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WAPITI RIVER HABITAT MAPPING STUDY

Segmentation Study and Habitat Mapping of the Wapiti River near Grande Prairie, Alberta



REPORT

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Stream Habitat Classification System



1.0 INTRODUCTION

1.1 Background and Objectives

The Wapiti River watershed is an important source of water for the City of Grande Prairie and numerous other smaller population centers and Aboriginal settlements. The Wapiti River (the river) also supports active oil and gas, forestry, and agricultural sectors. Maintaining water consumption and ecosystem conservation presents a challenge for resource managers. To address issues related to water management within the watershed, Alberta Environment and Sustainable Resource Development (ESRD) has collaborated with local stakeholders to establish the Wapiti River Water Management Plan (WRWMP) Steering Committee and initiated the development of a Water Management Plan for the river.

The goal of the WRWMP is to provide a regulatory context for balancing economic, social and environmental interests with respect to water demands. The Steering Committee has adopted a structured decision making process that requires the development of evaluation tools that will afford stakeholders opportunities to understand potential outcomes of different management strategies.

One interest identified by the Steering Committee is the maximization of fish and fish habitat in the river. To address this, the proposed evaluation tool is a habitat-rating method that relates river discharge and habitat area (Hatfield 2013). The development of the tool requires several steps including river segmentation and habitat mapping (Figure 1).

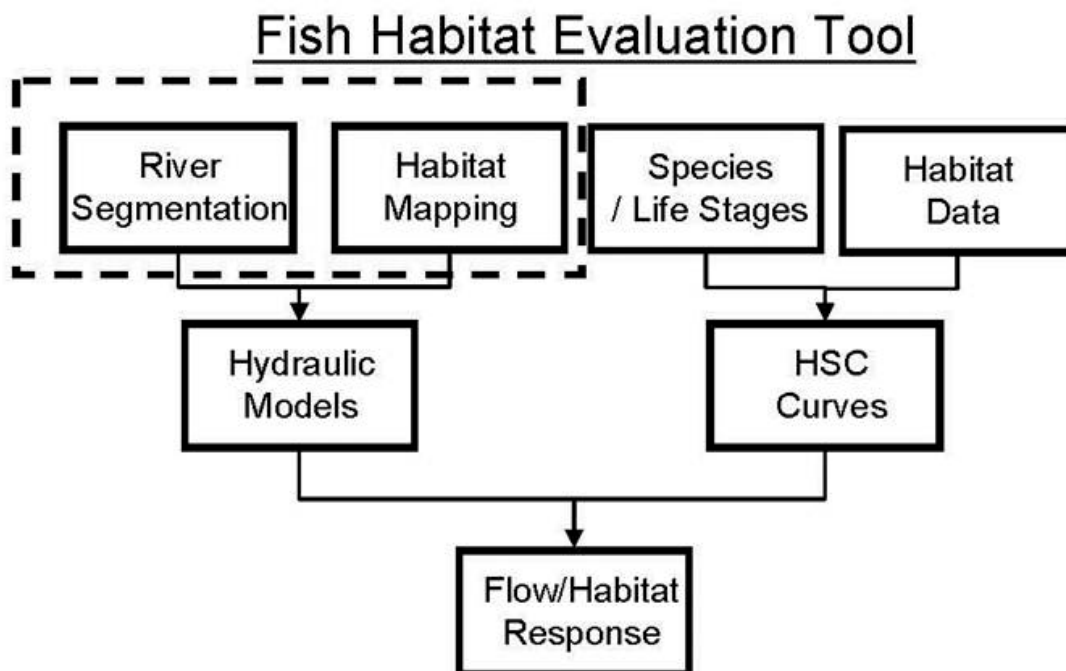


Figure 1: Anticipated steps to build fish habitat evaluation tools that relate discharge to the amount of fish data. Steps addressed by the Project are outlined by the dashed rectangle (Terms of Reference titled Segmentation Study and Habitat Mapping of the Wapiti River near Grande Prairie, Alberta). HSC – Habitat Suitability Criteria.



To address the river segmentation and habitat mapping portions of the Fish Habitat Evaluation Tool (the Project), Fisheries and Oceans Canada (DFO) and ESRD (the Proponent), requested the provision of consulting services by Golder Associates Ltd. (Golder), as described by the Terms of Reference titled *Segmentation Study and Habitat Mapping of the Wapiti River near Grande Prairie, Alberta*. Together, Golder and the Proponent developed the following objectives for the Project:

