Field Manual for Erosion-Based Channel Classification

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1. Introduction

Land managers require a naming system for streams that can be consistently applied in planning and field applications. Applied researchers also need a classification to organize projects and facilitate knowledge transfer to a technical audience. Many jurisdictions, including Alberta, have used classification systems based on flow permanence and channel width; however, these two parameters are problematic. In the rest of this introduction, these two problems are reviewed. In this report we describe a classification system that uses a more robust set of parameters related to erosion processes. The five classes within the erosion-based system are defined in Section 2. Section 3 includes the field procedure to differentiate the classes. Finally, Section 4 includes considerations for applying this system in the boreal region and limitations for using any classification to describe complex drainage networks.

The first challenge relates to the consistent application of flow-related stream categories (e.g., ephemeral, intermittent, permanent). With seasonal and annual fluctuations, flow permanence may vary from one visit to another. Physical characteristics that reflect flow permanence have proven more practical than actual flow observations for determining flow permanence (Fritz et al. 2008) and they form the basis of the erosion-based classification.

The second challenge relates the use of a width-based classification for forest planning applications and for protecting riparian functions. A width-based classification for forest management applications is consistent with the general premise that as stream size progressively increases down the length of any watercourse, greater levels of protection are required to preserve important functions and values; however, this approach presents both operational and theoretical challenges. From an operational perspective, foresters have encountered problems when applying a width-based classification in close proximity to source areas. Due to their low volume, these headwater channels lack sufficient power to regularly erode material from their banks; hence, channel width is highly variable and strongly influenced by the type of vegetation immediately adjacent to the stream (Figure 1). Even with repeated measurements, it can be difficult to get consistent width measures by different people or on successive visits. Channels with such characteristics are commonly encountered within or adjacent to cutblocks in the Foothills. Many such streams are not shown on available maps. For those streams that are mapped, there is no objective way to determine their width, other than determining the drainage area – channel width relation and extrapolating this across the area of interest. Without such maps, it is difficult to align strategic and operational forest harvest plans. For example, given the quantity of timber that may fall within riparian buffers, without accurate maps of channel class with buffers assigned, it is difficult to estimate wood supply across a region.

Figure 1. Variable width in a headwater Foothills stream.

From a theoretical perspective, it is important to consider features other than channel width for determining the sensitivity of a stream and it's riparian area to forestry-related impacts. Channel dimensions, specifically width and depth, are related to bankfull discharge; however, the width:depth ratio, floodplain extent and sensitivity of a channel to disturbance are also dependent upon other factors including the percentage of fine material (silt-clay) in the channel boundary (Schumm 1985). The greater the amount of fine material, the lower the width:depth ratio, the greater floodplain development, and the higher sensitivity to disturbance. For example, let's compare two channels with similar bankfull discharge volumes – one draining a basin in the Front Ranges of the Rocky Mountains, the other draining a Foothills watershed. The typical Front Ranges stream transports a mix of gravel, sand, and fine material with the streambanks made of a corresponding mix of material. The typical Foothills stream transports a greater percentage of fine material; hence the channel banks and floodplain surface are largely comprised of silt and sand. The Front Ranges stream will have a wider, shallower channel with less developed floodplain in comparison to the Foothills channel.

2. Erosion-based classification system

A system adapted from existing classifications (e.g., Montgomery and Foufoula-Georgiou 1993) was used for a regional stream mapping project in the Foothills region near Hinton. Important considerations of the overall project are described herein. The regional stream mapping project (McCleary 2011) was initiated for two main reasons. First, the complete representation of the headwaters portion of the Government of Alberta 1:20,000 scale stream network was limited by the effective resolution of available air-photographs – many of the smaller watercourses simply couldn't be detected beneath the shrubs and trees. Second, likely because ground truthing was very limited and mapping was done by a variety of photo interpreters, foresters have found that the classification system assigned to the Government of Alberta stream network was inconsistent from one mapsheet to the next, was difficult to interpret, didn't align well with actual field data, and didn't link with the width-based ground rules classification. Thus, the goals of the regional stream mapping project were to provide better information on the locations of headwaters streams and to assign a classification that could support management needs. Five categories were defined based on the dominant surface erosion processes (Table 1 and Figure 2). Because this system is based on stream functions, it aligns well with the overall goal for management of riparian areas in forested regions of Alberta "to maintain or enhance the structural and functional integrity of riparian areas and associated aquatic ecosystems" (Borutski et al. 2005).

