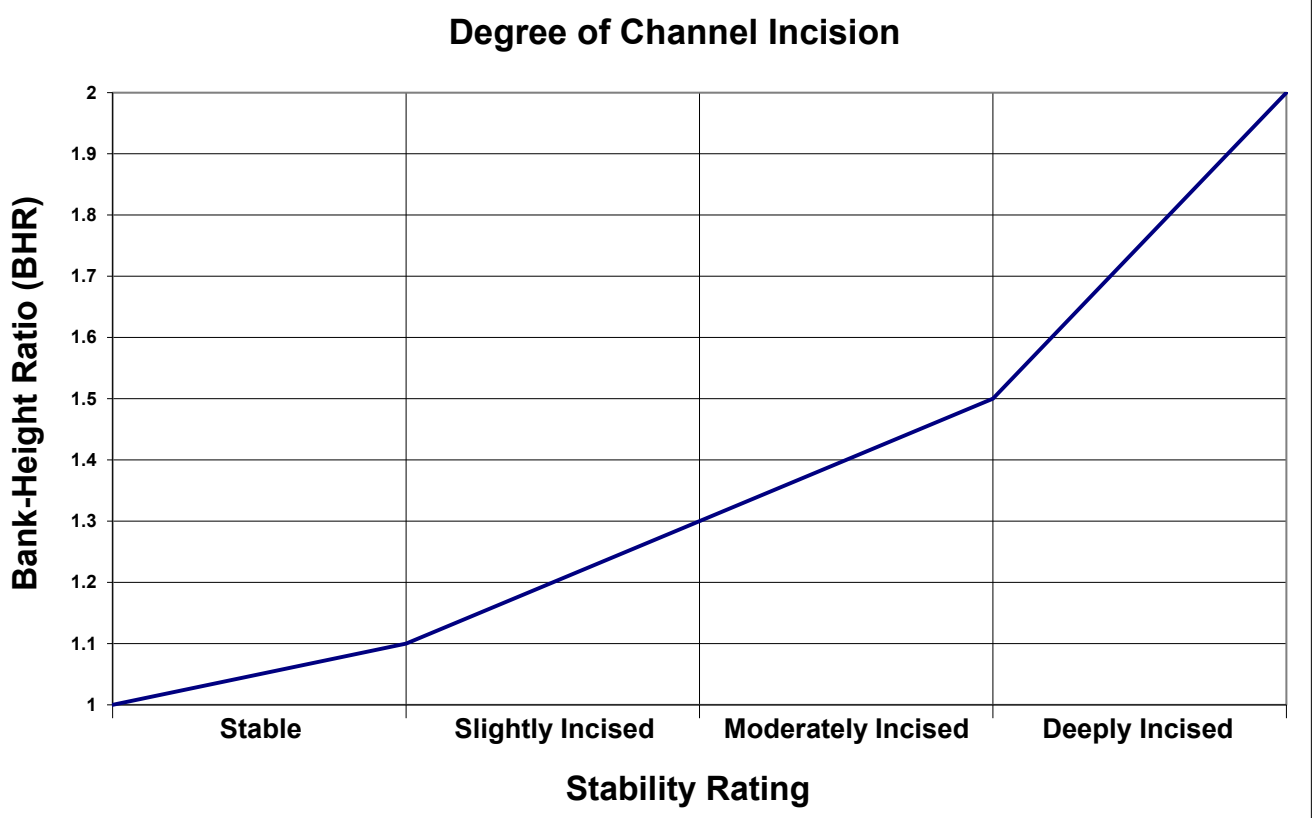
Degree of Channel Incision

Stream:	**Turtle River**	Stream Type:	**E5**
Location:	**SE¼, Section 4, T151N, R54W**	Landscape Type:	
Observers:	**DWR**	Date:	

Low Bank Height:	**6.07**
Bankfull Max Depth:	**4.5**

Bank-Height Ratio (BHR):	**1.35**

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



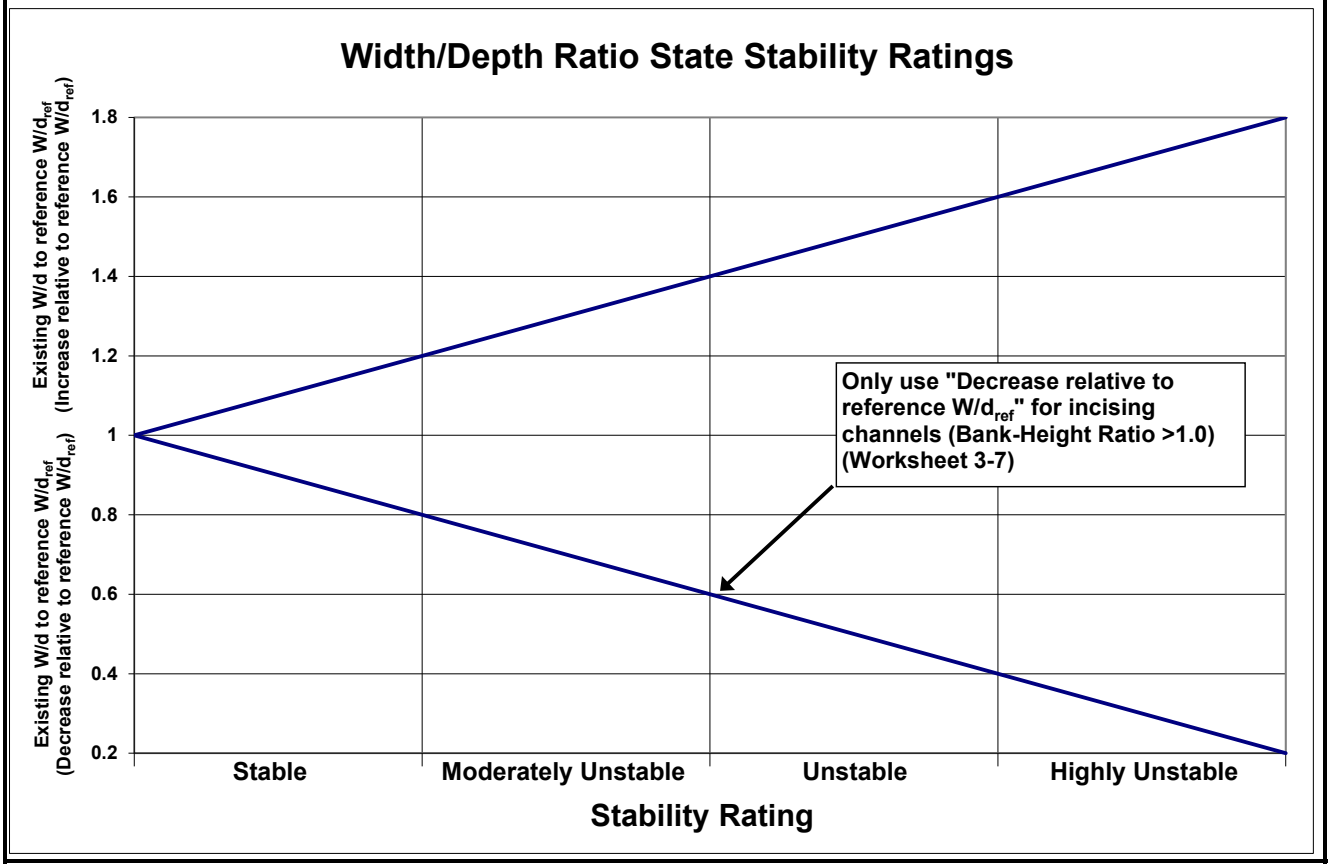
Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State