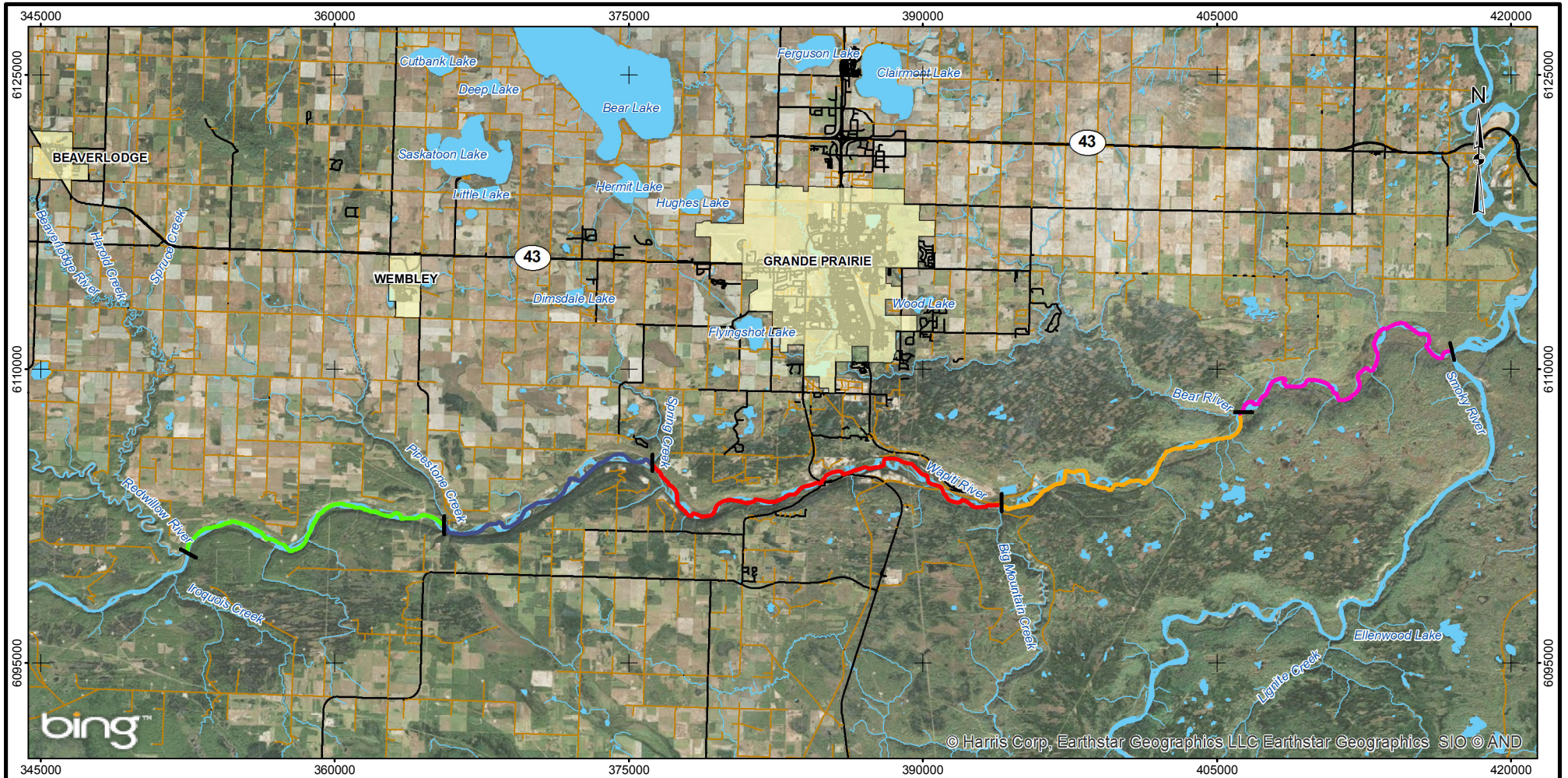
- Identify segment boundaries for the lower Wapiti River mainstem based on flows and channel morphology;
- Map mesohabitat, depth, and substrate distribution throughout the lower Wapiti River;
- Provide GIS line files that delineate segments and mesohabitat types within the lower Wapiti River;
- Illustrate habitat features through geo-referenced and annotated photographs;
- Analyze and summarize habitat distribution within each segment of the river; and
- Provide documentation and a summary of field results to be used for designing more detailed physical surveys in appropriately stratified river sections.

This document, in association with supplemental files (e.g., photographs, GIS [Global Information Systems] data), provides the information collected and analyzed to address these objectives. Also described are the methods by which the information was collected and analyzed.

1.2 Study Area

The Wapiti River originates in west-central British Columbia and flows northeast entering Alberta approximately 90 km southwest from Grande Prairie where it reaches its confluence with the Smoky River approximately 30 km east from Grande Prairie (Tchir et al. 2004). The Project focused on the lower Wapiti River extending from the Redwillow – Wapiti River confluence to the Wapiti – Smoky River confluence, a distance of 88.08 km (Figure 2).

The discharge of the Wapiti River has been continuously monitored at station 07GE001 near Grande Prairie since 1961 (WSC 2013). Mean monthly flows over the period of record were lowest in February ($12.5 \text{ m}^3/\text{s}$) and highest in June ($306 \text{ m}^3/\text{s}$). The flows experienced during the field survey in October 2013 were approximately $40 \text{ m}^3/\text{s}$ (Environment Canada 2013), and were about 30% lower than the historical mean monthly discharge for October ($64.6 \text{ m}^3/\text{s}$).



LEGEND

WAPATI RIVER THALWEG

RIVER SEGMENT

- 1- BEAR RIVER TO SMOKY RIVER
- 2- BIG MOUNTAIN CREEK TO BEAR RIVER
- 3- SPRING CREEK TO BIG MOUNTAIN CREEK
- 4- PIPESTONE CREEK TO SPRING CREEK
- 5- REDWILLOW RIVER TO PIPESTONE CREEK
- WATERCOURSE
- WATER BODY
- POPULATED PLACE

- PAVED ROAD
- UNPAVED ROAD

REFERENCE

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 DATUM: NAD83 PROJECTION: UTM ZONE 11



PROJECT		PUBLIC WORKS AND GOVERNMENT SERVICES CANADA, WAPATI RIVER SURVEY, WAPATI RIVER, AB		
TITLE		STUDY AREA FOR THE WAPATI RIVER SEGMENTATION AND HABITAT MAPPING SURVEY		
	PROJECT	13-1373-0023	FILE No.	
	DESIGN	RP	11 Dec. 2013	SCALE AS SHOWN
	GIS	GU	17 Dec. 2013	REV. 0
	CHECK	RP	29 Jan. 2014	FIGURE: 2
REVIEW	JP	29 Jan. 2014		



2.0 METHODS

2.1 Field Assessment

The field assessment occurred between October 16th and 20th, 2013. Field data were collected by a survey crew (crew) comprising two fish biologists that travelled the river using a Zebec Armada inflatable boat mounted with a 25 horsepower outboard engine with a jet leg. Georeferenced depth data were collected using a Garmin GPS (Global Positioning System) 521s sounder (depth sounder) affixed to a plank mounted across the bow of the boat. The transducer was set approximately 0.05 m below the surface of the water and depth measurements were recorded at one second intervals. The crew travelled along the deepest portion of the channel, the thalweg, throughout the survey. However, the boat was also manoeuvred into noteworthy habitat features (e.g., large back channels or side channels) to collect supplemental depth data. Boat speed varied between 2 and 10 kilometres per hour (kph), with an average speed of approximately 5 kph.

