STRUCTURE AND FUNCTION OF SMALL ROCKY MOUNTAIN FOOTHILLS STREAMS FOLLOWING FIRE

R.J. McCleary, Foothills Model Forest and M.A. Hassan, University of British Columbia

INTRODUCTION

Highly valued renewable resources within the Rocky Mountain foothills of Alberta include timber, water and fish habitat. Small streams represent more than 80% of the water courses in this region and very little was known about ecological processes within the riparian zones of these small streams. Forest management activities and forest fires are closely linked to sediment and large woody debris (LWD) processes. In October, 2001 the Dogrib fire burnt 6,740 ha of foothills forest. The goal of this phase of the project was to improve our understanding of sediment and LWD processes within the burned area with applications for riparian management. We selected a budget approach to track inputs, storage and outputs of these two elements.

Formula 1: Budget equation

OUTPUTS = INPUTS - CHANGE IN STORAGE

The specific objective was to identify key elements including input sources and storage sites so that future studies could be designed to determine exchange rates between these components.

METHODS

To document LWD recruitment, in the fall of 2002 we captured large-scale air photographs (1:1,800) of the stream and riparian area at selected reaches. LWD recruitment source-distance curves (Benda et al., 2003) were developed from photo-interpreted data. We used standard LWD field inventory methods (Schuett-Hames et al., 1999) to measure function and storage. To model watershed-wide LWD distribution, we linked instream LWD volumes with stand volumes from timber inventory maps. We used standard channel classification (Church, 1992) and assessment procedures (Anonymous, 1996). We delineated the active floodplain boundary using soil characteristics (Platts et al., 1987).

RESULTS

1. Large Woody Debris (LWD)

1.1. Recruitment

Debris flows were not an important process for recruiting LWD to foothills streams. Recruitment processes included bank erosion and tree mortality. On average, 90% of instream LWD originated from trees growing within 8 m of the stream channel (Figure 1). The time scale for long-term LWD management corresponds to several forest management cycles (centuries) and during this time the channel may migrate across the floodplain. Therefore, forest managers may consider the floodplain LWD recruitment zone (Figure 1) when managing long-term LWD supply.