Stream:	**Turtle River**	Stream Type:	**E5**
Location:	**SE¼, Section 4, T151N, R54W**	Landscape Type:	
Observers:	**DWR**	Date:	

Existing Width/Depth Ratio (W/d):	**9.722**	Existing W/d to Reference W/d_{ref} :	**0.68**
Reference Width/Depth Ratio (W/d_{ref}):	**14.24**		

Width/Depth Ratio State Stability Rating ☞ **Moderatlely Unstable**



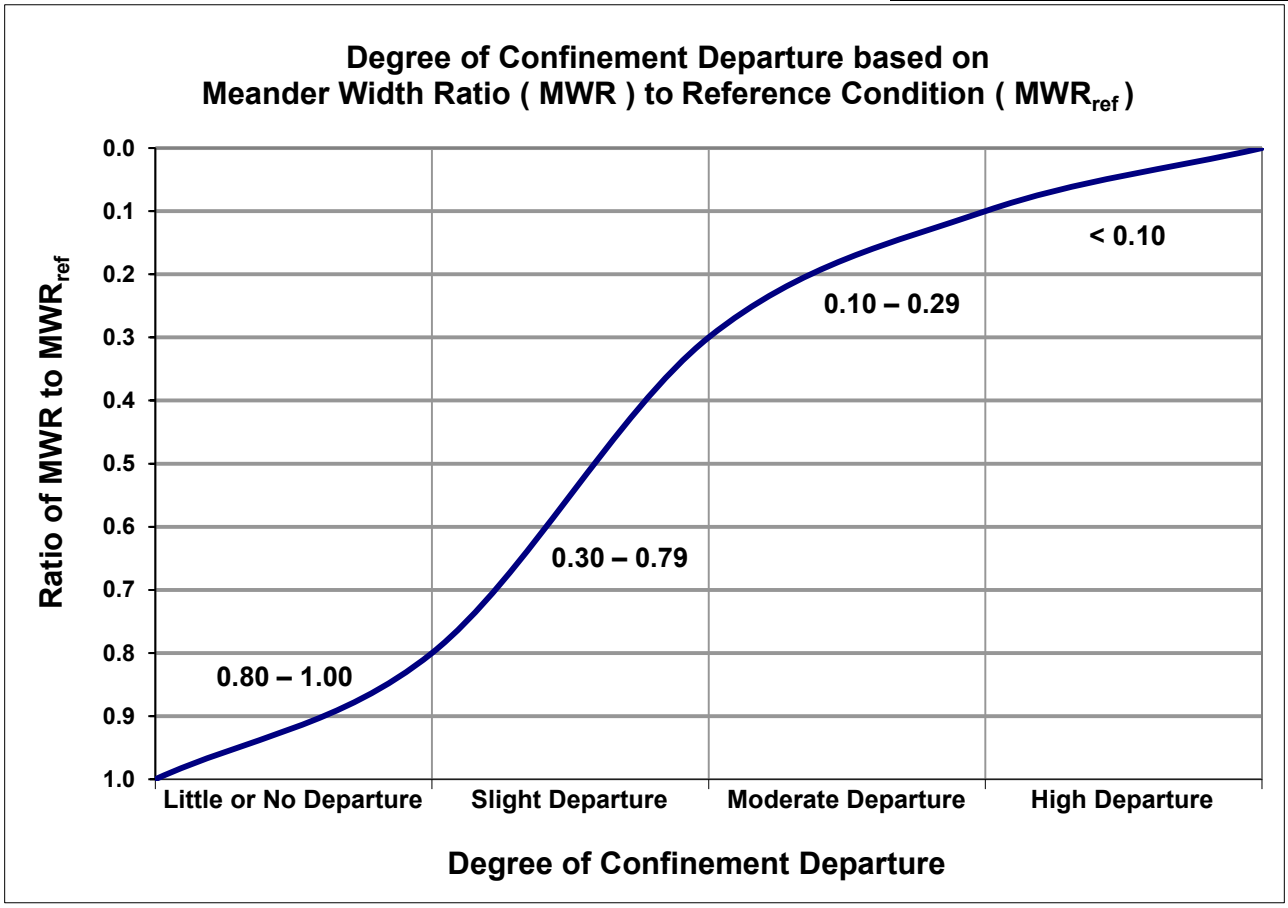
Worksheet 3-9. Degree of confinement departure based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement

Stream:	**Turtle River**	Stream Type:	**E5**
Location:	**SE¼, Section 4, T151N, R54W**	Landscape Type:	
Observers:	**DWR**	Date:	

Existing Meander Width Ratio (MWR):	**21.4**	Ratio of MWR to MWR_{ref} :	**0.88**
Reference Meander Width Ratio (MWR_{ref}):	**24.2**		

Degree of Confinement Stability Rating ☞ **Little or No Departure**



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

Stream: Turtle River **Location:** SE¼, Section 4, T151N, **Landscape Type:** **Observers:** DWR **Date:**

Location	Key	Category	Excellent		Good		Fair		Poor	
			Description	Rating	Description	Rating	Description	Rating	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 two 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 =	**18**	**Good Total =**	**30**	**Fair Total =**	**9**	**Poor Total =**	**8**

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 =	**65**
Existing Stream Type =	**E5**
***Potential Stream Type =**	**E5**
Modified channel stability rating =	**Good**

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

Worksheet 3-11. Form to calculate an overall Bank Erosion Hazard Index (BEHI) rating. Use **Figure 3-7** to determine individual BEHI scores.

Bank Erosion Hazard Index (BEHI)

Stream: **Turtle River** Location: **SE¼, Section 4, T151N, R54W**

Station: Observers: **DWR**

Date: Stream Type: **E5** Landscape Type:

						BEHI Score (Fig. 3-7)
Study Bank Height (C)						
Study Bank Height (ft) =	5.50 (A)	Bankfull Height (ft) =	2.60 (B)	(A) / (B) =	2.12 (C)	8.0
Root Depth to Study Bank Height (E)						
Root Depth (ft) =	3.00 (D)	Study Bank Height (ft) =	5.50 (A)	(D) / (A) =	0.55 (E)	3.7
Weighted Root Density (G)						
Root Density as % =	40.00 (F)	(F) × (E) =	21.8182 (G)			7.0
Bank Angle (H)						
Bank Angle as *Degrees* =	10 (H)					1.5
Surface Protection (I)						
Surface Protection as % =	95% (I)					0.8

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)

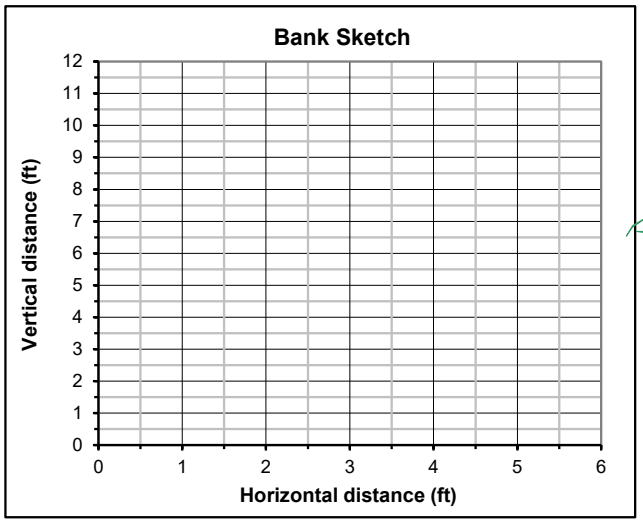
Silt/Clay (Add 10 points if uniform silt; No adjustment if silt with a mixture of clay; Subtract 10 points if silt/clay mixture with high % of clay; Subtract 20 points if clay)

