RS26 – Partridge River Level 1 Rosgen Geomorphic Survey

Rosgen Classification
Partridge River from Headwaters to Colby Lake

Prepared for

PolyMet NorthMet Project

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1.0 Introduction

This study is presented in accordance with the October 25, 2005, *NorthMet Mine and Ore Processing Facilities Project Final Scoping Decision*. According to Section 3.3.3 of that document:

> The EIS will include a watershed assessment of the upper Partridge River to assess the net hydrologic effects of PolyMet's proposal. This watershed assessment will evaluate the changes in watershed discharge due to land surface changes (loss of wetlands, vegetation, and mine pit construction), as well as the direct hydrologic changes from mine pit dewatering and other mine site discharges. Section 3.3.4 below describes a hydrogeologic study that will be used to quantify the mine site discharges. A Level 1 Rosgen geomorphic survey will be conducted for the Partridge River, down to Colby Lake to identify any potentially geomorphilogically sensitive stream reaches. If the watershed assessment combined with the Level 1 Rosgen geomorphic survey indicates a potential for fluvial geomorphic impacts resulting from Polymet's proposal, there will be additional evaluation of the impact. If this additional evaluation determines that the changes in stream flow will cause significant adverse impacts, additional mitigation and monitoring will be developed.

This report pertains to the Level 1 Rosgen geomorphic survey referenced above.

1.1 Description of Partridge River

The Partridge River once originated from Iron Lake near Babbitt, in the upper portion of the St. Louis River Watershed. The North Shore Mine has separated the Partridge River from Iron Lake, however, and the headwaters are now located immediately south of the mine. The Partridge River flows southwest to Colby Lake, and continues a short distance from there before joining the St. Louis River south of Aurora. The total length of the Partridge River is approximately 32 miles. The Partridge River watershed is a mix of upland and marshland, with very little development in its watershed. The Partridge River varies from sluggish, marshy reaches to large open ponds to steep boulder rapids.

1.2 Physical Classification of Channels

Physical classification of a stream or river determines its physical nature based on the relationship of its physical geometry and hydraulic characteristics. The purpose of a physical classification is to evaluate the stability of a stream under existing conditions, determine its sensitivity to change, and to indicate how restoration may be approached if a portion of the stream becomes unstable. The most popularly accepted system of physical classification is that developed by D.L. Rosgen. The Rosgen system has eight basic stream types, which are further subdivided according to channel slope and materials. Furthermore, the classification is separated into levels, ranging from Level I (broad level characterization) to Level IV (verification of field measurements).

A Level I Rosgen classification was completed for the Partridge River from its headwaters to Colby Lake. A Level I classification is performed using available topography, aerial photography, and other readily available information such as ground photographs.

A Level II Rosgen classification was performed in 2004 for two reaches of the Partridge River, as shown in Figure 1. A Level II classification includes basic field measurements of the selected reaches so that the channel can be characterized in greater detail.

2.0 Level I Rosgen Classification

A general description of the Rosgen classification system is presented in Appendix A. For this analysis, a Level I classification was performed on the Partridge River from its headwaters to Colby Lake. A Level I classification is performed to identify which of the eight major channel types are present on the stream system, but does not break the classification down into greater detail.

2.1 Method

The Level I classification was performed based primarily on 2003 aerial photography, USGS 7.5 minute quadrangles with 10-foot topography, two site visits with associated ground photographs, and additional ground photographs. Because the Level II classification was performed before the Level I classification, those results were used to verify the Level I classification at those locations.

The lack of detailed topography was a limiting factor in classifying the reaches. The available 10-foot topography provided only limited input into the channel characteristics. In many reaches, the elevation change is concentrated in steep rapids with relatively flat pools above and below. It is difficult to estimate the slope of either the rapids or the pools.