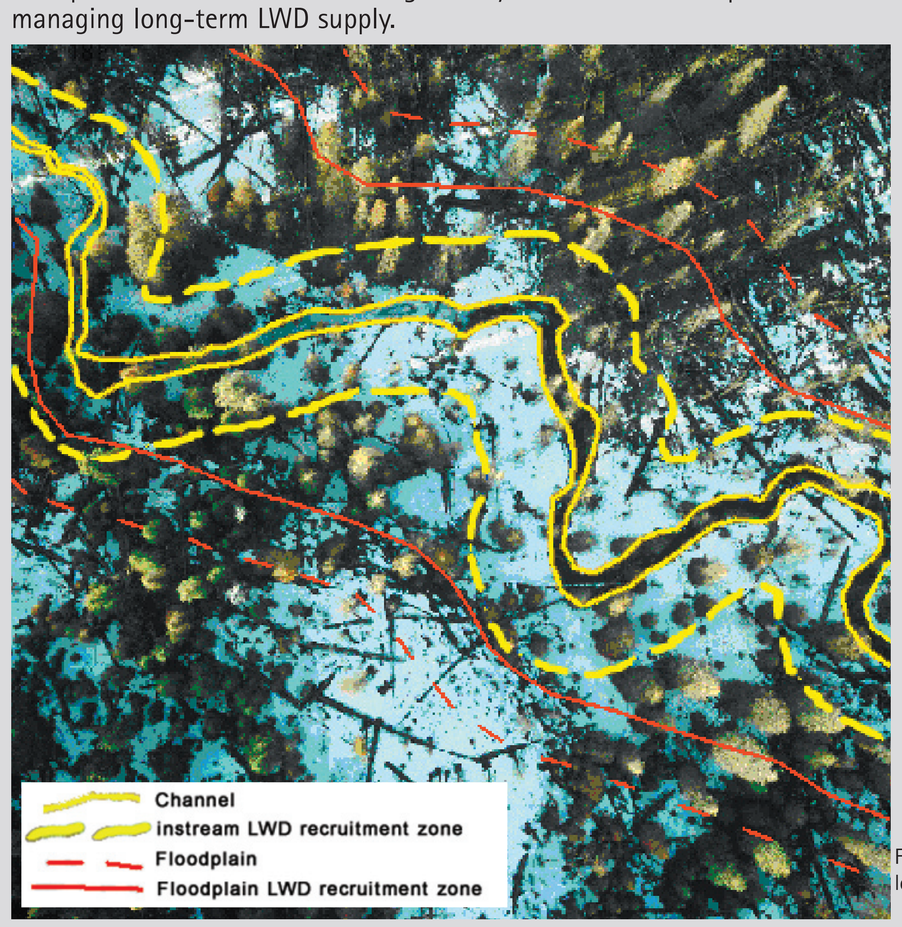

Figure 1. Plan view of short-term and long-term LWD recruitment zones.

1.2. Function

LWD influence on channel structure and sediment routing is greatest for pieces within the baseflow channel. The efficiency of producing baseflow channel LWD increases with stream size. For example, within a 1.5 m wide channel there are 9 pieces of non-functioning LWD for every piece of baseflow channel LWD, while within a 3 m wide channel there are 4 pieces of non-functioning LWD (Figure 2). Additional studies are required to determine the rates of converting LWD bridges that span the entire channel into functional LWD.

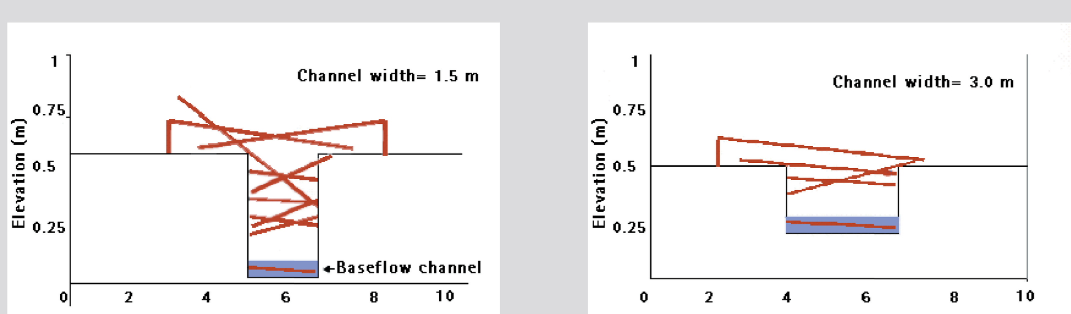

Figure 2. Channel cross sections for a 1.5 m wide stream and a 3.0 m wide stream showing different ratios of in-channel / baseflow-channel LWD.

1.3. Distribution

In small foothills streams, LWD inputs include recruitment from adjacent stands and LWD outputs are limited to decay. With this small number of processes, we anticipated a strong relationship between instream LWD volume and standing timber volume contained in detailed timber supply maps (Figure 3). Using this relationship, we were able to map watershed-wide instream LWD distribution (Figure 4). By combining this knowledge of LWD distribution with stream size, it may be possible to set goals for tree retention to meet instream LWD storage targets.

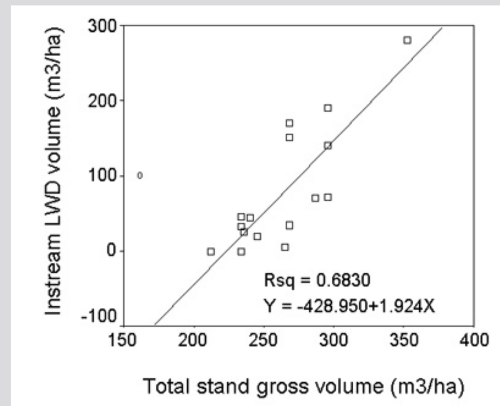

Figure 3. Instream LWD volume predicted from forest inventory stand volume.