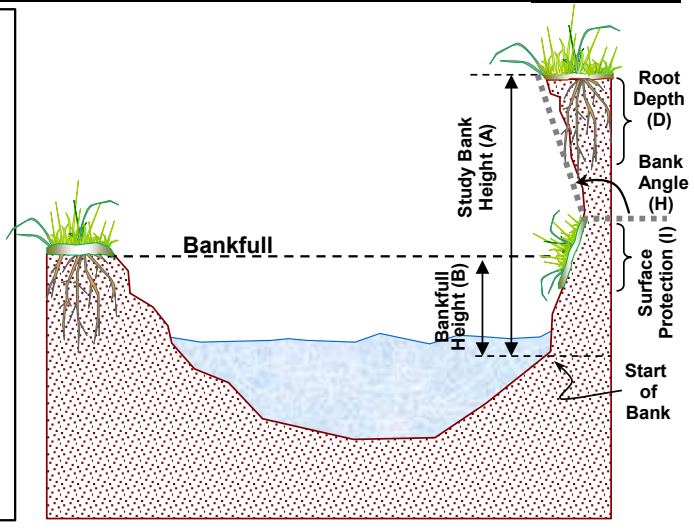
Bank Material Adjustment 7

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** 28.0





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

Estimating Near-Bank Stress (NBS)

Stream: **Turtle River** Location: **SE¼, Section 4, T151N, R54W**

Station: Stream Type: **E5** Landscape Type:

Observers: **DWR** Date:

Methods for Estimating Near-Bank Stress (NBS)

(1)	Channel pattern, transverse bar, or central bar creating NBS	Level I	Reconaissance
(2)	Radius of curvature to bankfull width (R_c / W_{bkf})	Level II	General Prediction
(3)	Pool slope to average water surface slope (S_p / S)	Level II	General Prediction
(4)	Pool slope to riffle slope (S_p / S_{rif})	Level II	General Prediction
(5)	Near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})	Level III	Detailed Prediction
(6)	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 or central bars - short 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)
135	**35**	**3.8571429**	**Very Low**

(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)

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

Worksheet 3-13. Annual streambank erosion estimates for various study reaches.

Streambank Erosion Prediction

Stream: **Turtle River** Location: **SE¼, Section 4, T151N, R54W**

Graph Used: Total Stream Length (ft): Date:

Observers: **DWR** Landscape Type: Stream Type: **E5**

(1) Station (ft)	(2) BEHI Rating (Worksheet 3-11) (adjective)	(3) NBS Rating (Worksheet 3-12) (adjective)	(4) Bank Erosion Rate (Figure 3-9 or 3-10) (ft/yr)	(5) Length of Bank (ft)	(6) Study Bank Height (ft)	(7) Erosion Subtotal [(4)×(5)×(6)] (ft^3/yr)	(8) Unit Erosion Rate (tons/yr/ft) {[(7)/27] × 1.3 / (5)}
1.	**Moderate**	**Very Low**	**0.090**	**1.00**	**5.50**	**0.50**	**0.02383**
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							
11.							
12.							
13.							
14.							
15.							
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**0.50**	
Convert erosion in ft^3/yr to yds^3/yr {divide *Total Erosion (ft^3/yr)* by 27}					**Total Erosion (yds^3/yr)**	**0.02**	
Convert erosion in yds^3/yr to tons/yr {multiply *Total Erosion (yds^3/yr)* by 1.3}					**Total Erosion (tons/yr)**	**0.02**	
Calculate erosion per unit length of channel {divide *Total Erosion (tons/yr)* by *Total Stream Length (ft)* surveyed}					**Unit Erosion Rate (tons/yr/ft)**		

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

Sediment Competence using Dimensional and Dimensionless Shear Stress Methods

Stream:	**Turtle River**		Stream Type: **E5**		
Location:	**SE¼, Section 4, T151N, R54W**		Landscape Type:		
Observers:	**DWR**		Date:		

Enter Required Information for Existing Condition

5.0	D_{50}	Median particle size of riffle bed material (mm)			
	$\hat{D}_{50}$	Median particle size of bar or sub-pavement sample (mm)			
0.00	D_{max}	Largest particle from bar sample (ft)	**0**	**(mm)**	304.8 mm/ft
0.0012	S	Existing average water surface slope (ft/ft)			
3.60	d	Existing bankfull mean depth (ft)			
1.65	γ_s-γ/γ	Immersed specific gravity of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

	$D_{50}/D_{50}^{\wedge}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\,(D_{50}/D_{50}^{\wedge})^{-0.872}$
0.00	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:	

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

	d	Required bankfull mean depth (ft) $d = \frac{\tau^*(\gamma_s - 1)D_{max}}{S}$	(use D_{max} in ft)

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

	S	Required average water surface slope (ft/ft) $S = \frac{\tau^*(\gamma_s - 1)D_{max}}{d}$	(use D_{max} in ft)

Check: ☑ Stable ☐ Aggrading ☐ Degrading

Sediment Competence Using Dimensional Shear Stress

0.270		Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.43, d = existing depth, S = existing slope
Shields **20**	CO **58**	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**
Shields **0.000**	CO **0.000**	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**
Shields **0.00**	CO **0.00**	Predicted mean depth required to initiate movement of measured D_{max} (mm) $d = \frac{\tau}{\gamma S}$ τ = predicted shear stress, γ = 62.43, S = existing slope
Shields **0.0000**	CO **0.0000**	Predicted slope required to initiate movement of measured D_{max} (mm) $S = \frac{\tau}{\gamma d}$ τ = predicted shear stress, γ = 62.43, d = existing depth

Check: ☐ Stable ☐ Aggrading ☐ Degrading

Worksheet 3-15. Stability ratings for stream type stage shifts.

Stream Succession Stage Shifts	
Stream: **Turtle River**	Stream Type: **E5**
Location: **SE¼, Section 4, T151N, R54W**	Landscape Type:
Observers: **DWR**	Date:
Stream Type Stage Shifts (Figure 3-14)	**Stability Rating (Check ✓ Appropriate Rating)**
Stream Type at Potential, (C→E), (F_b→B), (F→B_c), (F→C), (G→B), (D→C)	☐ Stable
(E→C), (B→High W/d B), (C→High W/d C)	☑ Moderately Unstable
(G_c→F), (G→F_b), (F→D), (C→F)	☐ Unstable
(C→D), (A→G), (B→G), (D→G), (C→G), (E→G), (E→A)	☐ Highly Unstable

Worksheet 3-16. Lateral stability prediction summary.