Table 1. Erosion classes and definitions

Class	Best corresponding class(es) in Alberta OGR classification	Description of erosion processes
Upland (U)	Upland	Drainage features are absent. Surface erosion is driven by overland flow and tree root throw. On LiDAR-generated stream network maps, false channels may appear on uplands. These features can be removed from the map as required.
Swale (S)	Ephemeral or water source areas	Historically, channels extended into these areas to remove material and create an obvious depression. Soil is sufficiently wet to support hydrophytic vegetation. These areas are susceptible to compaction and subsequent erosion.
Discontinuous channel (DC)	Intermittent	This drainage feature includes alternating sections of channel and vegetated ground. The channel may either be migrating upstream through headward extension or in the recovery process with vegetation encroaching into the old channel (Leopold et al. 1964). Erosion typically initiates at a headcut at the upstream end of the channel section with sediment transported a short distance downstream.
Seepage-fed channel (SFC)	Intermittent, transitional, or small permanent.	A channel with a continuous bed but insufficient stream power to transport larger streambed material including gravel and cobbles; hence, these channels typically lack bed features (e.g., regular sequences of pools and riffles) that Foothills fishes are adapted to. Sediment is transported as suspended load and bedload; however, only the smaller streambed material is mobile on an annual basis with larger clasts (e.g., cobbles and boulders) remaining stationary for long periods of time. In high relief areas, gravity transports upland sediment directly into these channels. In such areas, “colluvial channel” is a more appropriate name.
Fluvial channel (FC)	Small permanent or large permanent	A channel with a continuous bed and sufficient power to transport most of the material that it flows through. Sediment transport includes suspended and bed load. Bedload transport is not limited to fine material, and includes larger size materials such as gravel.

(a) Upland

(b) Swale

(c) Discontinuous channel

(d) Seepage-fed channel

(e) Fluvial channel

Figure 2. Example photos of erosion classes.

For the regional initiative, a stream network was derived from LIDAR data (Figure 3a). The extent of the network was over-estimated to ensure all streams were captured. Removal of the false drainage features will effectively truncate the original digital stream network. Spatial models calibrated with field survey data can be used to map streams by channel class for an area of interest (Figure 3b).