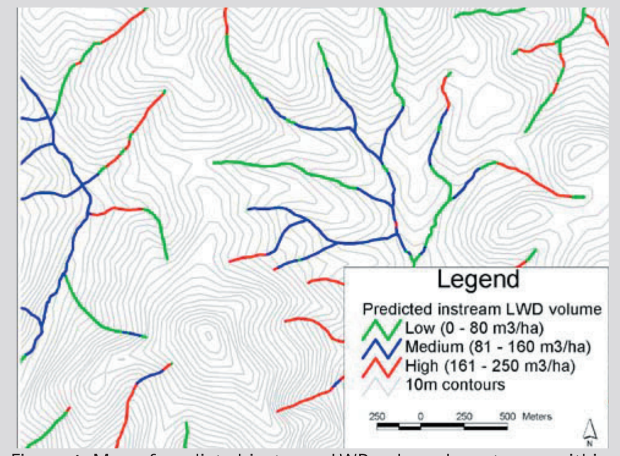

Figure 4. Map of predicted instream LWD volume by category within study area streams.

2. CHANNEL CLASSIFICATION

2.1. Classification

We identified two groups of streams that we called small alluvial channels and headwater channels (Figure 5). Small alluvial channels had drainage areas greater than 2.0 km² and they displayed characteristics (relative channel size vs. slope) consistent with an existing classification system (Church 1992). Headwater channels had a drainage area of less than 2.0 km² and the relative channel size was less than expected given the gradient.

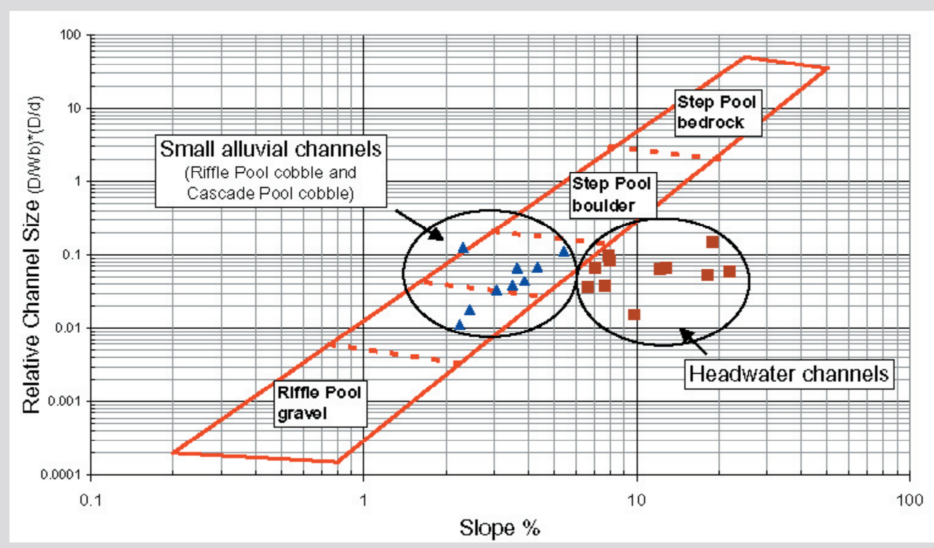

Figure 5. Nomogram to determine channel morphology with drainage area (km²) for each sample reach (adapted from Anonymous, 1996)

These headwater channels were consistent with previously described first-order channels characterized by accumulation of hillslope sediment rather than downstream transport (Reid and Dunne, 2003). Within the foothills, periodic headcutting of the channel bed was observed to be an important erosional process (Figure 6).

Figure 6. Headwater channel with pool formed below active headcut.