Lateral Stability Prediction					
Stream: **Turtle River**			Stream Type: **E5**		
Location: **SE¼, Section 4, T151N, R54W**			Landscape Type:		
Observers: **DWR**			Date:		
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	1.2 – 1.4	1.4 – 1.6	> 1.6	**2**
	(2)	**(4)**	**(6)**	**(8)**	
2 Depositional Patterns (Worksheet 3-5)	B1, B2	B4, B8	B3	B5, B6, B7	**1**
	(1)	**(2)**	**(3)**	**(4)**	
3 Meander Patterns (Worksheet 3-4)	M1, M3, M4		M2, M5, M6, M7, M8		**1**
	(1)		**(3)**		
4 Streambank Erosion: Unit Rate (Worksheet 3-13)	< 0.006	0.006 – 0.04	0.041 – 0.07	> 0.07	**4**
	(2)	**(4)**	**(6)**	**(8)**	
5 Degree of Confinement (MWR / MWR_{ref}) (Worksheet 3-9)	> 0.8	0.3 – 0.79	0.1 – 0.29	< 0.1	**1**
	(1)	**(2)**	**(3)**	**(4)**	
				Total Points	**9**
	Lateral Stability Category Point Range				
Overall Lateral Stability Category (use total points and check ✓ stability rating)	***Stable*** **< 10** ☑	***Moderately Unstable*** **10 – 12** ☐	***Unstable*** **13 – 21** ☐	***Highly Unstable*** **> 21** ☐	

Worksheet 3-17. Vertical stability prediction for excess deposition and aggradation.

Vertical Stability Prediction for Excess Deposition and Aggradation					
Stream: **Turtle River**			Stream Type: **E5**		
Location: **SE¼, Section 4, T151N, R54W**			Landscape Type:		
Observers: **DWR**			Date:		
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 slope to transport largest size available	Trend toward insufficient depth 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 or suspended sand	Reduction over 25% of annual sediment yield for bedload or suspended sand	**2**
	(2)	**(4)**	**(6)**	**(8)**	
3 W/d Ratio State (Worksheet 3-8)	< 1.2	1.2 – 1.4	1.4 – 1.6	> 1.6	**2**
	(2)	**(4)**	**(6)**	**(8)**	
4 Stream Succession Stage Shifts (Worksheet 3-15)	Current stream type at potential or does not indicate deposition/ aggradation	(E→C)	(B→High W/d B), (C→High W/d C), (C→F), (G_c→F), (G→F_b)	(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 and Aggradation				
Vertical Stability for Excess Deposition / Aggradation (use total points and check ✓ stability rating)	***No Deposition*** **< 15** ☑	***Moderate Deposition*** **15 – 20** ☐	***Excess Deposition*** **21 – 30** ☐	***Aggradation*** **> 30** ☐	

Worksheet 3-18. Vertical stability prediction for channel incision and degradation.

Vertical Stability Prediction for Channel Incision and Degradation					
Stream: **Turtle River**			Stream Type: **E5**		
Location: **SE¼, Section 4, T151N, R54W**			Landscape Type:		
Observers: **DWR**			Date:		
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	Trend to move larger sizes than D_{100} of bar or D_{84} of bed	D_{100} of bed moved	Particles much larger than D_{100} of bed moved	**2**
	(2)	**(4)**	**(6)**	**(8)**	
2 Sediment Capacity (POWERSED)	Does not indicate excess capacity	Slight excess energy: up to 10% increase above reference	Excess energy sufficient to increase load up to 50% of annual load	Excess energy transporting more than 50% of annual load	**2**
	(2)	**(4)**	**(6)**	**(8)**	
3 Degree of Channel Incision (BHR) (Worksheet 3-7)	1.00 – 1.10	1.11 – 1.30	1.31 – 1.50	> 1.50	**6**
	(2)	**(4)**	**(6)**	**(8)**	
4 Stream Succession States (Worksheets 3-15 and 3-7)	Does not indicate incision or degradation	If BHR > 1.1 and stream type has W/d between 5–10	If BHR > 1.1 and stream type has W/d less than 5	(B→G), (C→G), (E→G), (D→G), (A→G), (E→A)	**4**
	(2)	**(4)**	**(6)**	**(8)**	
5 Confinement (MWR / MWR_{ref}) (Worksheet 3-9)	0.80 – 1.00	0.30 – 0.79	0.10 – 0.29	< 0.10	**1**
	(1)	**(2)**	**(3)**	**(4)**	
				Total Points	**15**
	Vertical Stability Category Point Range for Channel Incision and Degradation				
Vertical Stability for Channel Incision/ Degradation (use total points and check ✓ stability rating)	***Not Incised*** **< 12** ☐	***Slightly Incised*** **12 – 18** ☑	***Moderately Incised*** **19 – 27** ☐	***Degradation*** **> 27** ☐	

Worksheet 3-19. Channel enlargement prediction summary.

Channel Enlargement Prediction					
Stream: **Turtle River**			Stream Type: **E5**		
Location: **SE¼, Section 4, T151N, R54W**			Landscape Type:		
Observers: **DWR**			Date:		
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 Stream Succession Stage Shifts (Worksheet 3-15)	Stream Type at Potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C)	(B→High W/d B), (C→High W/d C), (E→C)	(G→F), (F→D)	(C→D), (A→G), (B→G), (D→G), (C→G), (E→G), (E→A), (C→F)	**4**
	(2)	**(4)**	**(6)**	**(8)**	
2 Lateral Stability (Worksheet 3-16)	*Stable*	*Moderately Unstable*	*Unstable*	*Highly Unstable*	**2**
	(2)	**(4)**	**(6)**	**(8)**	
3 Vertical Stability Excess Deposition and Aggradation (Worksheet 3-17)	*No Deposition*	*Moderate Deposition*	*Excess Deposition*	*Aggradation*	**2**
	(2)	**(4)**	**(6)**	**(8)**	
4 Vertical Stability Channel Incision and Degradation (Worksheet 3-18)	*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*** **< 11** ☐	***Slight Increase*** **11 – 16** ☑	***Moderate Increase*** **17 – 24** ☐	***Extensive*** **> 24** ☐	

Worksheet 3-20. Overall sediment supply rating determined from individual stability rating categories.

Overall Sediment Supply Prediction			
Stream: **Turtle River**		Stream Type: **E5**	
Location: **SE¼, Section 4, T151N, R54W**		Landscape Type:	
Observers: **DWR**		Date:	
Overall Sediment Supply Prediction Criteria (choose corresponding points for each criterion 1–5)	**Stability Rating**	**Points**	**Selected Points**
1 Lateral Stability (Worksheet 3-16)	***Stable***	**1**	**1**
	Mod. Unstable	**2**	
	Unstable	**3**	
	Highly Unstable	**4**	
2 Vertical Stability Excess Deposition or Aggradation (Worksheet 3-17)	***No Deposition***	**1**	**1**
	Mod. Deposition	**2**	
	Excess Deposition	**3**	
	Aggradation	**4**	
3 Vertical Stability Channel Incision or Degradation (Worksheet 3-18)	***Not Incised***	**1**	**2**
	Slightly Incised	**2**	
	Mod. Incised	**3**	
	Degradation	**4**	
4 Channel Enlargement Prediction (Worksheet 3-19)	***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	**7**

	Category Point Range			
Overall Sediment Supply Rating (use total points and check ✓ stability rating)	***Low*** **< 6** ☐	***Moderate*** **6 – 10** ☑	***High*** **11 – 15** ☐	***Very High*** **> 15** ☐

Worksheet 3-21. Summary of stability condition categories.