2.1.1 Habitat Classification

Habitat data were collected using visual observations and were documented continuously. The biologists assessed and categorized instream habitat using a modified O'Neil and Hildebrandt (1986) habitat classification system (Appendix A) and delineated habitat unit breaks by recording UTM's (Universal Transverse Mercator) using hand-held GPS units. Supplemental track logs were also recorded using hand-held GPS units as a redundancy measure. The biologists monitored the depth sounder display to help sub-classify habitat units based on depth, and used visual observations to qualitatively assess the dominant and subdominant substrate type in each habitat unit. The biologists also took representative digital photographs and opportunistically recorded the location of important features (e.g., large bank slumps) using hand-held GPSs.

Upon commencement of the survey, the crew made a discretionary decision to adjust the habitat classification system for Flat habitat. Several areas were encountered that fit the description of Flat habitat; however substrate composition varied and was not always dominated by fines as described by O'Neil and Hildebrandt (1986) (Appendix A). Rather, Flats were typically associated with varying proportions of both fines and coarser substrates. Therefore, the crew categorized flat habitat based solely on depth and velocity, not substrate.

Water depth was measured manually using a rigid metre stick or lengthing rope in areas representative of the range of depths encountered during the survey. The depth sounder occasionally failed to measure depths in shallow (<0.3 m) and/or turbulent water; as such, manual depth measurements were taken more frequently in these instances. The crew waited for the depth sounder to regain proper function prior to resuming the survey.

The proportion (%) of each habitat unit's length comprised by back channels or side channels was visually estimated; if a habitat unit was bounded entirely by a back channel or side channel, a 100% rating was assigned, and a 0% rating was given to habitat units confined to a single channel. The crew attempted to document (UTM, photographs) connection points between the primary channel and back channels or side channels, however inlets and outlets were frequently out of view and could not be documented given the scope of the Project. The crew recorded UTM's, took representative photographs, and recorded field observations at these locations, where possible.



2.1.2 Assessments of Fish Habitat Potential

Fish habitat potential in each habitat unit was assessed by estimating the proportional area (%) of each habitat unit that had the potential to provide high quality overwintering and spawning habitat for sport fish species including Arctic Grayling (*Thymallus arcticus*), Burbot (*Lota lota*), Bull Trout (*Salvelinus confluentus*), Mountain Whitefish (*Prosopium williamsoni*), Northern Pike (*Esox lucius*), and Walleye (*Sander vitreus*). Habitat potential was assessed using visual observations and the depth sounder; habitat components such as habitat type and water velocity were considered, along with substrate where visible. Overwintering habitat was assessed based on the estimated potential of the habitat unit to support large-bodied fish (>300 mm) throughout winter. Spawning habitat potential was assessed based on the estimated potential of the habitat unit to provide spawning habitat for Mountain Whitefish. Spawning habitat for other species known to inhabit the river was either rare, as in the case of Northern Pike, or difficult to assess given the scope of the Project. A more thorough assessment of spawning habitat for sport fish species would require a level of effort beyond that which was proposed for the Project.

2.2 Desktop Assessment

2.2.1 Geographic Information Systems

Depth measurement coordinates (points) from the depth sounder were imported into Global Mapper version 15.0 (Global Mapper) from which a thalweg line file was produced by manually linking points. Manual linking was required to avoid the inclusion of extraneous data collected from non-thalweg areas. Once the thalweg line file was produced, distances between points and total thalweg distance were calculated and specific values were attributed to each point. Kilometre values, starting at the confluence between the Wapiti and Smoky rivers, were then calculated for each point along the thalweg line and assigned to other parameters. All thalweg point data, including added attribute values, were then exported from Global Mapper and integrated into spreadsheets for analysis.

2.2.2 Data Analysis

Data were organized for analyses using standard Microsoft® Office software. Decisions regarding modifications to the data included:

- A correction factor for the transducer offset (0.05 m below the surface of the water) was not incorporated into the analysis. Although the offset relative to the boat remained consistent (+/- 0.05 m), variations between the distance between the transducer and the surface of the water varied depending on river surface turbulence, weight distribution in the boat, etc.;
- Sounder depth measurements of less than 0.3 m were not included in the analysis;
- Several points collected in Riffle habitat were removed because of inaccurate readings in shallow, turbulent water;
- Some error is inherent to data collected using satellite-based devices (+/- 2-5 m). As such, there are subtle discrepancies between the precise location of the habitat unit boundaries, the categorization of said habitat type, and the respective recorded depths. Data collected in these transition areas were not corrected based on depth (i.e., habitat unit boundaries were not adjusted based on sounder depth); and
- River segment boundaries were selected based on major confluences with consideration to slope (elevation) and coarse-scale habitat distribution. Segment boundaries at these locations were further refined using available satellite imagery and the Canvec 1:50 000 scale watercourse layer.



3.0 RESULTS

3.1 Segmentation

The study area was divided into five river segments (Table 1). Segments length ranged between 13.34 km (S4) and 22.77 km (S3). Mean thalweg depths varied from 1.18 m (S4) to 1.57 m (S1) and generally increased in downstream direction. Maximum recorded depths were similar (between 3.9 and 4.2 m) in the upper four segments, but much greater (6.3 m) in S1, due to a deep water area immediately adjacent to the confluence with the Smoky River. Mean gradient decreased with distance downstream from the Redwillow – Wapiti River confluence; it ranged from 1.36 to 0.49 m/km, with the overall study area gradient of 0.91 m/km.