2.2. Floodplain

Well-developed floodplains comprised of recently deposited fluvial sediment occurred along small alluvial and headwater channels (Figures 7 and 8). Floodplain width was predictable from the size of the upstream drainage area and the slope of the channel (Figure 9). Using this model, we mapped predicted floodplain widths for study area streams (Figure 10).

Figure 7. Small alluvial channel with vegetation re-sprouting on floodplain and terraces following fire.

Figure 8. Recent fluvial deposits with floodplain.

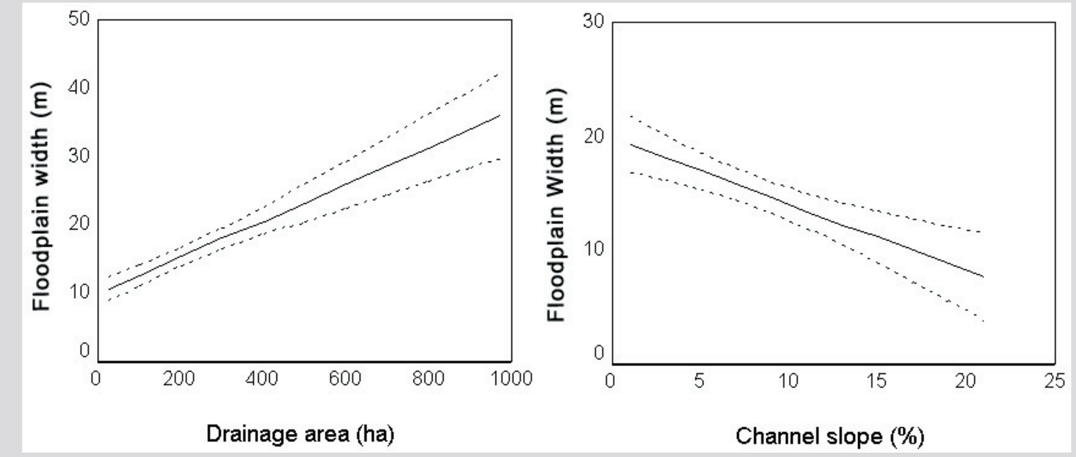

Figure 9. Predicted floodplain width and 95% confidence intervals for range of drainage area and reach slope values.

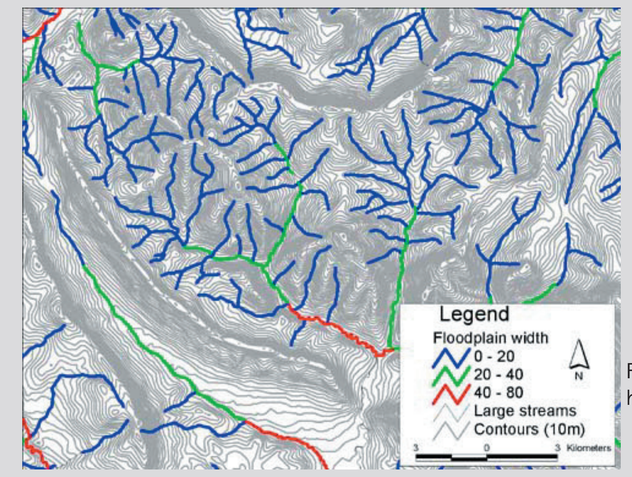

Figure 10. Map of predicted floodplain width for small streams (<1,000 ha drainage area) within the study area.

2.3. Bed-Pool Spacing

Pool spacing decreased as channel slope increased (Figure 11). On average, two out of every three pools were formed by LWD (Figures 12 and 13).

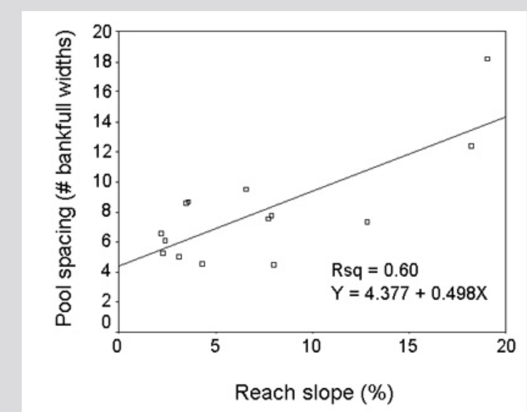

Figure 11. Model for predicting pool spacing (channel widths/pool) from reach slope (%).