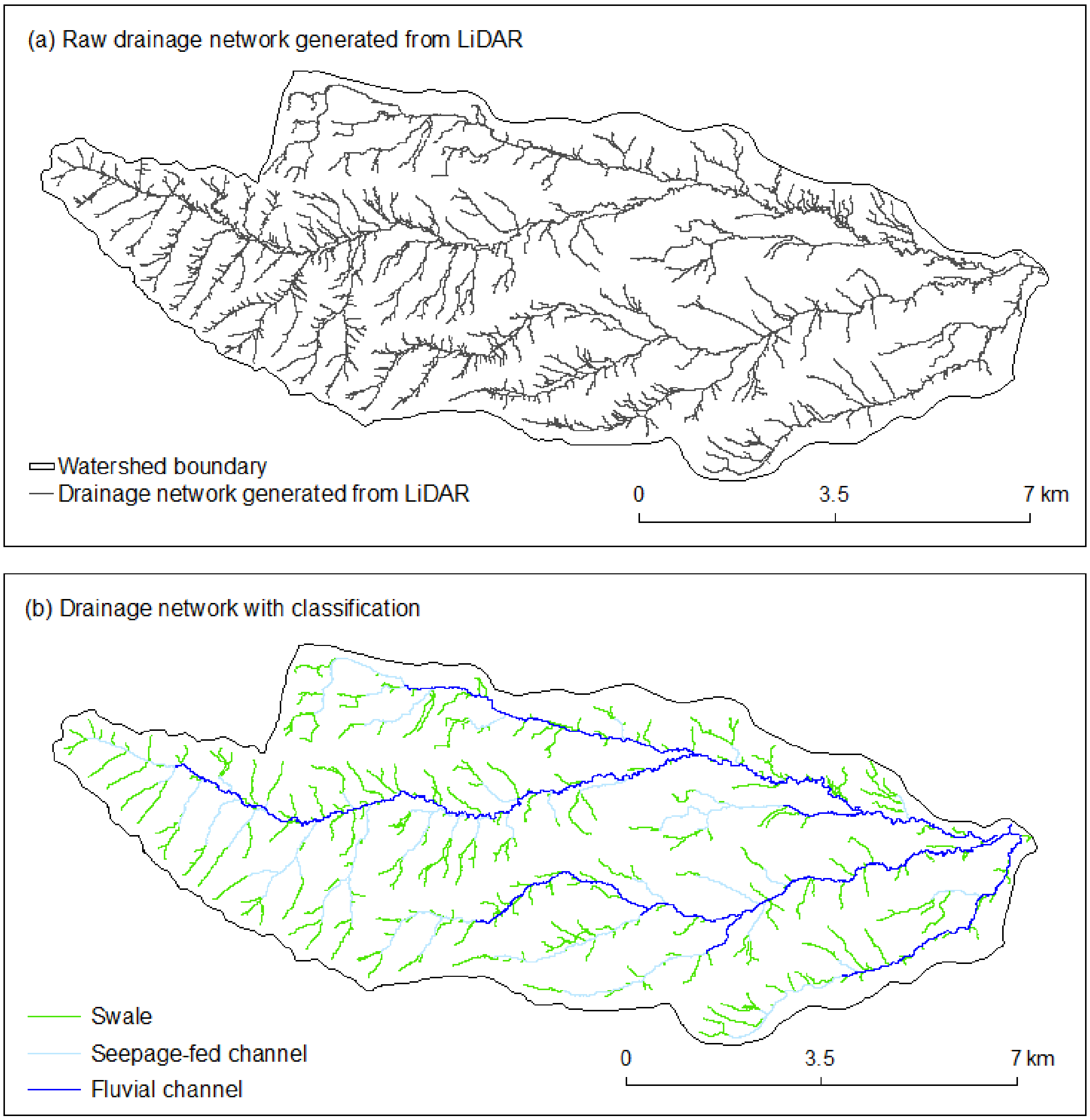


Figure 3. Maps of (a) a raw LIDAR-generated stream network and (b) a stream network with channel classes assigned. Note that for this modelling exercise, the discontinuous channels were grouped within the swale category.

3. Field Classification Procedure

A two part process is used to determine the erosion class. In Part I, a number of simple observations are made to distinguish between the first three classes (Figure 4). In Part II, a total of eight criteria are considered to determine if a continuous water course is a seepage-fed or fluvial channel (Table 2). The field sheet (Appendix 1) can be used to record the measurements and results from both parts of the exercise.