Table 1: Length, Depth and Gradient Characteristics of the Lower Wapiti River Segments

Segment	Description	Km ^a	Length (km)	Thalweg Depth (m)			Elevation (m)		Gradient (m/km)	
				n	Mean	SD	Max.	Max.		Min.
S5	Redwillow River to Pipestone Creek	71.17 - 88.08	16.91	8 057	1.36	0.71	3.9	569	546	1.36
S4	Pipestone Creek to Spring Creek	57.83 - 71.17	13.34	6 281	1.18	0.64	4.1	546	529	1.27
S3	Spring Creek to Big Mountain Creek	35.06 - 57.83	22.77	1 2062	1.40	0.73	4.2	529	509	0.88
S2	Big Mountain Creek to Bear River	18.26 - 35.05	16.81	9 061	1.50	0.80	4.2	509	498	0.65
S1	Bear River to Smoky River	0.00 - 18.25	18.25	9 427	1.57	0.68	6.3	498	489	0.49
All	Lower Wapiti River	0.00 - 88.08	88.08	44 888	1.42	0.73	6.3	569	489	0.91

^a Rounded to the nearest 0.01 km, as measured along the thalweg in an upstream direction.
n = number of depth measurements; SD = standard deviation; Max. = maximum; Min. = minimum



3.2 Habitat Types

Much of the study area was dominated by deep (>1.5 m), low velocity water and associated deep Run (R1) and Flat (F1) habitat (Figure 3). The proportions of shallow (<0.5 m) water and habitats (e.g., Riffle [RF], Rapid [RA]) associated with higher gradients and faster-flowing water were higher in the upstream portion of the study area as expected. Deep Run and Flat habitats became more dominant in the lower portion of the study area

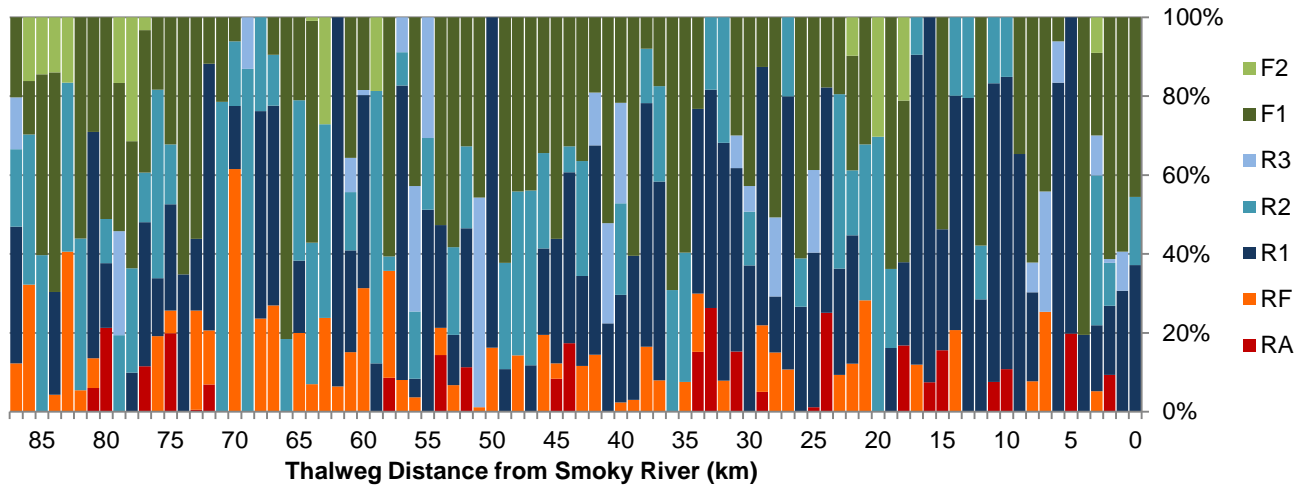


Figure 3: Distribution of dominant habitat types along the length of the Wapiti River. F=Flat, R=Run, RF=Riffle, and RA=Rapid as per O’Neil and Hildebrandt (1986), Appendix A. Segment boundaries: S1 (0.0-18.3 km); S2 (18.3-35.1); S3 (35.1-57.8); S4 (57.8-71.2); S5 (71.2-88.1).

Mean habitat distribution within river segments showed the predominance of deep Run (R1) and Flat (F1) habitats among all segment, whereas, RA, RF, shallow Run (R2 and R3), and shallow Flat (F2) habitats were less common (Figure 4). The relative proportion of habitat types associated with shallow (<1.5 m) water, such as RF and shallow Run was highest in Segment 4, whereas deep Flat (F1) habitat was recorded in higher proportions in segments S5 and S3.

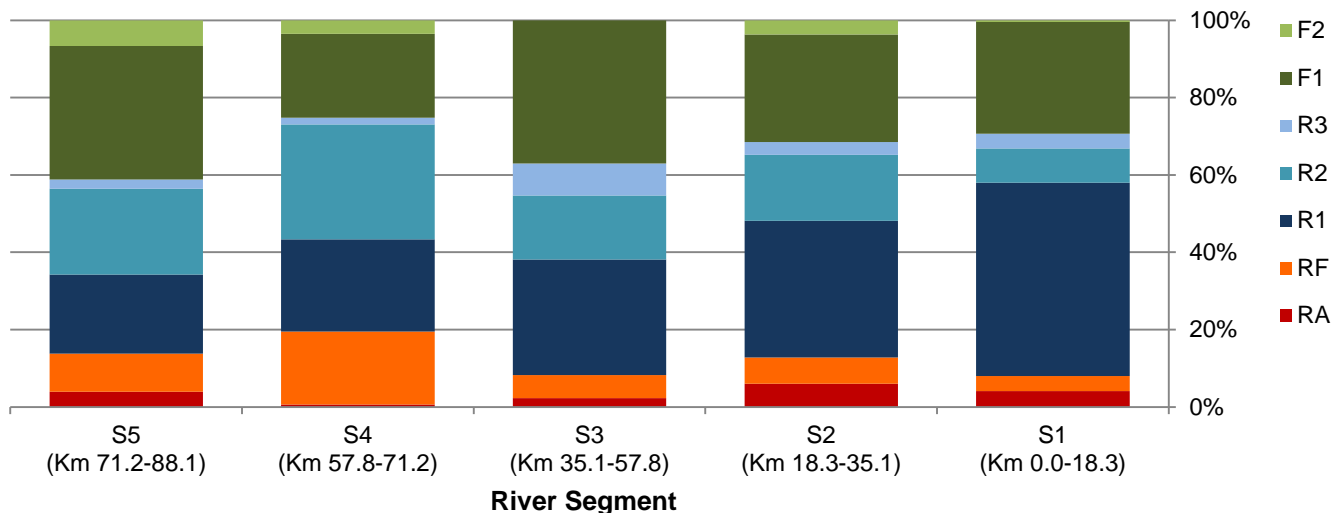


Figure 4: Distribution of dominant habitat type in the Wapiti River by river segment, October 2013



3.3 Longitudinal Profile – Thalweg Depth

Deep (>1.5 m) sections were common throughout the study area with mean depth fluctuating mainly between 1 m and 2 m (Figures 5 and 6). Maximum depth fluctuated throughout the study area and ranged between 1 m and 5 m, with the exception of the downstream-most 200 m where maximum depths increased sharply including a the deepest portion of the river within the study area 6.3 m.