Figure 12. Pool formed by LWD with headwater channel.

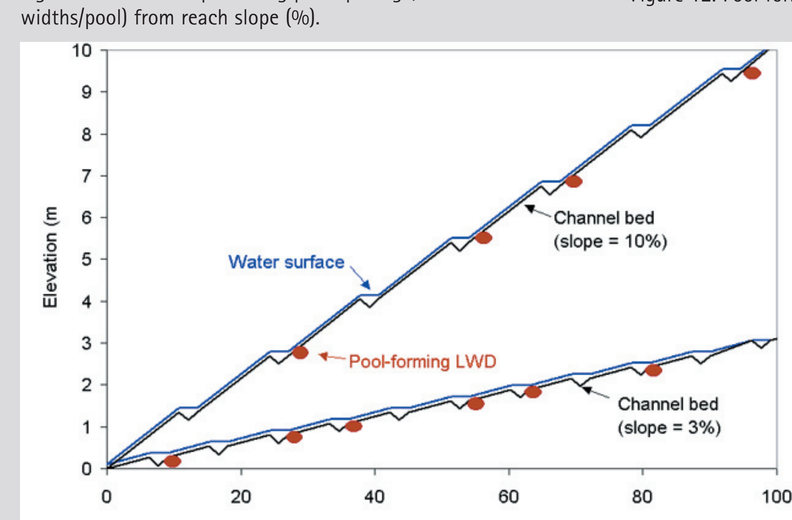

Figure 13. Longitudinal profiles of two headwater streams (3% slope and 10% slope) with pool extent, pool frequency and LWD function.

2.4. Banks

As indicated by increasing width/depth ratios, the role of riparian vegetation for maintaining channel form decreased with increasing drainage area and increasing stream slope (Figures 14 and 15).

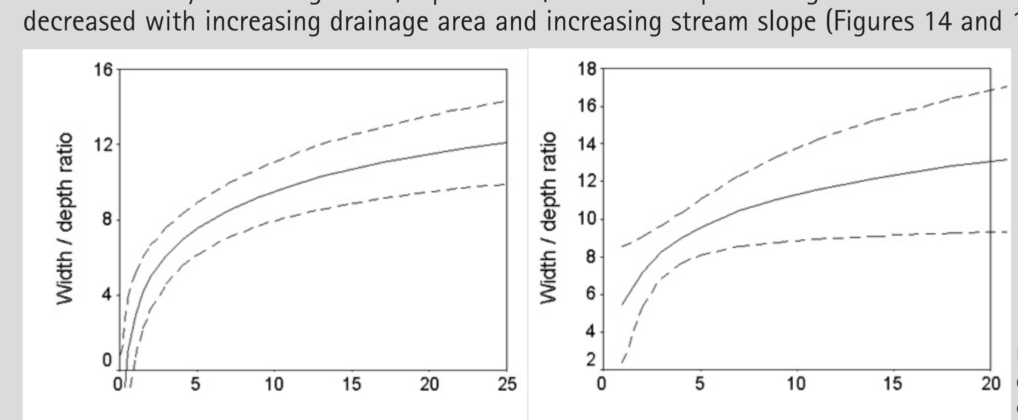

Figure 14. Predicted width/depth ratio and 95% confidence intervals. R^2 = 0.692.

Figure 15. Low gradient headwater channel with low width/depth ratio.