2.2 Results

The results of the Level I classification are tabulated in Table 1, and illustrated in Figures 2 through 7. From the results, 54 percent of the Partridge River was classified as a Type C channel. Type C channels are characterized as being moderately sinuous (meandering), having a mild slope, a well developed floodplain, and fairly shallow relative to their width. Many of the Type C reaches have short rapids sections, and many are influenced by beaver dams.

Approximately 31 percent of the river was classified as Type E channel. Type E channels are similar to Type C, except they tend to be more sinuous and tend to be deeper relative to their width. When Type E channels are impacted they may convert to a Type C channel. The reaches that were classified as Type E were done so based primarily on their sinuosity and channel width. It was assumed that the reaches were deep enough to be classified as Type E. If the reaches are shallower, they would be better classified as Type C.

Approximately 13 percent of the Partridge River was classified as Type B channel. Type B channels are steeper, straighter, and have less floodplain available than the Type C or E channels. Type B channels tend to be less sensitive to impact than Type C or E channels. On the Partridge River, these reaches are dominated by boulder material.

3.0 Level II Rosgen Classification

A level II classification was performed for two stream reaches in October 2004. The surveyed reaches are shown in Figure 8. A Level II classification consists of a survey of the channel profile and cross-sections of the channel and floodplain. Bed material is also sampled in order to provide a sub-classification of the stream reach, providing greater insight into the sensitivity of the stream reach.

3.1 Data Collection

Two reaches of the Partridge River were physically classified on October 25, 2004. At each reach, the profile and cross section of the channel were surveyed. Water surface elevations and bankfull elevation indicators were also surveyed, and the dominant bed material was characterized for each reach.

During the field survey, GPS coordinates were surveyed for each site to enable incorporation of the data into an ArcMap file. Cross-section measurements were recorded using a survey level and recorded in a field book. Ground photographs were also taken of each site.

3.2 Partridge River Reach 1

Reach 1 is located south of the Dunka road, about 1.5 miles upstream of the confluence with Stubble Creek. The measured parameters, cross-sections and photographs of this reach are shown in Appendix B, Data Sheet 1. In this area, the Partridge River is characterized by frequent beaver ponds, with steep, boulder-dominated riffles. It is best characterized as a Rosgen Type C through this reach, although its sinuosity is quite low (it is relatively straight). The channel is slightly entrenched and has a moderately high width/depth ratio. This means that it has an adequate floodplain to dissipate energy during higher-than-bankfull flows. Although the riffle sections are steep, they are not confined and have a reasonably wide adjacent floodplain. No erosion problems were evident on this reach. Downstream of the surveyed reach, the channel becomes much more sinuous and is either a C or an E channel. This area was not surveyed, however, because the channel features were rather indistinct due to beaver activity.

Because Reach 1 is dominated by boulder riffles and beaver-pond pools, it is not very sensitive to disturbance, as indicated in Table A-2 for type C2. The boulders tend to minimize channel erosion, and the beaver ponds dissipate energy. The recovery potential of this channel (should it be disturbed) is very good.

3.3 Partridge River Reach 2

Reach 2 of the Partridge River is located south of the power line corridor (south of Dunka Road), about 0.5 miles upstream of the confluence with the South Branch Partridge River, and about one mile downstream of Stubble Creek. The measured parameters, cross-sections and photographs of this reach are shown in Appendix B, Data Sheet 2. Reach 2 has a milder slope than Reach 2, and is also affected by frequent beaver dams. The flow was at nearly bankfull level during the survey. This was due to significant precipitation in the weeks prior to the survey, and the presence of a beaver dam a few hundred yards downstream of the surveyed reach. Although boulders are common at the riffle sections of Reach 2, silt/clay was the dominant material at the surveyed cross-sections. The presence of silt/clay is due to the milder slope at this reach and the presence of the beaver dam. No erosion problems were evident on this reach.

According to Table A-2, this channel type (C5) should be sensitive to disturbance. However, it appears that boulders underlay a thin layer of topsoil in the stream corridor, and they would likely serve to keep significant erosion in check.