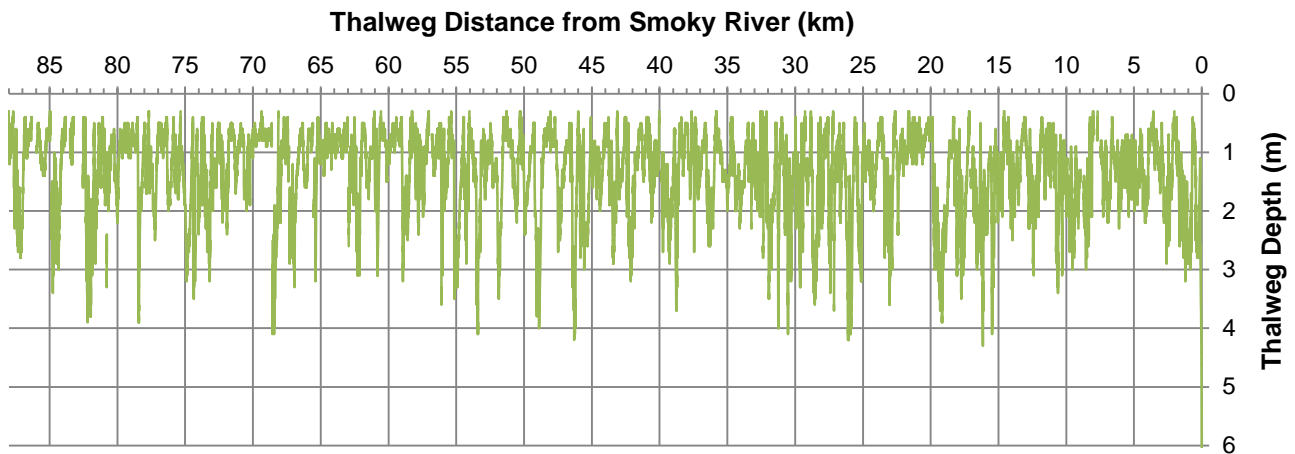


Figure 5: Recorded point depths along the Wapiti River thalweg, October 2013. Segment boundaries: S1 (0.0-18.3 km); S2 (18.3-35.1); S3 (35.1-57.8); S4 (57.8-71.2); S5 (71.2-88.1).

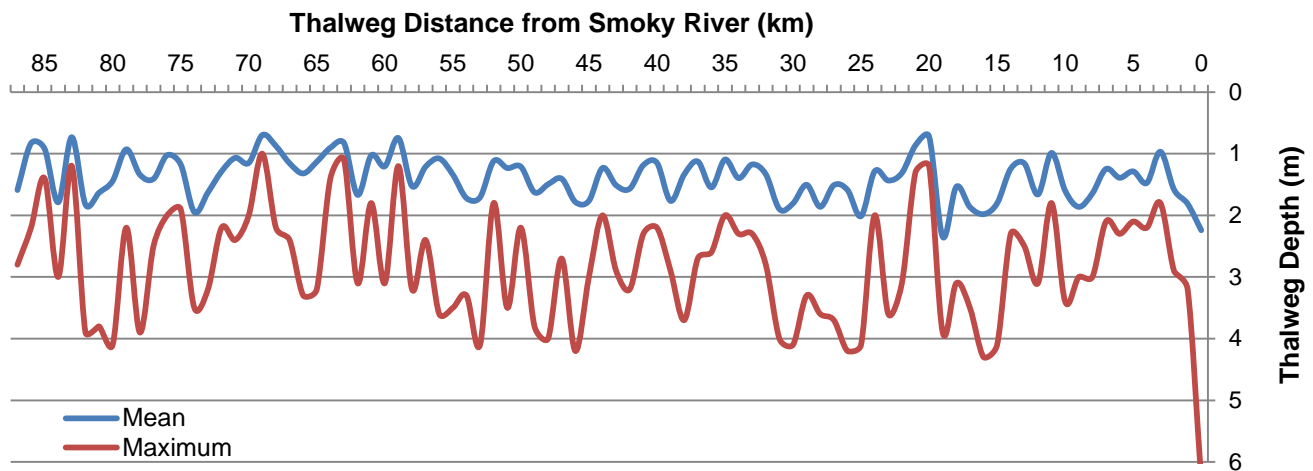


Figure 6: Mean and maximum depths along the Wapiti River thalweg, October 2013. Mean and maximum depths were calculated using thalweg depth measurements within 1-km sections of the river. Segment boundaries: S1 (0.0-18.3 km); S2 (18.3-35.1); S3 (35.1-57.8); S4 (57.8-71.2); S5 (71.2-88.1).



Mean depths among habitat types was consistent with the habitat classification system used (O’Neil and Hildebrandt 1986), suggesting that observations made by the crew, including monitoring the depth sounder display, proved to be an effective method of assessing and categorizing habitat types. Mean and maximum depths were considerably higher in F1 and R1 habitats, than in F2, R2 and R3 habitats (Table 2). Mean depth values were somewhat higher than expected in Riffles because the depth sounder did not measure shallow (i.e., <0.3m) depths well and as such, data from shallow sections were underrepresented in this calculation. It is important to note that categorizations were based on the habitat type as a whole, whereas the depth data were representative of depth along the thalweg.

Table 2: Depth Characteristics of Habitat Types in the Lower Wapiti River, October 2013

Habitat Type	Thalweg Depth (m)			
	n	Mean	SD	Maximum
Rapid (RA)	1117	1.14	0.38	2.30
Riffle (RF)	2453	0.80	0.36	2.10
Deep Run (R1)	15437	1.63	0.66	4.30
Shallow Run (R2)	7836	0.84	0.30	3.60
Shallow Run (R3)	1734	0.72	0.27	2.10
Deep Flat (F1)	14946	1.76	0.75	6.30
Shallow Flat (F2)	1365	0.78	0.16	1.20

n = number of depth measurements; SD = standard deviation.