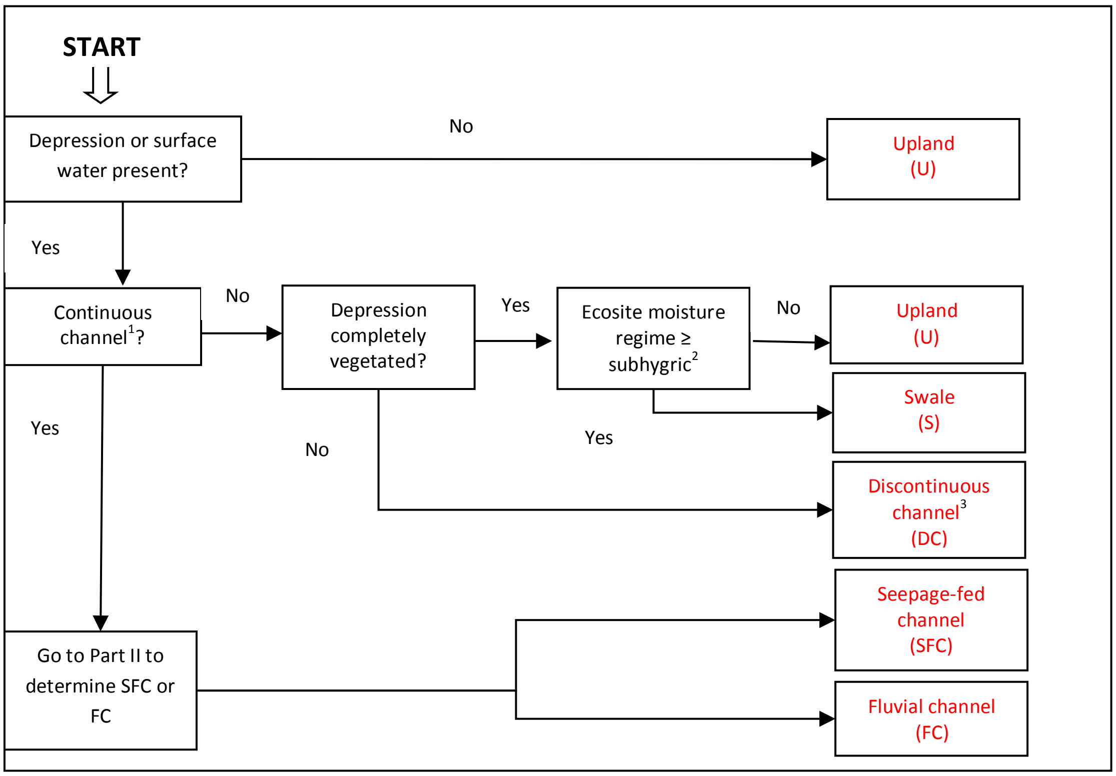


Figure 4. Key to erosion classes – Part I.

[1]Bed of channel is visible over extended lengths and if organic bridges are present, they are limited in length with an obvious connecting channel under the ground surface (see Figure 2c and 2d).

[2]Ecosite moisture regime is determined first by using the key to plant community types from the ecosite field guide (e.g., Beckingham et al. 1996) and then by referring to description of typical moisture regime for corresponding plant community type.

[3]Sections of channel are interspersed between vegetated areas that function to filter out sediment that is transported from upstream areas. If organic bridges are present, they are long and lack an obvious underground flowpath. For statistical modelling and subsequent mapping

(see Figure 2c and 2d), discontinuous channels were grouped with swales due to lack of statistical evidence to support their use as a fifth category in the classification system.

Table 2. Key to erosion classes – Part II.

Feature number	Seepage-fed channel features	Fluvial channel features
1	Fine bed material collected from deepest part of channel is mostly silt and organic matter. If required, use a hand texturing procedure to confirm[a].	Fine bed material collected from deepest part of channel is mostly well-sorted sand. If required, use a hand texturing procedure to confirm[a].
2	Unconsolidated bed along the deepest part of channel. Indicated if when standing on one foot, the surveyor's boot sinks to a depth > 10 cm.	Consolidated channel bed. Indicated if the surveyor's boot does not sink to a depth of > 10 cm.
3	No steps / riffles created by mobile gravel or cobbles[b].	Steps / riffles with regular spacing created by mobile gravel or cobbles[b].
4	No pools present[b].	Pools present with regular spacing[b].
5	Organic bridges present[b].	No organic bridges present[b].
6	Head cuts present[b and c].	No head cuts present[b and c].
7	Maximum bankfull width[d] >3x the minimum width.	Maximum bankfull width[d] <3x the minimum width.
8	Total undercut width[e] > bankfull width.	Total undercut width[e] < bankfull width.
Total	**See Section 3.1 for interpreting tally**	**See Section 3.1 for interpreting tally**

a. Grab a handful of material from the bottom of the deepest part of the channel. Squeeze it tightly and wring out as much water as possible. If possible, remove the larger pieces of organic matter including fibers, leaves, twigs, etc. Hand texturing procedures are developed for dry soils that are wetted just to the point where soil begins to adhere to fingers, so if possible, set the material aside to allow it to dry out. Given that clay should not be a major component of any stream bottom sample, focus the test to determine whether the material has > or < 50 % sand. Based on the procedures detailed in Beckingham et al. (1996), do the following:

    i. Start with a 2.5 cm mass. Roll into a ball. Throw the ball in the air to a height of 30 cm. If the ball falls apart easily, material is > 50 % sand.

    ii. Roll the ball into a cigarette shaped cylinder and then squeeze out between forefinger and thumb. If the ribbon is less than 3 cm long before breaking, the material is > 50 % sand, otherwise the material is < 50 % sand.

b. See reference photos (Figure 5).