3. CHANNEL DISTURBANCE ASSESSMENT

Post-fire erosion is largely dependent upon rainfall. In the two-year period between the Dogrib fire (fall 2001) and our channel disturbance assessment (fall 2003), maximum annual daily rainfall and total summer precipitation were well below average. Channel disturbance levels are expected to continue to increase following major rainfall events that occur prior to under-story and over-story reestablishment. Total disturbance extent was twice as high in headwater streams compared to small alluvial channels. Bed scour was prominent only within headwater channels in parent material comprised on deep till (Figure 16). Common post-fire channel disturbance types included deposition of sediment wedges (Figure 17), bank erosion (Figure 18), and formation of multiple channels

Figure 16. Bed scour in headwater channel located with moraine parent material.

Figure 17. Recently formed sediment wedge.

Figure 18. Post-fire bank erosion.

SUMMARY

Three categories of streams emerged during our study (Figure 19) and they corresponded to valley types described by Platts et al. (1987). Each of these types represents an endpoint along a continuum rather than a discreet type. Components of a sediment budget for each of these stream types were also identified (Figures 20 – 22). Relative importance of vegetation and LWD for channel structure also differed among the three categories. Managing riparian areas for water quality and fish habitat entails maintaining LWD storage and streambank stability. From this phase of the study we learned that to achieve these objectives tree retention considerations include: proximity of trees to channel and floodplain; stream size; tree productivity within streamside forest; and slope of channel.

In the first phase of the study we identified key components of the LWD and sediment budgets for foothills streams. In the second phase, we will incorporate knowledge on timing of LWD recruitment and LWD decay rates from another Foothills study. Sediment exchange rates within the floodplain over various scales (decades and centuries) will also be determined. In the final phase, we will calibrate an existing model (Miller et al., 2003) to quantify effects of various landscape disturbance scenarios (forest management and fire) on fish habitat and water quality based on changes in wood and sediment fluxes.

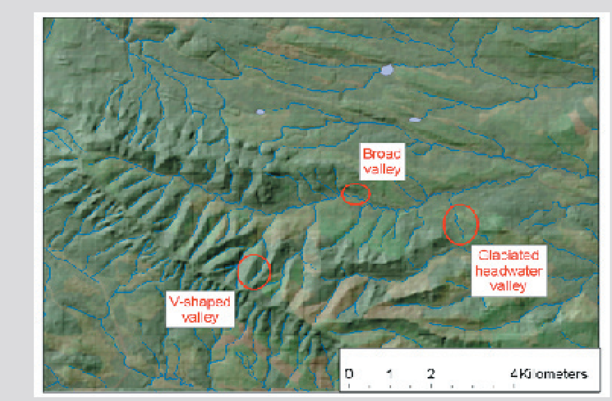

Figure 19. Landscape map showing location of three valley types (adapted from Platts et al., 1987).

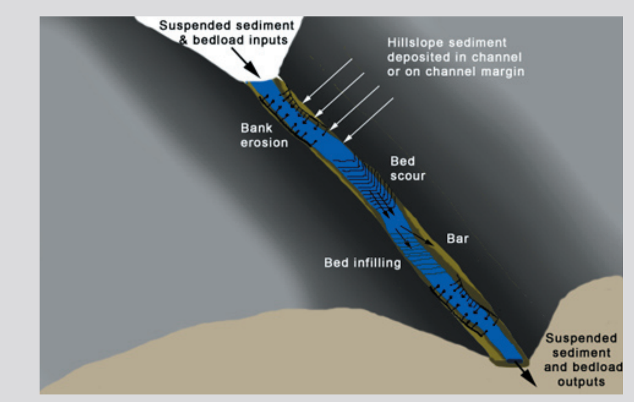

Figure 20. A sediment budget for a stream within a V-shaped valley (adapted from Reid and Dunne, 2003).