4.0 Conclusions

The Rosgen Level I physical classification the Partridge River indicates that it has a variety of stream types, including B, C, and E. There is no evidence of erosion problems between Station 0 and Station 131,000. It appears that there may be some erosion and/or channel widening from Station 131,000 to Station 147,600 (the upstream-most limits of the river). This may be due to previous dewatering pumping to the river, or due to straightening of the channel adjacent to a railroad. In general, the Partridge River has excellent vegetation for nearly its entire length, and has a very well developed floodplain for all but the Type B reaches. The Type B reaches, as well as many shorter portions of the Type C reaches, tend to be boulder-dominated rapids. There are many beaver dams along the entire length of the Partridge River, particularly at the top of rapids sections. The dams create wide pools and in some cases large ponds behind them.

Because its steep reaches are well armored and the flatter reaches tend to have excellent vegetation, the Partridge River is considered to be a robust stream, and should be able to withstand a moderate increase to its base flow with no significant degradation, as has been demonstrated by previous dewatering pumping to the river.

The need for more detailed classification or monitoring of the river should be based on the level of impact to base flow due to proposed dewatering pumping.

References

Rosgen, D.L. (1994). "A Classification of Natural Rivers." Catena 22: 169-199.

Rosgen, D.L. (1996). *Applied River Morphology*. Pagosa Springs, Colorado, Wildland Hydrology.

Tables

Table 1. Rosgen Level I Classification Summary

Start Station (ft)	End Station (ft)	Reach Length (ft)	Average Slope	Sinuosity	Avg Channel Width (ft)	Rosgen Channel Type	Notes
2,000	10,000	8,000	0.005	1.1	60	Type B	Straight, rapids with few pools, narrow floodplain
10,000	22,000	12,000	0.0007	1.7	150	Type C	Backwater, very wide, high sinuosity
22,000	40,000	18,000	0.0004	1.4	60	Type C	Sluggish and wide
40,000	48,500	8,500	0.0004	1.5	65	Type C	Riffle/pool sequence
48,500	55,200	6,700	0.002	1.1	50	Type B	Straight, rapids with few pools, narrow floodplain
55,200	61,000	5,800	0.0004	1.1	75	Type C	Riffle/pool sequence, low sinuosity
61,000	71,000	10,000	0.0004	2.0	35	Type E	Narrow, high sinuosity
71,000	75,000	4,000	0.0004	1.2	45	Type C	Moderate width, low sinuosity
75,000	78,000	3,000	0.0004	1.1	40	Type B	Straight, narrow floodplain
78,000	84,000	6,000	0.0004	1.7	35	Type E	Narrow, high sinuosity
84,000	91,000	7,000	0.0004	1.3	65	Type C	Wide, moderate sinuosity, narrower floodplain
91,000	94,500	3,500	0.0004	1.7	20	Type E	Narrow, high sinuosity
94,500	99,000	4,500	0.0004	1.3	20	Type C	Narrow, moderate sinuosity
99,000	107,400	8,400	0.001	1.5	12	Type E	Very narrow, moderate sinuosity
107,400	112,000	4,600	0.001	1.3	12	Type E	Marshy, narrow, moderate sinuosity
112,000	117,000	5,000	0.001	1.5	19	Type E	Narrow, moderate sinuosity
117,000	118,800	1,800	0.006	1.1	30	Type C	Riffle/pool sequence
118,800	120,100	1,300	0.008	1.0	20	Type B	Straight, rapids, narrow floodplain
120,100	128,000	7,900	0.002	1.5	25	Type E	Narrow, moderate sinuosity
128,000	132,800	4,800	0.002	1.1	30	Type C	Degraded, former Type E?
132,800	134,700	1,900	0.0006	1.0	25	Ditch	Ditch/straightened
134,700	147,600	12,900	0.0006	1.2	25	Type C	Degraded, former Type E?