3.4 Substrate

Cobble and gravel (Appendix A) were the most common dominant substrate types observed in the study area (Figure 7). Cobble and gravel were most prevalent in the upper portion of the study area, while silt was most common in the middle reaches. Substrates were difficult to observe in the lower reaches because of the prevalence of long and deep sections where the river bed was not visible to the crew. A large proportion of substrate in the lower reaches was not visible and could not be assessed.

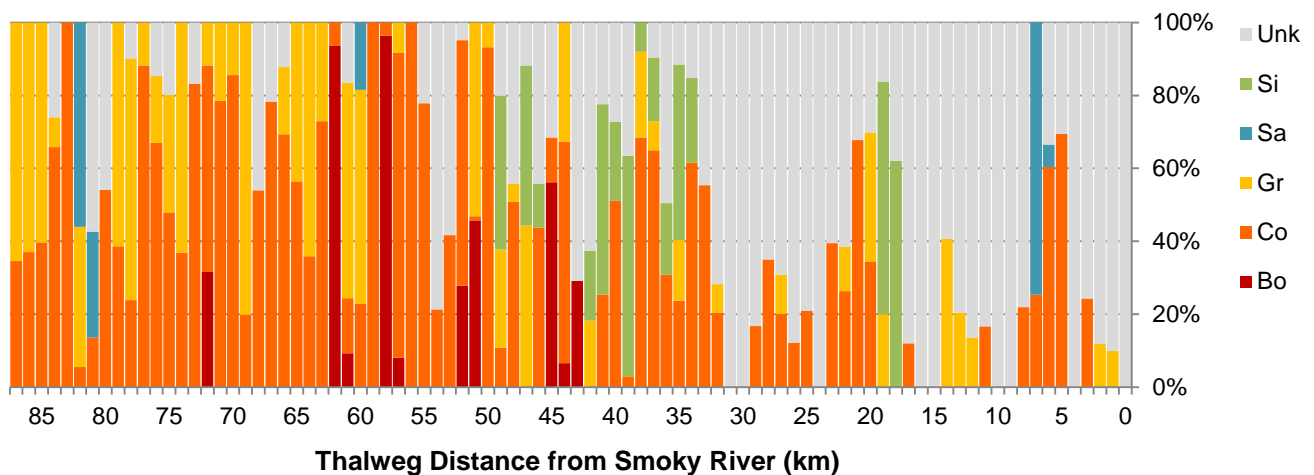


Figure 7: Distribution of dominant substrate type along the length of the Wapiti River, October 2013. Segment boundaries: S1 (0.0-18.3 km); S2 (18.3-35.1); S3 (35.1-57.8); S4 (57.8-71.2); S5 (71.2-88.1).



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To assess the relative composition of substrate of the segment level, thalweg areas with undetermined (unknown) substrate were not included in the analysis. Cobble was consistently the most prevalent dominant substrate type in all river segments (Figure 8). Gravel was common as well with the relative proportion decreasing with distance downstream with the exception of S1. Among segments where boulders were the dominant substrate, boulders were most common in S4 followed by S3, but were largely absent from the other segments. Sand as dominant substrate was most frequent in S1, whereas silt was more common in S2 and S3.

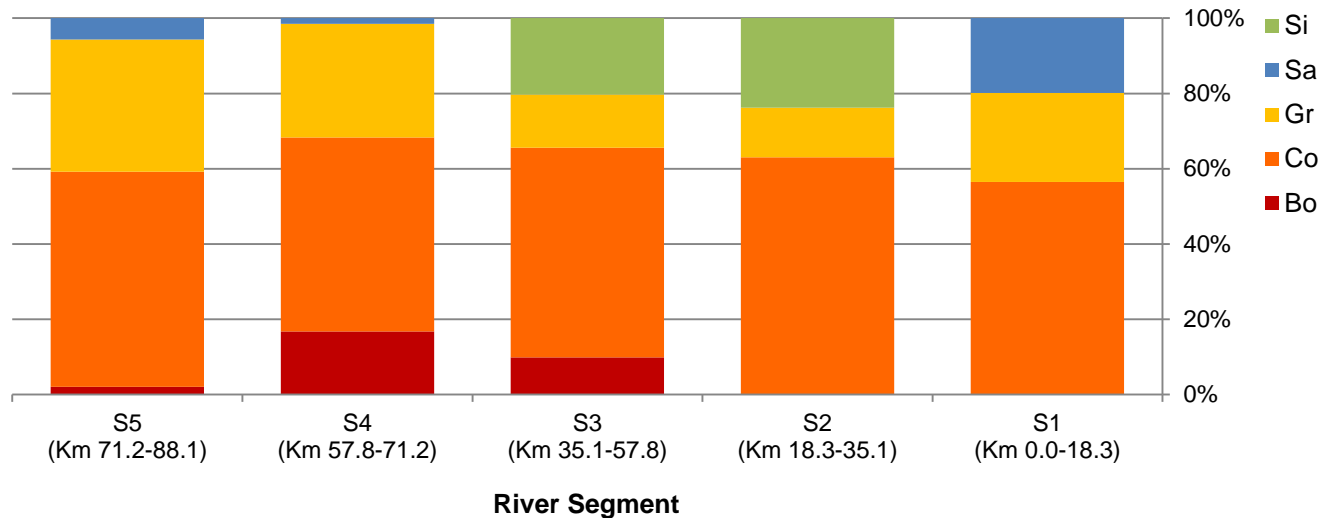


Figure 8: Distribution of dominant substrate observed in the Wapiti River by river segment, October 2013. Note, the contribution of unassessed substrate to the overall substrate composition in S1 and S2 was higher than for other sections (see Figure 7). Therefore, data presented for S1 and S2 are less representative of actual substrate composition compared with S3, S4, and S5.