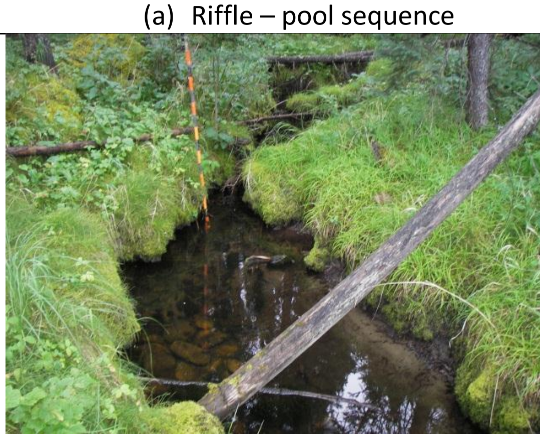
c. Head cuts are an abrupt vertical drop in the bed of a stream. This active erosion feature appears as a small waterfall flowing over roots or the forest floor. This indicator of seepage-fed channels is a transient structure and can exhibit relatively rapid upstream movement during periods of high runoff. Groundwater seepage may also be present from the face or base of the head cut.

d. Bankfull width is measured from the base of rooted woody bank vegetation typically near the break in slope on one bank across to a corresponding feature on the opposite side (see photos in Appendix 2).

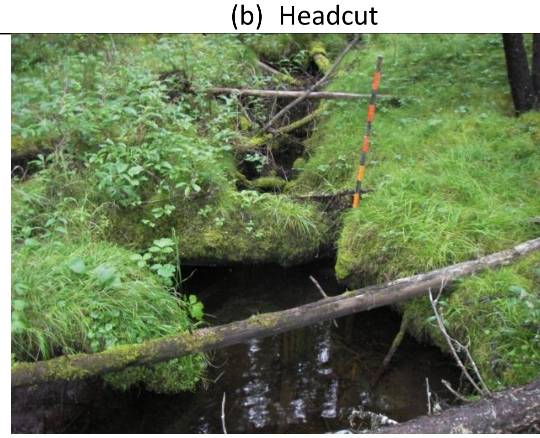
e. To measure undercut width, stand with one leg in a vertical position against the tip of the bank that has the undercut of interest (Figure 6). Take your ruler and extend it underneath and at right angles to the bank to its furthest point. Press the ruler back until it contacts solid material. This is the back of the undercut. Read the distance at the point where the ruler meets the outside of your leg. Depending on the water depth, your ruler may be under the water surface. Measure the undercuts on both banks and add the measurements together to get the total undercut width.

(a) Riffle – pool sequence

(b) Headcut



(c) Variable width channel



(d) Undercut banks and organic bridge

Figure 5. Channel feature photographs.

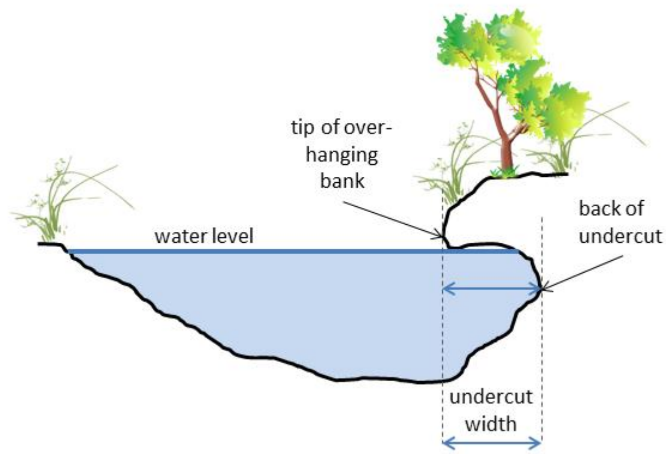


Figure 6. Reference points for measuring undercut width on a stream with an undercut only on a single side.

3.1 Determining the continuous channel class

From Table 2, the tally of features for seepage-fed and fluvial channels will vary between zero and eight for each class respectively. Based on this tally, the channel class should be obvious in the vast majority of cases. For example, in 2008 and 2009, the classification was completed in the Hinton region at 842 sites that were selected using a stratified random sampling method. Of those 842 sites, 281 were continuous channels that were further classified using the eight criteria from Table 2. Channel class determination was only made in the field when six or more of the eight criteria were met for a single class. Of the 281 sites with a continuous channel, 94% had six or more indicators for a single class and the remaining 6 % (16 sites) had five indicators for one type and three for the other. No sites were assigned as a tie. For those 16 sites with five indicators for one class and three for the other, the field crew completed a more detailed assessment of channel morphology. In the office, a geomorphologist reviewed the data and assigned the appropriate class.