Figures

Appendix A

Rosgen Classification System

Appendix A Rosgen Classification System

The classification system used to classify the stream channels was developed by D.L. Rosgen ("A Classification of Natural Rivers", Catena, 1994) Rosgen's classification system describes a stream on a reach-by-reach basis. A single stream can have several different stream types over its length. The system defines a stream type according to the shape, pattern, and profile of the reach. In particular, the following parameters are used to classify a stream type: the degree of entrenchment of the channel, the ratio of width to depth, degree of channel meandering or sinuosity, channel material, and the channel surface slope. Some of these parameters are illustrated on Figure A-1.

The Rosgen classification system specifies seven basic stream types, ranging from A to G as shown on Figure A-2. Each type has six subclasses corresponding to the predominant bed material present in the reach. These subclasses are numbered from 1 to 6: 1 is bedrock, 2 is boulder, 3 is cobble, 4 is gravel, 5 is sand, and 6 is silt. This allows for 42 combinations of stream type. A description of the stream types is given in Table A-1. This table gives a range of values of the criteria used for stream classification. These ranges are those most commonly observed; the actual observed values can lie outside of these ranges to a certain extent, recognizing that as the stream type changes, the criteria will adjust accordingly.

Entrenchment Ratio is defined as the ratio of the width of the flood-prone area to the bankfull surface width of the channel. Flood-prone area is defined by Rosgen as the width measured at an elevation which is determined at twice the maximum bankfull depth. Field observation shows this elevation to be a frequent flood (50 year) or less, rather than a rare flood elevation. The entrenchment ratio describes the interrelationship of the river to its valley and landform features. It is a measure of channel down-cutting compared to its floodplain. This interrelationship determines whether the river (stream) is deeply incised or entrenched in the valley floor or deposit feature. The entrenchment ratio indicates whether the flat area adjacent to the channel is a frequent floodplain, a terrace (abandoned floodplain), or is outside the flood-prone area.

W*idth/Depth Ratio* is the ratio of bankfull channel width to bankfull mean depth; it is used to describe the dimension and shape of the channel.

Sinuosity is the ratio of stream length to valley length. It can also be described as the ratio of valley slope to channel slope. This value typically varies from 1.0 to 2.5, where a value of 1.0 corresponds to a straight channel. Sinuosity can often be determined from aerial photographs, and interpretations can then be made of slope, channel materials, and entrenchment. Values of sinuosity appear to be modified by bedrock control, roads, channel confinement, and vegetation types, among other factors. Generally, as gradient and particle size decrease, there is a corresponding increase in sinuosity. Meander geometry characteristics are directly related to sinuosity following minimum expenditure of energy concepts. Based on these relations and ease of determination, sinuosity is one of the delineative criteria for stream classification.

Water Surface Slope is of major importance to the morphological character of the channel and its sediment, hydraulic, and biological function. It is determined by measuring the difference in water surface elevation per unit stream length. It is typically measured through at least 20 channel widths or two meander wavelengths (Rosgen). In broad level delineations, slope can be estimated by measuring sinuosity from aerial photos and measuring valley slope from topographic maps.

Channel Materials refer to the bed and bank materials of the stream. Channel material is critical for sediment transport and hydraulic influences, and also modifies the form, plan, and profile of the stream. Interpretations of biological function and stability also require this information. The channel materials can often be predicted from soils maps and geologic information. They can also be determined in the field, and at the detailed level the materials are measured and the size plotted on percent distribution paper.

Bankfull Discharge occurs at approximately the 1.5 year recurrence interval and is referenced to as the dominant discharge for the stream. Hydraulic geometry and sediment transport relations rely heavily on the frequency and magnitude of bankfull discharge.

Different types of streams have differing sensitivities to disturbance and varying recovery potential. Sensitivity and recovery potential are interrelated to sediment supply in the stream, bank erosion potential, and the influence of vegetation on controlling bank erosion. These differences are itemized by stream type in Table A-2. The information in this table is best applied when a stream's behavior can be predicted by appearance and by extrapolating information from similar stream types. Knowing the sensitivity of each stream type allows for better management of the stream systems, potential impact assessment, and risk analysis.