Summary of Stability Conditions

Stream:	**Turtle River**					Location:	**SE¼, Section 4, T151N, R54W**				
Observers:	**DWR**		Date:			Stream Type:	**E5**		Landscape Type:		
Channel Dimension	Bankfull Mean Depth (ft):	**3.6**	Bankfull Width (ft):	**35**		Cross-Sectional Area (ft^2):	**127.7**	Width/Depth Ratio:	**9.7**	Entrenchment Ratio:	**6.7**
Channel Pattern	Mean: Range:	λ/W_{bkf}:		L_m/W_{bkf}:		R_c/W_{bkf}:		MWR:		Sinuosity:	
Streamflow	Bankfull Mean Velocity ($\bar{u}_{bkf}$) (ft/sec):		Bankfull Discharge (Q_{bkf}):	**480**		Estimation Method:				Drainage Area (mi^2):	**311**
River Profile & Bed Features	Check: ☑ Riffle/Pool ☐ Step/Pool ☐ Plane Bed ☐ Convergence/Divergence ☐ Dunes/Antidunes/Smooth Bed										
	Bankfull Max Depth (ft):	Riffle: **5.8**	Pool:	Depth Ratio (max to mean):	Riffle: **1.6**	Pool:	Pool-to-Pool Spacing:	Ratio:	Slope: Valley:	Water Surface:	**0.0012**
Level III Stream Stability Indices	Riparian Vegetation	Current Composition/Density:		Potential Composition/Density:			Remarks: Condition, Vigor & Usage of Existing Reach:				
	Flow Regime:	**P1**	Stream Size & Order:	**S5(3)**	Meander Patterns:	**M3, M7**	Depositional Patterns:	**B1, B2**	Debris/Channel Blockages:	**D2, D3**	
	Degree of Incision (Bank-Height Ratio):	**1.35**	Degree of Incision Stability Rating:	**Moderately Incised**	Modified Pfankuch Stability Rating (Numeric & Adjective Rating):	**65, Good**					
	W/d Ratio State $(W/d)/(W/d_{ref})$:	**0.68**	W/d Ratio State Stability Rating:	**Moderately Unstable**	Degree of Confinement (MWR/MWR_{ref}):		MWR / MWR_{ref} Stability Rating:	**0.88, Little or No Departure**			
Bank Erosion Summary	Length of Reach Studied (ft):	**1**	Annual Streambank Erosion Rate: **0.024** (tons/yr)	**0.024** (tons/yr/ft)	Curve Used: **Very Low**	Remarks:					
Sediment Capacity (POWERSED)	☑ *Sufficient Capacity* ☐ *Insufficient Capacity* ☐ *Excess Capacity*					Remarks:					
Entrainment/ Competence	Largest Particle from Bar Sample (mm):		$\tau =$ **0.27**	$\tau^* =$ **0**	Existing Depth:	Required Depth:	Existing Slope:	Required Slope:			
Stream Succession	→	→	→	→	→	Existing Stream State (Type):	Potential Stream State (Type):				
Lateral Stability	☑ *Stable*	☐ *Mod. Unstable*	☐ *Unstable*	☐ *Highly Unstable*		Remarks:					
Vertical Stability (Aggradation)	☑ *No Deposition*	☐ *Mod. Deposition*	☐ *Ex. Deposition*	☐ *Aggradation*		Remarks:					
Vertical Stability (Degradation)	☐ *Not Incised*	☑ *Slightly Incised*	☐ *Mod. Incised*	☐ *Degradation*		Remarks:					
Channel Enlargement	☐ *No Increase*	☑ *Slight Increase*	☐ *Mod. Increase*	☐ *Extensive*		Remarks:					
Sediment Supply (Channel Source)	☐ *Low*	☑ *Moderate*	☐ *High*	☐ *Very High*		Remarks:					

NRCS ADDENDUM TO STREAM CLASSIFICATION AND RIPARIAN AREA ASSESSMENT

April 21, 2025

Larimore Dam Watershed Rehabilitation Plan

Background & Concerns:

This document serves as an addendum to Appendix D-8: Stream Classification and Riparian Area Assessment conducted by HDR Engineering Inc on February 3, 2023. An addendum was deemed necessary by NRCS to include additional stream cross sections and re-evaluate regional curves. Only two cross section locations were analyzed, one upstream of reservoir and another downstream; which potentially lack precision and diversity in understanding South Branch Turtle River geomorphology details. For reference, the reservoir catchment is 65.5 mi^2, which is watershed that would be supporting details needed for decommissioning alternative. Primary concerns with existing cross sections and regional curves include …

- The downstream data point is for the Main Stem Turtle River, which DA=310 mi^2. The catchment to this point is 470% larger than application of this data, which is a primary concern.
- The upstream and downstream points are consistently below ND USGS gauge calibrate curve. The alignment of these points and curves is a primary concern.
- Only having two points of considerable distance from the reservoir is a primary concern.

Secondary concerns with existing cross sections, regional curves, and riparian areas include…

- The upstream data point is for the South Branch Turtle River, which DA=51 mi^2. The catchment to this point is 78% smaller than application of this data, which is a secondary concern.
- Riparian areas of two points are predominately prairie landscapes. The landscape of South Branch River adjacent to the reservoir is much more forested. Gaining more information about forested riparian areas is a secondary concern.

Additional Cross Sections:

Four cross sections were surveyed along the South Branch Turtle River in summer of 2024 by Christi Fisher and Rita Sveen, as summarized in Table D-8A-1 and mapped in Figure D-8A-1. XS1, XS2, and XS3 are upstream of the dam, while XS4 is downstream of the dam. The watershed catchment is within 3% of reservoir catchment as the goal was to obtain geomorphology information of existing South Branch Turtle River on both sides of dam as close to where resulting data will be applied to decommissioning alternative. The upstream cross sections are outside the effects of sedimentation delta of confluence between river and reservoir. The downstream cross section is outside effects of principal spillway exit channel shaping. All cross sections are also outside effects of major anthropogenic features, i.e. bridges or channel modification, other than the Larimore Dam regional effects, which are unavoidable.

XS1, XS3, and XS4 are taken at riffle facets, to determine bankfull parameters, classification, stability, and riparian vegetation. The upstream reach (XS1 & XS3) attained fair stability rating according to Pfankuch method, which is summarized in Figure D-8A-2. Riparian vegetation is summarized in Figure D-8A-3 and D-8A-4. XS2 is at a pool facet, to determine ratios for reach quantities. XS2 bankfull area is 96.6 ft^2. Therefore, the pool is approximately 1.6 times larger in cross sectional area than riffle sections, which is typical for E type channel obtained on other rivers in North Dakota and Minnesota.