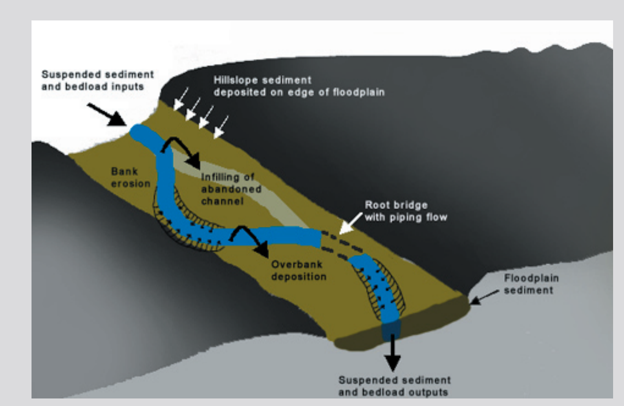

Figure 21. A sediment budget for a stream within a glaciated headwater valley (adapted from Reid and Dunne, 2003).

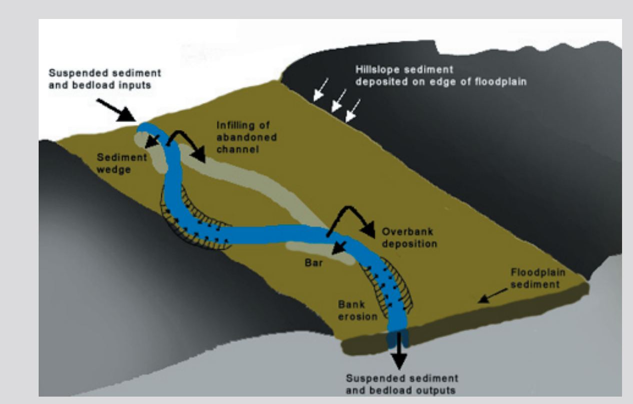

Figure 22. A sediment budget for a stream within a broad valley (adapted from Reid and Dunne, 2003).

REFERENCES

Anonymous, 1996. Channel assessment procedure field guidebook. Ministry of Forests and BC Environment.

Benda, L. et al., 2003. Wood recruitment processes and wood budgeting. In: S. Gregory, K. Boyer and A. Gurnell (Editors), International conference on wood in world rivers, American Fisheries Society Symposium 37. The ecology and management of wood in world rivers. American Fisheries Society, Oregon State University, Corvallis, Oregon, pp. 49-74.

Church, M., 1992. Channel morphology and typology. In: G.E. Peets (Editor), The rivers handbook: Hydrological and ecological principles. Blackwell Scientific Publications, Oxford, pp. 126-143.

Miller, D., Luce, C. and Benda, L., 2003. Time, space, and episodicity of physical disturbance in streams. Forest Ecology and Management, 178: 121-140.

Platts, W.S. et al., 1987. Methods for evaluating riparian habitats with applications to management. General Technical Report INT-221, Intermountain Research Station, USDA Forest Service, Ogden, Utah.

Reid, L.M. and Dunne, T., 2003. Sediment budgets as an organizing framework in fluvial geomorphology. In: G.M. Kondolf and H. Piegay (Editors), Tools in fluvial geomorphology. John Wiley and Sons Ltd., West Sussex, England, pp. 463-500.

Schuett-Hames, D., Pleus, A.E., Ward, J., Fox, M. and Light, J., 1999. TFW Monitoring Program method manual for the large woody debris survey. TFW-AM9-99-004. DNR #106., Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish and Wildlife Agreement.

Support provided by: Alberta SUSTAINABLE RESOURCE DEVELOPMENT; foothills MODEL FOREST research growing into practice; Hinton Wood Products A Division of West Fraser Mills Ltd.; Sundre Forest Products A division of West Fraser Mills Ltd.

R.J. McCleary
Foothills Model Forest
Box 6330, Hinton Ab T7V 1X6
Phone: (780) 865-8383
Fax: (780) 865-8331
Email: rich.mccleary@gov.ab.ca

M.A. Hassan
Department of Geography, UBC
Vancouver BC V6T 1Z2
Phone: (604) 822-5894
Fax: (604) 822-6150
Email: mhassan@geog.ubc.ca