Cobble was the most common dominant substrate in all habitat types, except for F1 and F2 (Figure 9). Habitats associated with higher water velocities were associated with coarse substrates. As expected, silt and sand were associated with slower moving Flat habitat.

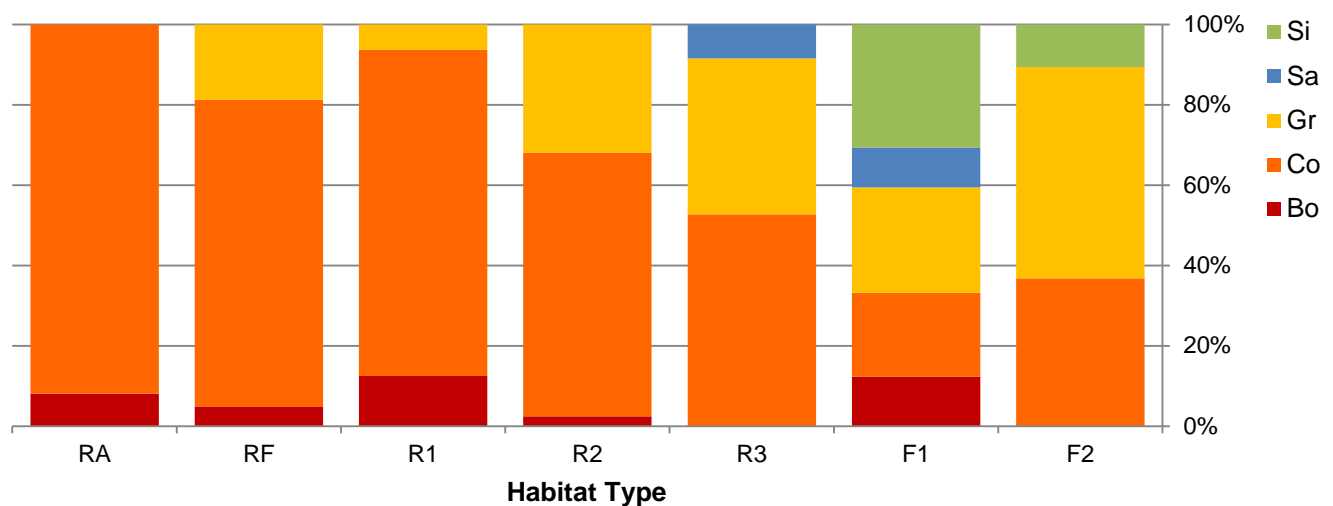


Figure 9: Distribution of dominant substrate in the Wapiti River by habitat type, October 2013.



3.5 Assessment of Fish Habitat Potential

The study area contained several areas with a high potential to provide overwintering habitat for large-bodied fish. Deep (>1.5 m) habitat was common and offered suitable overwintering habitat for species known to inhabit the river. Further, spawning habitat for Mountain Whitefish was also common. Transitional areas between Rapid or Riffle habitat and deep Run habitats with associated peripheral pools appeared to be suitable for Mountain Whitefish spawning. These areas also contained large quantities of clean, unembedded substrates. Regarding spawning of other species, redds were not observed; however, spawning habitat for Bull Trout appeared to be prevalent from a flow and substrate perspective. Similarly, spawning habitat suitable for Arctic Grayling and Walleye was observed within the study area.

3.6 Electronic Files and Attached Data

In addition to the information reported above, GIS and Excel-based tabular data files are attached to the electronic submission of this report (Table 3).

Table 3: Summary of files submitted electronically for the Project.

File name	File type	Description
Wapiti R._Thalweg Line.shp	Shapefile	Line file that delineates surveyed thalweg
Wapiti R._Thalweg Points.shp	Shapefile	Points that delineate thalweg line. All depth, distance and habitat data provided as point attributes
Wapiti R._Supplemental Data.shp	Shapefile	Raw depth data minus points used to generate the thalweg line file
Wapiti R._River Segments.shp	Shapefile	Line file that delineates river segments along the thalweg
1313730023_Wapiti R._MASTER Data file.xlsx	MS Excel (tab I)	Wapiti R._Master Sheet
_Wapiti R._MASTER Data file.xlsx	MS Excel (tab II)	Wapiti R._Thalweg Data: All sounder depth, distance, and habitat data collected along the thalweg (excludes points not along thalweg)
Wapiti R._MASTER Data file.xlsx	MS Excel (tab III)	Wapiti R._Raw Data: All sounder depth, distance and habitat data collected during the Project.
Wapiti R._MASTER Data file.xlsx	MS Excel (tab IV)	Wapiti R._Manual Depth Data: Manual depth data recorded by the crew
Wapiti R._MASTER Data file.xlsx	MS Excel (tab V)	Wapiti R._Clipped Data Final: All sounder depth, distance and habitat data collected that does not fall along the thalweg
Wapiti R._Photos	File folder	Contains photographs and a photo log (Wapiti R._Photo Log)



Report Signature Page

We trust the above meets your present requirements. If you have any questions or require additional details, please contact the undersigned.

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APPENDIX A

Stream Habitat Classification System



STREAM HABITAT CLASSIFICATION SYSTEM

(Modified from O'Neil and Hildebrand 1986)

Riffle - Portion of channel with increased velocity relative to Run and Pool habitat types; broken water surface due to effects of submerged or exposed bed materials; relatively shallow (less than 0.25 m) during moderate to low flow periods.

Riffle (RF) - Typical riffle habitat type; limited submerged or overhead cover for juveniles and adult life stages; coarse substrate

Riffle-Boulder Garden (RF/BG) - Riffle habitat type with significant occurrence of large boulders; availability of significant instream cover for juveniles (to lesser extent adults) at moderate to high flow events.

Rapids (RA) - Portion of channel with highest velocity relative to other habitat types. Deeper than Riffle (ranging from 0.25 m to 0.5 m); often formed by channel constriction. Substrate extremely coarse; dominated by large cobble and boulder material. Instream cover provided in pocket eddies (P3) and associated with cobble/boulder substrate.

Run - Portion of channel characterized by moderate to high current velocity relative to Pool and Flat habitat; water surface largely unbroken. Deeper than Riffle habitat type.