Table D-8A-1: Riffle Cross Sections Geomorphology Summary

	Upstream			Downstream	
Parameter	D-8 Table 1	XS 1	XS 3	D-8 Table 1	XS 4
Watershed Area (mi^2)	51	63.4	63.4	310	65.6
Bankfull Width, W_{bkf} (ft)	19	20.7	22.7	35	31.4
Bankfull Mean Depth, d_{bkf} (ft)	2.02	2.6	2.7	3.6	2
Bankfull Area, A_{bkf} (ft^2)	38.3	54	60.5	127.7	61.3
Width/Depth, W_{bkf}/d_{bkf} (ft/ft)	9.4	7.9	8.5	9.7	16.1
Bankfull Max Depth, d_{max} (ft)	3.12	3.1	3.1	5.82	3.1
Flood-prone Area Width, W_{fpa} (ft)	65	150	150	233	200
Entrenchment Ratio, ER (ft/ft)	3.42	7.2	6.6	6.67	6.4
Channel Materials, D_{50} (mm)	5	N/A	N/A	5	N/A
Avg Water Surface Slope, S (ft/ft)	0.0037	0.0006	0.0006	0.0012	0.0026
Channel Sinuosity, k (ft/ft)	1.92	1.91	1.91	1.54	2.1
Classification	E5	E	E	E5	C

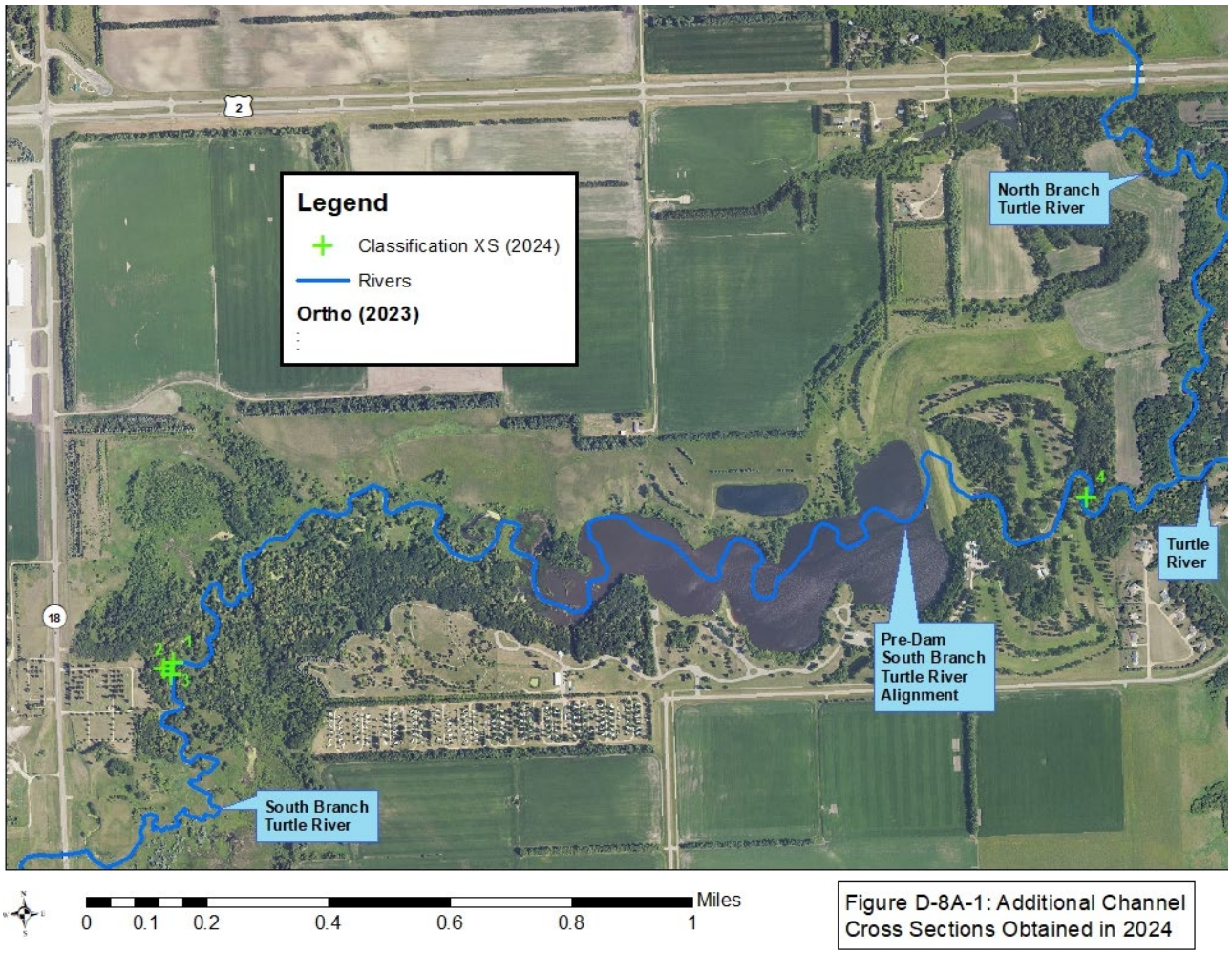


Figure D-8A-1: Additional Channel Cross Sections Obtained in 2024

Figure D-8A-1: Additional Cross Sections Obtained in 2024

Stream: Turtle River	Location: Upstream	Valley Type:	Observers: Fisher, Sveen	Date: Summer 2024

Location	Key	Category	Excellent		Good		Fair		Poor	
			Description	Rating	Description	Rating	Description	Rating	Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	5	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.	3	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	Bankfull stage 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 deposition 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.	15	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 =	10	Good total =	35	Fair total =	18	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	94-90	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	E5
*Potential stream type	E5
Modified channel stability rating =	Fair

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

Figure D-8A-2: Upstream Pfankuch Stability Rating

Riparian Vegetation

Stream: **Turtle River** Location: **XS 1,2,3**

Observers: **Sveen** Reference reach ☐ Disturbed (impacted reach) ☐ Date: **10/22/2024**

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	30%	20%	Oak	50%
				Basswood	20%
				Green Ash	20%
				Box Elder	10%
					0%
					0%
					100%
2. Understory	Shrub layer		20%	Snowberry	60%
				Saplings	40%
					0%
					0%
					0%
					0%
					100%
3. Ground level	Herbaceous		90%	Horsetail	50%
				Brome	40%
				Northern Reed Grass	10%
					100%
				Remarks: Condition, vigor and/or usage of existing reach: **Only bare areas are along the intermittant eroding banks.**	
	Bare ground		10%		

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

Figure D-8A-3: Upstream Riparian Vegetation

Riparian Vegetation

Stream: **Turtle River**		Location: **XS 4**	
Observers: **Sveen, Fisher**	Reference reach ☐	Disturbed (impacted reach) ☐	Date: **10/22/2024**
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%	5%	Oak	50%
				Basswood	30%
				Box Elder	20%
					0%
					0%
					0%
					100%
2. Understory	Shrub layer		80%	Snowberry	50%
				Box Elder saplings	25%
				Green Ash saplings	10%
				Honeysuckle	10%
				Chokecherry	5%
					0%
					100%
3. Ground level	Herbaceous		60%	Reed Canary	70%
				Kentucky Bluegrass	20%
				Brome	10%
					100%
				Remarks: Condition, vigor and/or usage of existing reach: **Only bare areas are along the intermittant eroding and undercut banks.**	
	Bare ground		10%		

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

Figure D-8A-4: Downstream Riparian Vegetation

Re-evaluate Regional Curves:

As noted previously, the upstream and downstream points are consistently below ND USGS gauge calibrate curve in Appendix D-8 regional curves (Figures 2-5). Therefore, more points as described in prior section are applied to re-evaluation of curves that should be applied to decommissioning alternatives. Four regional curves were evaluated to gain insights into applicability of best fit curves shown in Figure 2-5, including…

- Upper Salmon River, ID (NRCS, 2007)
- Upper Green River, WY (NRCS, 2007)
- Western Minnesota Rivers (Hernick et al, 2019)
- East-Central Montana River (MT), (Perrett, 2001)

These regional curves were chosen because they are nearby, with similar watershed parameters and average annual rainfall, or documented in National Engineering Handbook (NEH) and similar average annual rainfall as the Larimore Dam watershed. Regional curves are strongly based on average annual rainfall, which makes these four curves the most applicable for comparison. The Park River point (DA=695 mi^2) from Appendix D-8 regional curves (Figures 2-5) was consistently an outlier and removed from consideration. This could have been due to anthropogenic changes throughout the watershed, at the site, or data survey and processing. Therefore, regional bankfull curves for use in North Dakota have been developed based on calibrated USGS gauge stations and corresponding field measurements at five sites.