Although the use of a detailed assessment of channel morphology is an option for sites that do not obviously fall into one class or the other, this extra work is difficult to justify. For sites that score with four indicators for each class, it may be more prudent to err on the side of caution and designate such sites as fluvial channels. Remember that transition locations between seepage-fed and fluvial channels are not stationary, and major runoff events can trigger the rapid upstream migration of fluvial channels followed by a prolonged retreat.

Strategies for achieving consistent application of the classification system should be applied. For example, establish a 10 km loop with at least 20 stream crossings that follows the road system in close proximity to headquarters. Have trainees stop at all stream crossings (which typically include an identification number painted on the structure), then walk upstream into an un-disturbed reach and complete the classification. Immediately review the classification calls that were made and inform trainees of the correct class. Proceed to the next location. This system was applied in 2008 and 2009 in Hinton and proved important. Other quality assurance measures could include requiring new crews to meet a certain classification accuracy in comparison to sites classified by the crews from previous years. The system may require some modification of indicators depending upon surficial material, bedrock geology, and relief. For example, indicators that refer to gravel and cobble may not apply in areas with extensive glacio-lacustrine deposits were sand is the largest stream bed material.

4. Conclusion

4.1 Applying this Foothills system into Boreal regions

Portions of this classification system, based on erosion-processes, should have application to any drainage network. An original classification for mountain regions described by Montgomery (1993), was adapted for use in the Foothills region by considering the different runoff and erosion processes between these two regions (McCleary 2011). These differences are reviewed because they are further amplified between the Foothills and Boreal regions. In mountain regions, runoff moves relatively rapidly from uplands into channels. In contrast, given the lower relief in Foothills, runoff moves slower and water may reside in wetlands before moving into an open channel. In high relief mountain regions, gravity drives surface erosion, landsliding, and soil creep across the upland portion of the landscape. In the Foothills, these upland processes are largely limited to over-steepened valley bottoms along large streams and rivers. Furthermore, any sediment generated by upland erosion often becomes stored within lower relief valley bottom landforms .

There are two important considerations when applying this Foothills classification into Boreal regions. First, the wet swale portion of the drainage network will have a much greater extent than in the Foothills. In areas of large plateaus, drainage features including topographic depressions and flow direction may be difficult to discern. As a result, upland sediment sources will be very limited and organic matter will be the dominant material entering most headwater stream channels. Secondly, salmonids are the dominant fish family in the Foothills. The habitat of rainbow trout and bull trout, the two most common native salmonid species in small streams near Hinton, has been closely linked to features associated with fluvial channels; hence, certain connections between presence of a fluvial channel and presence of fish habitat may be considered. However, boreal streams provide habitat for other fish families (e.g., minnow and stickleback) that are not specifically adapted to flowing water ecosystems. Thus, seepage fed channels may include all of the required habitat elements for various boreal region fishes.

4.2 Considerations for applying any channel classification system

Streams develop along a continuum from source to mouth and while various categories can be established based on established thresholds, stream classes cannot be considered discrete entities to the degree that plant and animal species are. Stream classification systems that emphasize correct identification to a given type inevitably end up with a large number of categories. For example, Rosgen (1994) identifies 94 different categories. Other classification systems that emphasize channel processes as opposed to correct identification have much fewer categories. For example, Montgomery and Buffington (1998) identify two main types – colluvial and fluvial channels – and further differentiate fluvial channels into seven additional classes. Where mapping and management applications are primary concerns, the systems with fewer categories and close links to channel processes have obvious benefits.

5. Literature Cited

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6. Glossary

Bedload: sediment that moves in contact with the bed of the stream rather than in suspension.

Colluvial: accumulations of rock and debris from gravity driven erosion processes, such as landsliding and soil creep, that operate on hillslopes.

Ecosite: ecological units that develop under a similar climate, moisture and nutrient regime that are often named by a commonly occurring plant species (Beckingham et al. 1996).