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Table A-1 Summary of Criteria for General Classification (from Rosgen)

Stream Type	General Description	Entrenchment Ratio	W/D Ratio	Sinuosity	Slope	Landform/Soils/Features
A	Steep, entrenched, debris transport streams.	< 1.4	<12	1.0 to 1.2	0.04 to 0.10	High relief, mountainous environments; entrenched and confined streams with cascading reaches; frequent deep pools
B	Moderately entrenched, moderate gradient, riffle dominated channel with infrequent pools. Very stable.	1.4 to 2.2	>12	>12	0.02 to 0.039	Moderate relief, colluvial deposition and/or residual soils. Moderate entrenchment and W/D ratio. Narrow, gently sloping valleys. Rapids with occasional pools.
C	Low gradient, meandering alluvial channels with broad, well defined floodplain.	>2.2	>12	>1.4	<0.02	Broad valleys with terraces, associated with floodplain, alluvial soils. Slightly entrenched with well-defined meandering channel. Riffle-pool bed morphology.
D	Braided channel; very wide channel with eroding banks.	n/a	>40	n/a	<0.04	Broad valleys with alluvial and colluvial fans. Abundant sediment supply.
E	Low gradient, meandering stream with low width/depth ratio and little deposition. Very efficient and stable.	>2.2	<12	>1.5	<0.02	Broad valley/meadows. Alluvial materials with floodplain. Highly sinuous with stable, well vegetated banks. Riffle-pool morphology with very low width/depth ratio.
F	Entrenched meandering riffle/pool channel on low gradients with high width/depth ratio	<1.4	>12	>1.4	<0.02	Entrenched in highly weathered material. Gentle gradients with high W/D ratio. Meandering, laterally unstable with high bank-erosion rates. Riffle-pool morphology.
G	Entrenched Gully step/pool with low width/depth ration on moderate gradients	<1.4	<12	>1.2	0.02 to 0.039	Gully, step-pool morphology with moderate slopes and low W/D ratio. Narrow valleys, or deeply incised in alluvial or colluvial materials. Unstable, with grade control problems and high bank erosion rates.

Table A-2. Management Interpretations of various stream types (from Rosgen, 1996)

Stream Type	Sensitivity to Disturbance[a]	Recovery Potential[b]	Sediment Supply[c]	Streambank Erosion Potential	Vegetation Controlling Influence[d]
A1	Very low	Excellent	Very low	Very low	Negligible
A2	Very low	Excellent	Very low	Very low	Negligible
A3	Very high	Very poor	Very high	Very high	Negligible
A4	Extreme	Very poor	Very high	Very high	Negligible
A5	Extreme	Very poor	Very high	Very high	Negligible
A6	High	Poor	High	High	Negligible
B1	Very low	Excellent	Very low	Very low	Negligible
B2	Very low	Excellent	Very low	Very low	Negligible
B3	Low	Excellent	Low	Low	Moderate
B4	Moderate	Excellent	Moderate	Low	Moderate
B5	Moderate	Excellent	Moderate	Moderate	Moderate
B6	Moderate	Excellent	Moderate	Low	Moderate
C1	Low	Very good	Very low	Low	Moderate
C2	Low	Very good	Low	Low	Moderate
C3	Moderate	Good	Moderate	Moderate	Very high
C4	Very high	Good	High	Very high	Very high
C5	Very high	Fair	Very high	Very high	Very high
C6	Very high	Good	High	High	Very high
D3	Very high	Poor	Very high	Very high	Moderate
D4	Very high	Poor	Very high	Very high	Moderate
D5	Very high	Poor	Very high	Very high	Moderate
D6	High	Poor	High	High	moderate
Da4	Moderate	Good	Very low	Low	Very high
DA5	Moderate	Good	Low	Low	Very high
DA6	Moderate	Good	Very low	Very low	Very high
E3	High	Good	Low	Moderate	Very high
E4	Very high	Good	Moderate	High	Very high
E5	Very high	Good	Moderate	High	Very high
E6	Very high	Good	Low	Moderate	Very high
F1	Low	Fair	Low	Moderate	Low
F2	Low	Fair	Moderate	Moderate	Low
F3	Moderate	Poor	Very high	Very high	Moderate
F4	Extreme	Poor	Very high	Very high	Moderate
F5	Very high	Poor	Very high	Very high	Moderate
F6	Very high	Fair	High	Very high	Moderate
G1	Low	Good	Low	Low	Low
G2	Moderate	Fair	Moderate	Moderate	Low
G3	Very high	Poor	Very high	Very high	High
G4	Extreme	Very poor	Very high	Very high	High
G5	Extreme	Very poor	Very high	Very high	High
G6	Very high	Poor	High	High	High