Updated regional curves are plotted in Figures D-8A-5 through D-8A-8. The five calibrated North Dakota points are black triangles, with best fit curve as solid black line. The nearby regional plots are identified accordingly as dashed lines. The two points from Appendix D-8 are squares and new (2024) points as diamonds. The new (2024) points match considerably better to best fit curves than two points from Appendix D-8, especially for bankfull flow area which is the most important. The regional curves provide strong validation of Turtle River points, as well as North Dakota calibrated best fit lines. These best fit line equations are documented in each of the figures; which should be used for decommissioning alternative design considerations.

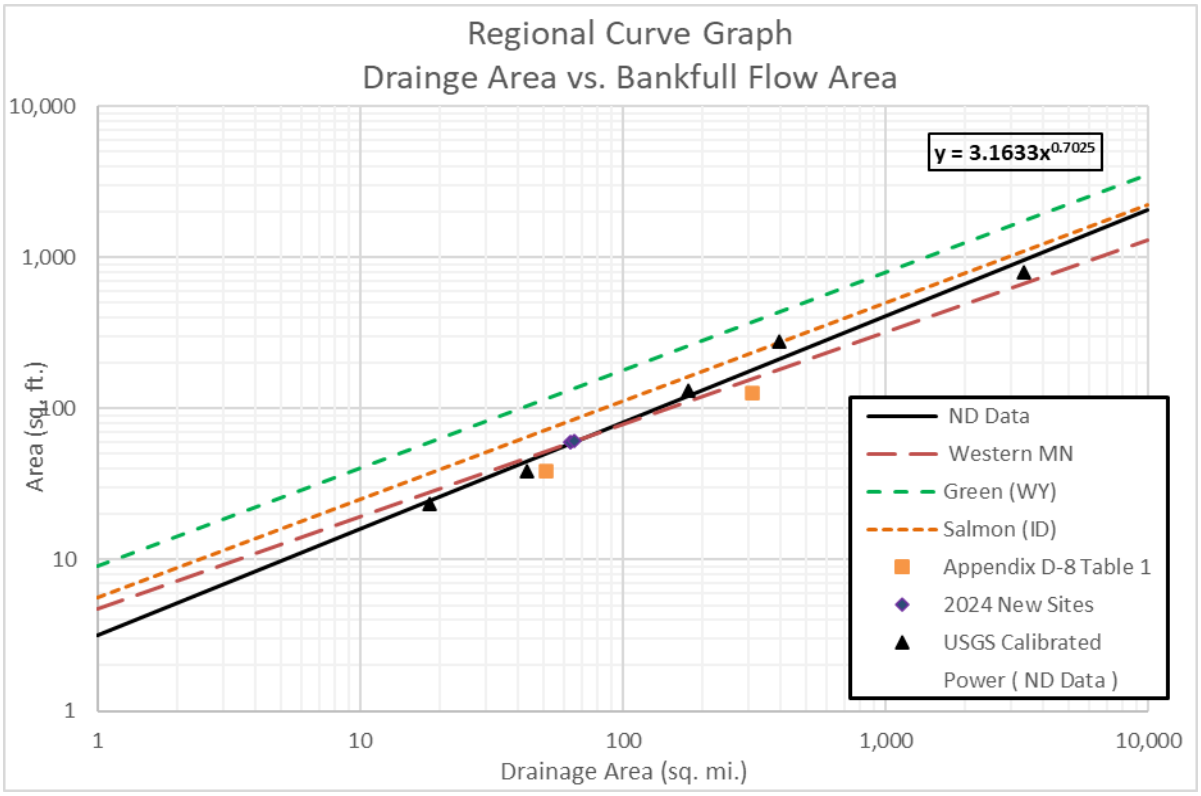


Figure D-8A-5: Regional Curve – Drainage Area vs. Bankfull Flow Area

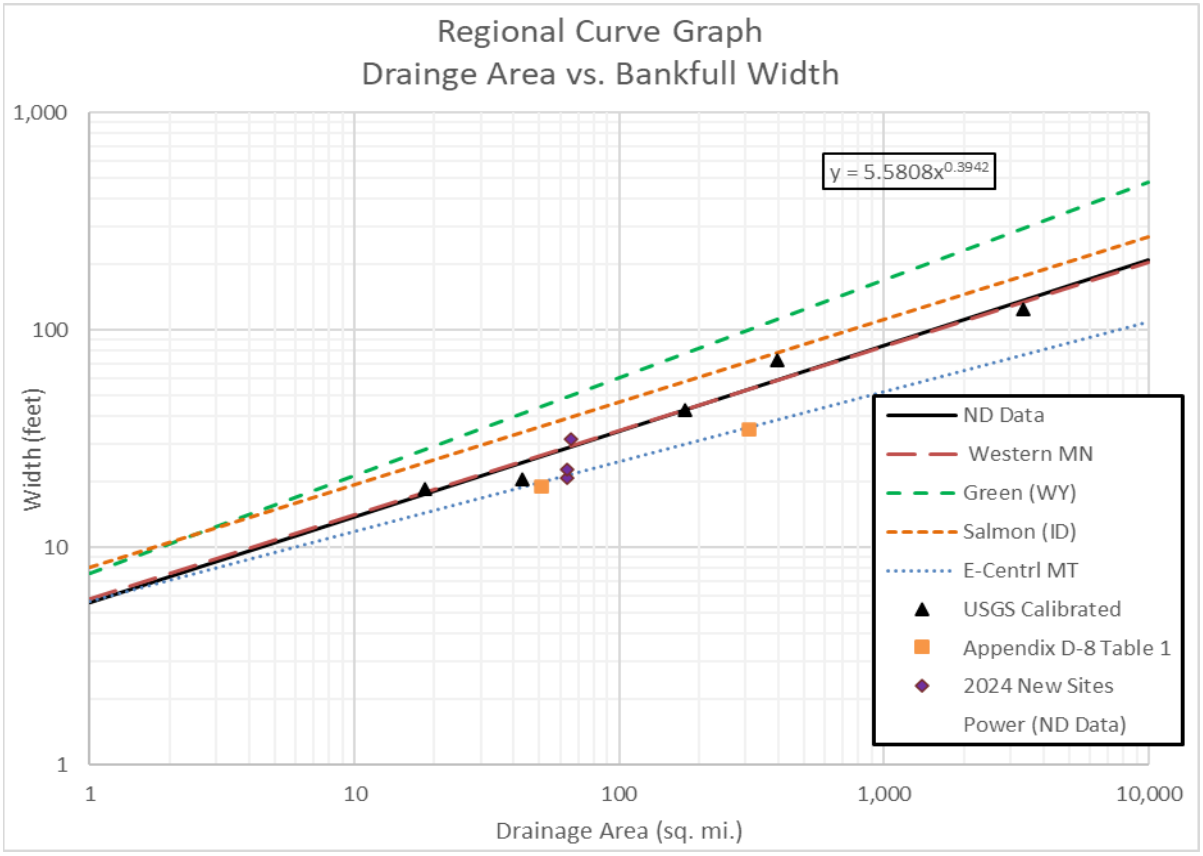


Figure D-8A-6: Regional Curve – Drainage Area vs. Bankfull Flow Width

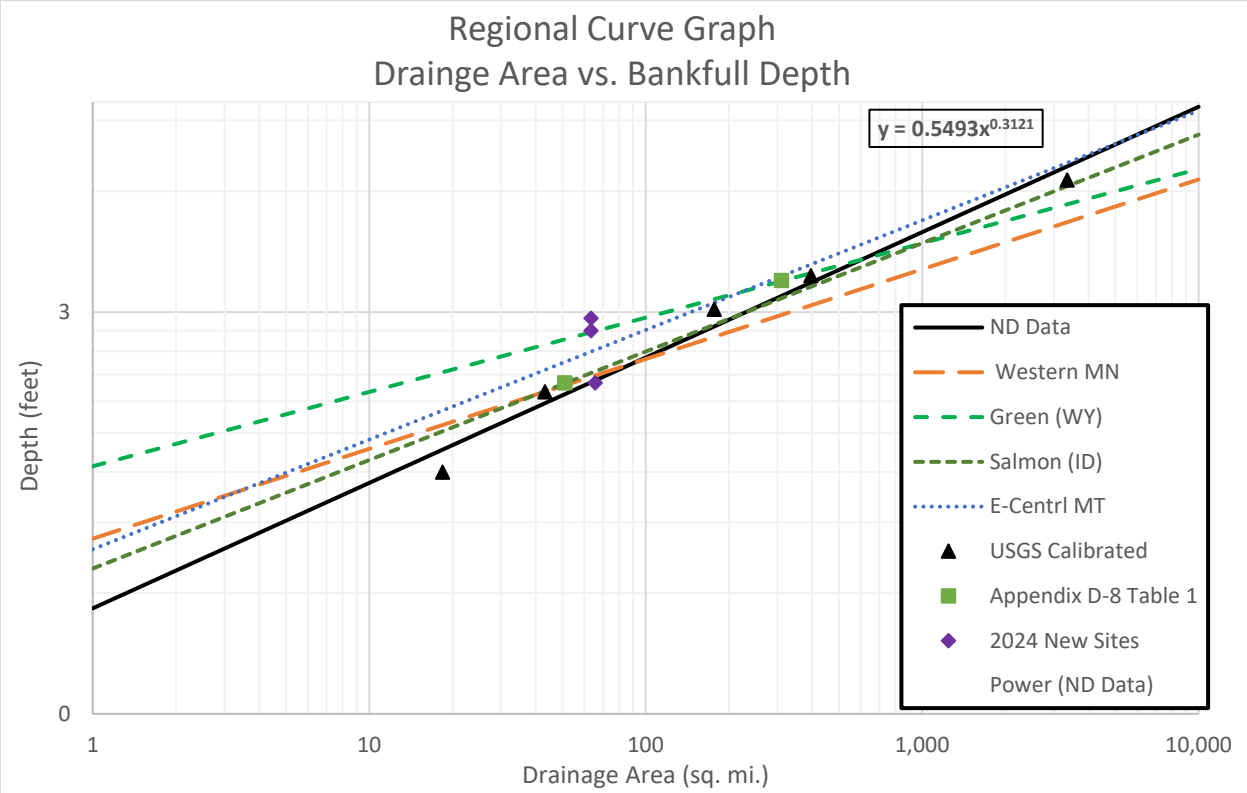


Figure D-8A-7: Regional Curve – Drainage Area vs. Bankfull Flow Depth

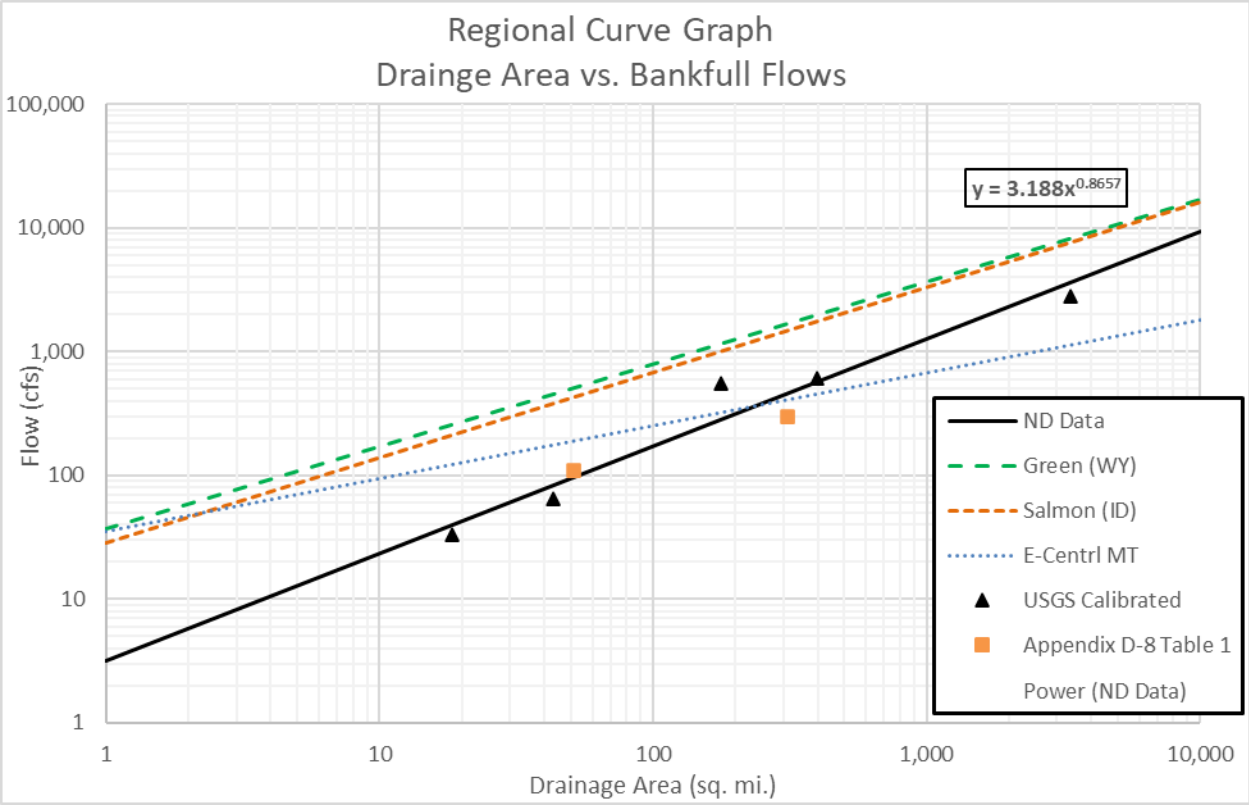


Figure D-8A-8: Regional Curve – Drainage Area vs. Bankfull Flow

References:

Hernick, M., Lenhart, C., Kozarek, J., and Nieber, J., 2019. Minnesota Guide for Stream Connectivity and Aquatic Organism Passage Through Culverts, January 2019.

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