Fluvial channel: a stream with sufficient power to regularly transport the material that forms the stream bed and alter the structure of the stream banks (Hassan et al. 2005). These streams have regularly spaced features such as riffle – pool sequences.

Headcut: an abrupt vertical drop in the bed of a stream. This active erosion feature appears as a small waterfall flowing over roots or the forest floor. This indicator of seepage-fed channels is a transient structure and can exhibit relatively rapid upstream movement during periods of high runoff. Groundwater seepage may also be present from the face or base of the head cut.

Seepage-fed channel: streams that lack sufficient power to regularly move bed materials (Hassan et al. 2005). In these channels, upland and ecological processes contribute to more complex channel morphologies than in fluvial streams. Streams lack the power to modify roots of streamside vegetation or transport large woody debris and hence these features exert major influence on channel structure.

Organic bridge: created when roots extend across a channel or large woody debris falls over a channel. The forest floor extends across the channel and the streambed remains continuous beneath the bridge. These features form in seepage-fed channels that lack sufficient power to prevent the growth of roots within the active channel. These features, when measured parallel to the channel in the direction of flow, can be as narrow as 0.2 m or cover a section of stream as long as 5-10 m. They can occur in channels with a bankfull width of 2 m or more (see Figure 5d).

Pool: a deep section of stream created by scouring flows typical of fluvial channels. Fallen logs that create dams can also create backwater pools on the upstream side of an obstruction; however, such pools should be excluded in the field survey because they occur in both seepage-fed and fluvial channels.

Riffle / step: local sections of stream where the gradient increases. Fluvial processes create recurring sequences of riffle–pools or step–pools. Gravel or cobbles often form the bed in these steeper sections with the size of the bed material typically larger than the bed material in adjacent pools. Steps may also be created by large woody debris in the streambed.

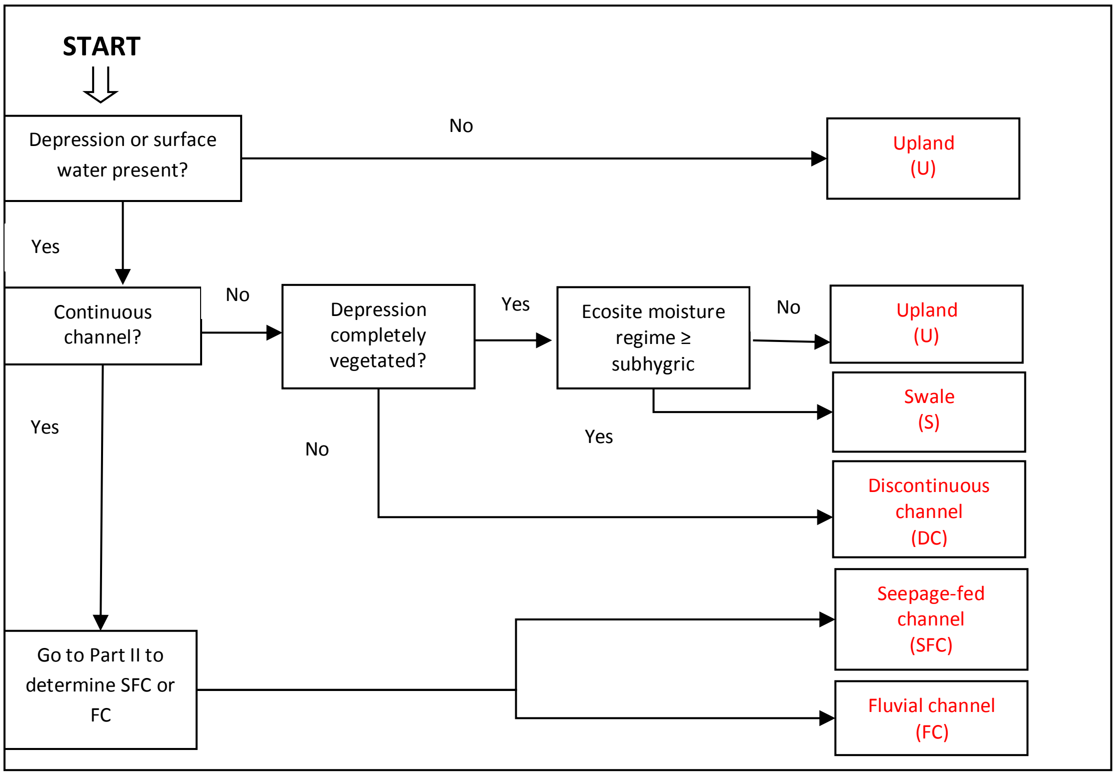
Appendix 1. Field Card

Date:	Crew:	Site/GPS ID:	UTM:
Working Circle:	Compartment:	Road:	Crossing ID:

Ground Rules Classification:

Ephemeral	Intermittent	Small perm.	Large perm.	Avg. width (m):

Part I. Flowchart for Erosion Process Classification



Part II. Seepage-fed / fluvial channel feature tally table

Feature Number	Seepage-fed channel features	Fluvial channel features
1	Fine bed material collected from deepest part of channel is mostly silt and organic.	Fine bed material collected from deepest part of channel is mostly well-sorted sand.
2	Unconsolidated bed (i.e., surveyor's boot sinks to a depth > 10 cm).	Consolidated channel bed (i.e., surveyor's boot does not sink to a depth of > 10 cm).
3	No steps / riffles created by recently mobile gravel or cobbles.	Steps / riffles with regular spacing created by mobile gravel or cobbles.
4	No pools present.	Pools present with regular spacing.
5	Organic bridges present.	No organic bridges present.
6	Head cuts present.	No head cuts present.
7	Channel maximum width >3x the minimum width.	Channel maximum width <3x the minimum width.
8	Total undercut width > bankfull width.	Total undercut width < bankfull width.
Total		

Part III. Comments:

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____

Erosion Process Class (circle one)

Upland	Swale	Discontinuous channel	Seepage-fed channel	Fluvial

Appendix 2. Example photographs showing a measuring tape at bankfull width (W_{bkf}) from fish inventories conducted by Foothills Research Institute in the Hinton region

Inventory identification number and bankfull depth (D_{bkf}) are also included in caption.

Site 202006. Unnamed; W_{bkf}=1.4m; D_{bkf}=0.90m.

Site 202001. Unnamed; W_{bkf}=4.7m; D_{bkf}=0.50m.

Site 202017. Unnamed; W_{bkf}=1.8m; D_{bkf}=0.49m.

Site 202045. Unnamed; W_{bkf}=1.3m; D_{bkf}=0.78m.

Site 202053. Unnamed; W_{bkf}=2.0m; D_{bkf}=0.63m.

Site 202060. Lambert; W_{bkf}=3.3m; D_{bkf}=1.08m.

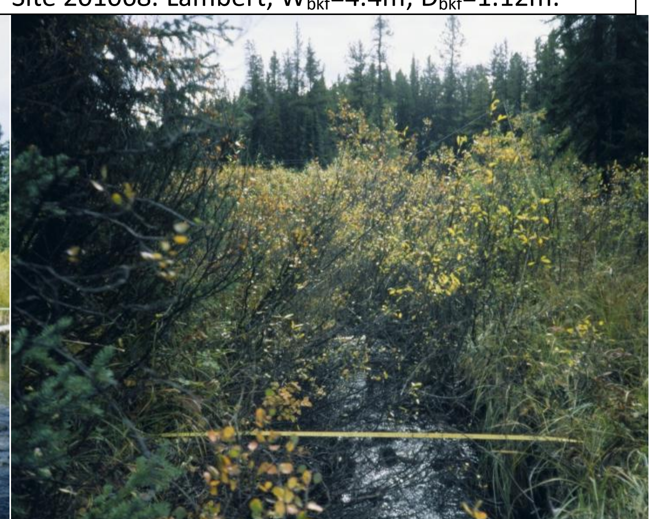
Site 201022. Unnamed; W_{bkf}=5.1m; D_{bkf}=0.57m.

Site 201023. Unnamed; W_{bkf}=0.8m; D_{bkf}=0.6m.

Site 201059. Baril; W_{bkf}=5.7m; D_{bkf}=1.8m.

Site 201068. Lambert; W_{bkf}=4.4m; D_{bkf}=1.12m.

Site 201071. Antler; W_{bkf}=9.3m; D_{bkf}=1.02m.



Site 201079. Unnamed; W_{bkf}=1.6m; D_{bkf}=0.58m.