[a] Includes increases in streamflow magnitude and timing and/or sediment increases.
[b] Assumes natural recovery once cause of instability is corrected.
[c] Includes suspended and bedload from channel derived sources and/or from stream adjacent slopes.
[d] Vegetation that influences width/depth ratio-stability.

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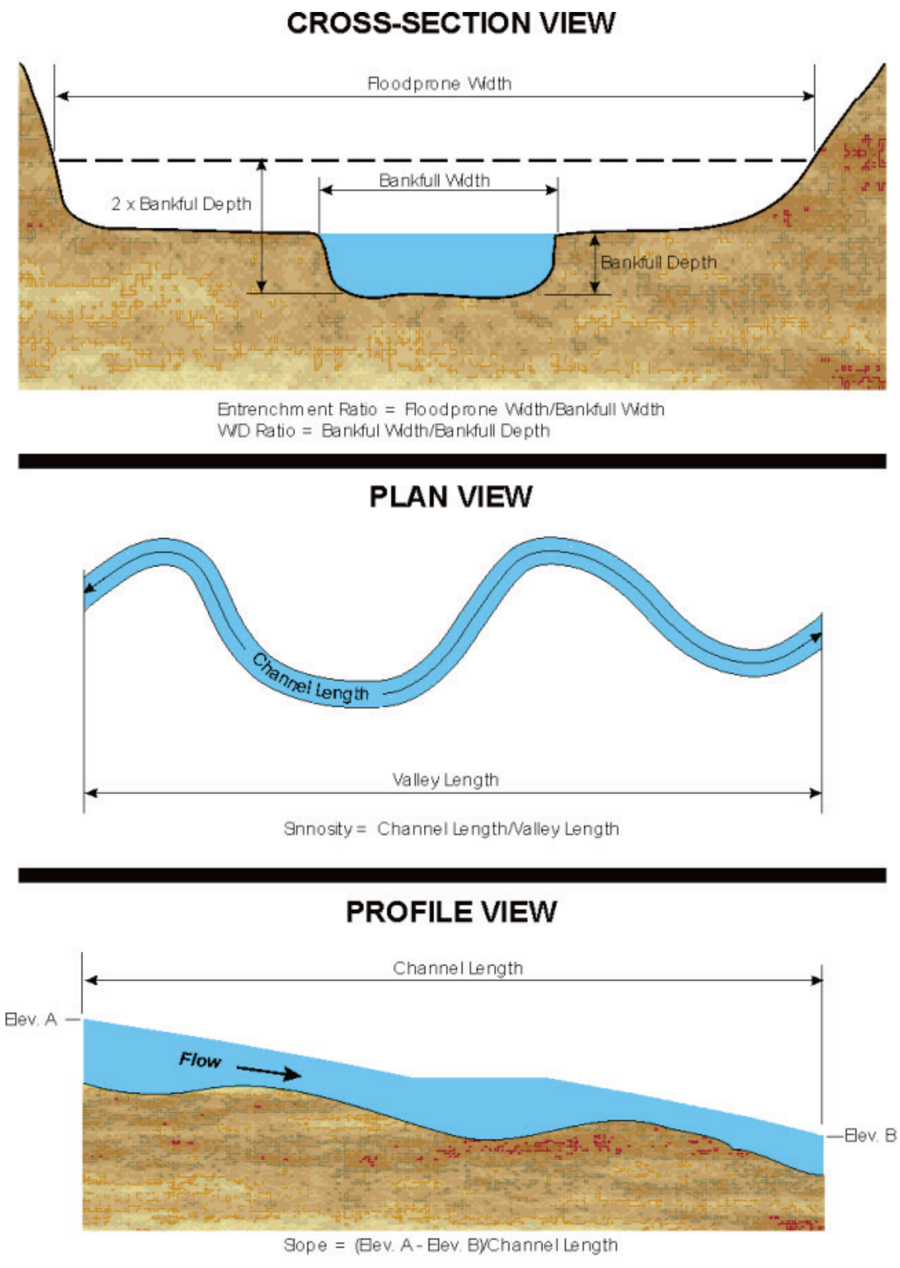
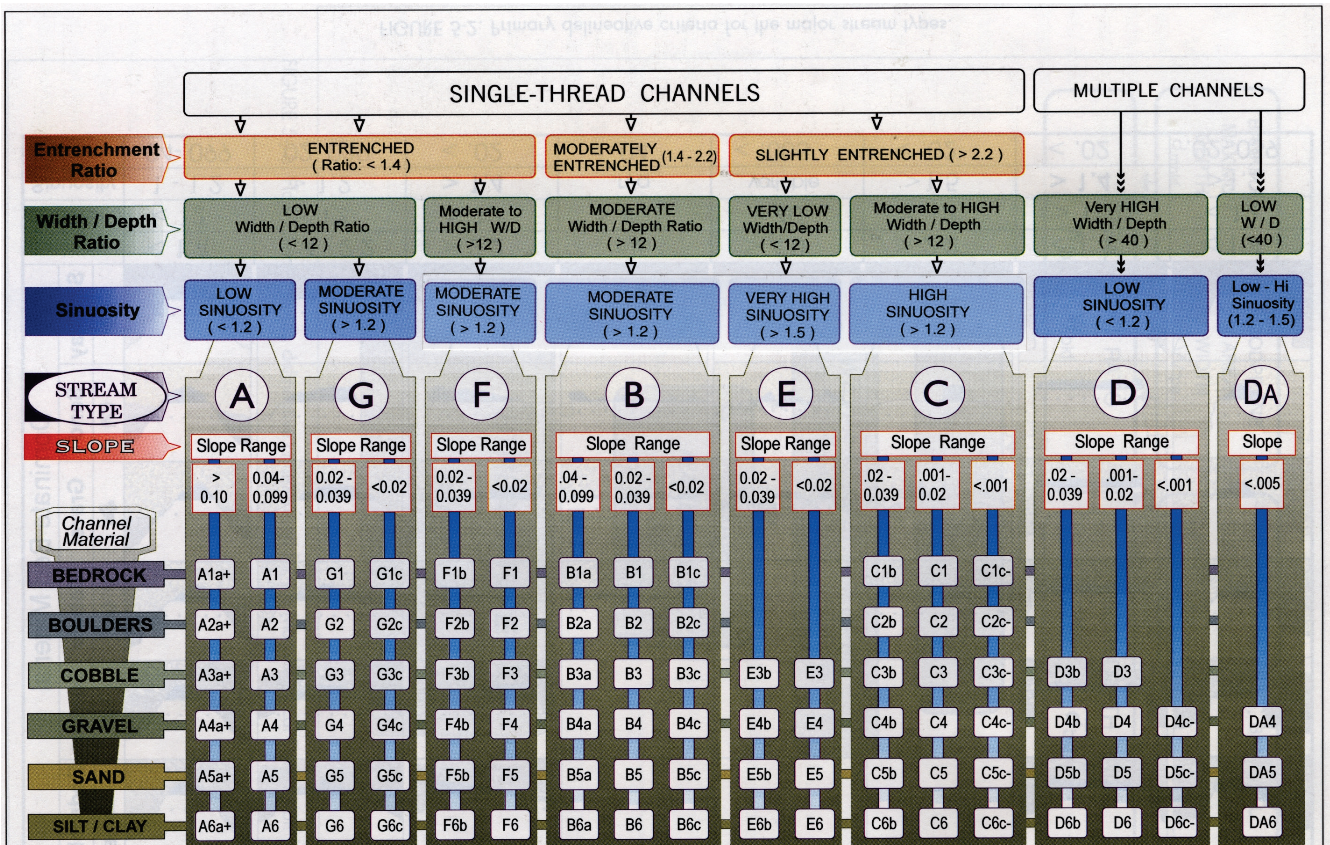