Run Class 1 (R1) - Highest quality Run habitat type. Maximum depth exceeding 1.5 m; average depth 1.0 m. High instream cover at all flow conditions (submerged boulders/bedrock fractures, depth). Generally of deep-slow type (to lesser extent deep-fast) and situated proximal to upstream food production area (i.e., RF, R3).

Run Class 2 (R2) - Moderate quality Run habitat type. Maximum depth reaching or exceeding 1.0 m, generally exceeding 0.75 m. High instream cover during all but low flow events (baseflow). Generally of either deep-fast type or moderately deep-slow type.

Run Class 2 / Boulder Garden (R2/BG) - Moderate quality Run habitat type; presence of large boulders in channel; high instream cover (boulder, bedrock fractures, turbulence) at all but low-flow events (baseflow). Depth characteristics similar to R2; however, required maximum depth lower due to cover afforded by boulders.

Run Class 3 (R3) - Lowest quality Run habitat type. Maximum depth of 0.75 m, but averaging <0.50 m. Low instream cover at all but high flow events.

Run Class 3 / Boulder Garden (R3/BG) - Similar to R3 in depth and velocity characteristics; presence of large boulders in channel offers improved instream cover during moderate and high flow events.



Flat - Area of channel characterized by low current velocities (relative to RF and Run cover types); near-laminar (i.e., non-turbulent) flow character. Depositional area featuring predominantly sand/silt substrate. Differentiated from Pool habitat type on basis of high channel uniformity and lack of direct riffle/run association. More depositional in nature than R3 habitat (sand/silt substrate, lower food production, low cover).

Flat Class 1 (F1) - High quality Flat habitat type. Maximum depth exceeding 1.5 m; average depth 1.0 m or greater.

Flat Class 2 (F2) - Moderate quality Flat habitat type. Maximum depth exceeding 1.0 m; generally exceeding 0.75 m.

Flat Class 3 (F3) - Low quality Flat habitat type. Maximum depth of 0.75 m, averaging less than 0.50 m.

Pool - Discrete portion of channel featuring increased depth and reduced velocity (downstream oriented) relative to Riffle and Run habitat types; formed by channel scour.

Pool Class 1 (P1) - Highest quality Pool habitat type. Maximum depth exceeding 1.5 m; average depth 1.0 m or greater; high instream cover at all flow-conditions (submerged boulder, bedrock fractures, depth, bank irregularities). Generally featuring high Riffle and/or Run association (i.e., food input). Often intergrades with deep-slow type of R1.

Pool Class 2 (P2) - Moderate quality Pool habitat type. Maximum depth reaching or exceeding 1.0 m, generally exceeding 0.75 m. High instream cover at all but low flow events (baseflow).

Pool Class 3 (P3) - Low quality pool habitat type. Maximum depth of 0.75 m, averaging <0.50 m. Low instream cover at all but high flow events. Includes small pocket eddy type habitat.

Impoundment - Pools formed behind dams; tend to accumulate sediment/organic debris more than scour pools; may have cover associated with damming structure.

Impoundment Class 1 (IP1) - Maximum depth exceeding 1.5 m; average depth 1.0 m or greater.

Impoundment Class 2 (IP2) - Maximum depth reaching or exceeding 1.0 m, average depth generally exceeding 0.75 m.

Impoundment Class 3 (IP3) - Maximum depth of 0.75 m, averaging <0.50 m.

Backwater (BW) - Discrete, localized area of variable size, exhibiting reverse flow direction; generally produced by bank irregularities; velocities variable but generally lower than the main flow; substrate similar to adjacent channel, but with higher proportion of fines.



Habitat Classification and Coding System for Streams

Habitat Type		Mean Depth	Max. Depth	Surface	Turbulence	Substrate	Velocity
Rapids	RA	> 0.3 m	> 0.5 m	broken	high	very coarse	very high
Riffles	RF	< 0.3 m	< 0.5 m	broken	high	coarse	high
Runs	R1	> 1.0 m	> 1.5 m	irregular	moderate	coarse	mod.- high
	R2	0.5 - 1.0 m	0.75 - 1.0 m	irregular	moderate	coarse	mod.- high
	R3	< 0.5 m	< 0.75 m	rarely broken	moderate	coarse	moderate
Pools	P1	> 1.0 m	> 1.5 m	smooth	low	variable	low
	P2	0.5 - 1.0 m	0.75 - 1.0 m	smooth	low	variable	low
	P3	< 0.5 m	< 0.75 m	smooth	low	variable	low
Flats	F1	> 1.0 m	> 1.5 m	smooth	laminar	finer	very low
	F2	0.5 - 1.0 m	0.75 - 1.0 m	smooth	laminar	finer	very low
	F3	< 0.5 m	< 0.75 m	smooth	laminar	finer	very low
Impoundments	IP1	> 1.0 m	> 1.5 m	smooth	laminar	finer	very low
	IP2	0.5 - 1.0 m	0.75 - 1.0 m	smooth	laminar	finer	very low
	IP3	< 0.5 m	< 0.75 m	smooth	laminar	finer	very low
BD		beaver dam height (i.e., vertical drop) should be recorded for each dam					

Habitat Features

- FA falls water falling over vertical drop
- CA cascade rapid vertical descent over cobble/boulder substrate
- CH chutes areas of channel constriction
- LE ledge bedrock intrusion into channel
- BW backwater areas with reversed flow direction
- SN snye non-flowing water connected to flowing channel only at d/s end
- DP debris pile e.g., log jam
- RW root wad large enough to provide cover for fish
- IS island
- SB exposed sand bar
- MB exposed mud bar
- GB exposed gravel bar

Substrate Classification

- Or organics
- Si silt (<0.06 mm)
- Sa sand (0.06 - 2 mm)
- Gr gravel (2 - 64 mm)
- Co cobble (64 - 256 mm)
- Bo boulder (>256 mm)
- Br bedrock

Instream Cover

- BG boulder garden
- WD woody debris
- D/T depth/turbulence
- AV macrophytes or flooded terrestrial veg.
- OV overhanging terrestrial vegetation
- UC undercut, overhanging bank

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