Figure A-1. Channel Parameters Defined



KEY to the *ROSGEN* CLASSIFICATION of NATURAL RIVERS. As a function of the *"continuum of physical variables"* within stream reaches, values of ***Entrenchment*** and ***Sinuosity*** ratios can vary by +/- 0.2 units; while values for ***Width / Depth*** ratios can vary by +/- 2.0 units.

Figure A-2. Rosgen Classification System (from Rosgen, 1996)

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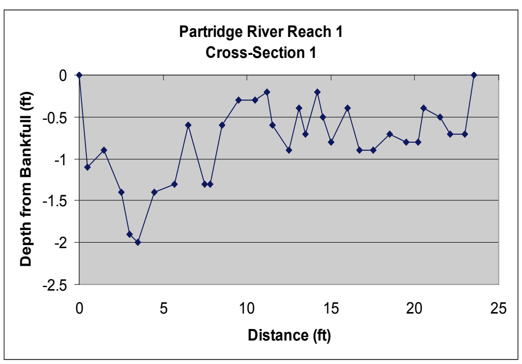
Appendix B

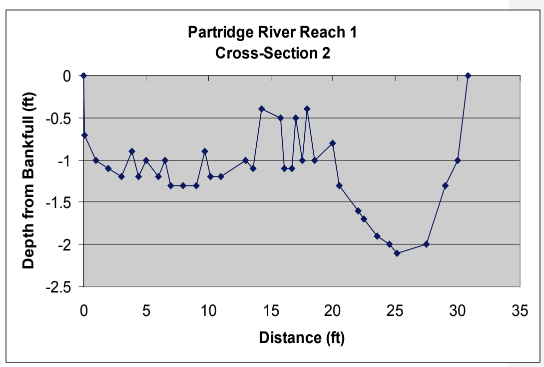
Rosgen Level II Classification Data Sheets

Data Sheet 1. Partridge River Reach 1

Channel Dimensions:

Parameter	Cross-Section 1	Cross-Section 2
Bankfull Width	24 ft	31 ft
Bankfull Area	19 ft^2	37 ft^2
Bankfull Mean Depth	0.8 ft	1.2 ft
Bankfull Max. Depth	2.0 ft	2.1 ft
Entrenchment Ratio	5	4
Width/Depth Ratio	29	26
Floodprone Width	125 ft	114
Dominant Bed Material	Boulder	Boulder
Riffle Slope	.035	.013
Avg. Channel Slope	0.0062	
Sinuosity	1.1	
Channel Type	**C2**	





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Data Sheet 2. Partridge River Reach 2

Channel Dimensions:

Parameter	Cross-Section 1	Cross-Section 2
Bankfull Width	29 ft	22 ft
Bankfull Area	59 ft^2	39 ft^2
Bankfull Mean Depth	2.1 ft	1.8 ft
Bankfull Max. Depth	2.4 ft	2.3 ft
Entrenchment Ratio	4	6
Width/Depth Ratio	14	12
Floodprone Width	120 ft	129 ft
Dominant Bed Material	Silt/clay	Silt/clay
Riffle Slope	n/a	n/a
Avg. Channel Slope	n/a	
Sinuosity	1.2	
Channel Type	**C6**