Forest Disturbance and Recovery: Presentation Summaries from the 2006 Canadian Geophysical Union (CGU) Special Session in Banff, Alberta

Introduction by Dan Moore and Robin Pike

To minimize the hydrologic impacts of forest harvesting and related activities, land managers typically place restrictions on the extent of harvesting that can occur within a watershed. In British Columbia, under the *Forest Practices Code of British Columbia Act*, restrictions were based on recommendations from watershed assessments. These assessments were undertaken once the extent of past and proposed forest harvesting reached a threshold—typically 20–30% of a catchment's area. Once the prescribed limit had been reached, further harvesting was restricted until the initial effects had diminished in association with regrowth of forest cover.

In watersheds with cutblocks of different ages, a typical approach is to calculate the percent recovery (PR) based on the height of the trees, and other factors such as stocking levels and forest health. The equivalent clearcut area (ECA) of the block would then be computed as the product of the area of the block and the factor (1 – PR/100). The total ECA for a catchment would then be expressed as a percentage—the sum of the recovery-weighted areas for individual blocks divided by total watershed area, and multiplied by 100%.

While simple in principle, the concept of hydrologic recovery is difficult to apply to forestry operations. Different processes (e.g., snow accumulation, snowmelt, rainfall interception, root decay related to slope stability) recover at different rates, with the rates depending on factors such as the original forest cover type, the species and stocking levels of the regenerating forest, and the climatic regime. Only a few studies have attempted to quantify rates of hydrologic recovery at either the stand level (i.e., in terms of processes such as snow accumulation) or the catchment level (in terms of streamflow), and it is unclear how to generalize from these specific sites. Furthermore, the immediate impact and rate of recovery associated with variable retention harvesting does not appear to have been studied comprehensively.

To begin to address the knowledge gaps associated with hydrologic recovery, a special session was organized at the 2006 Annual Meeting of the Canadian Geophysical Union in Banff, Alberta. Professor Julia Jones of Oregon State University provided an invited keynote address based on her in-depth analyses of long-term paired-catchment studies in the United States. The session also included eight oral presentations and six posters on the topic, which are summarized below. An ad hoc working group was formed following the session to continue working on the topic.

We acknowledge the CGU for financial support and CGU–Hydrology Section for hosting the special session.

Presentation:

Seasonal and successional influences on streamflow response to forest harvest disturbances in the western and eastern United States

J.A. Jones

The term "recovery" implies that hydrologic processes return to a static pre-disturbance state following forest harvesting or natural disturbance. While this may be the case for some processes, others may not return to a pre-disturbance state. Thus, in many instances the term "response" may be more appropriate than "recovery."

Trajectories of hydrologic change vary with the process under study. For example, the post-disturbance responses (trajectories) of low flows and peak flows will differ as they occur in different seasons and are influenced by different processes linking the vegetation and atmosphere (e.g., transpiration for low flows, interception loss for peak flows). Seven types of potential hydrologic response trajectories could occur (Figure 1): asymptotic return (addition), spike, spring model, episodic disturbances (add material), return with overshoot, episodic disturbances (remove material), and asymptotic return (removal).

To understand trajectories, studies must examine hydrologic processes over several decades, often at a fine time step, to separate the effects of successional and phenological changes in vegetation. Paired-catch-

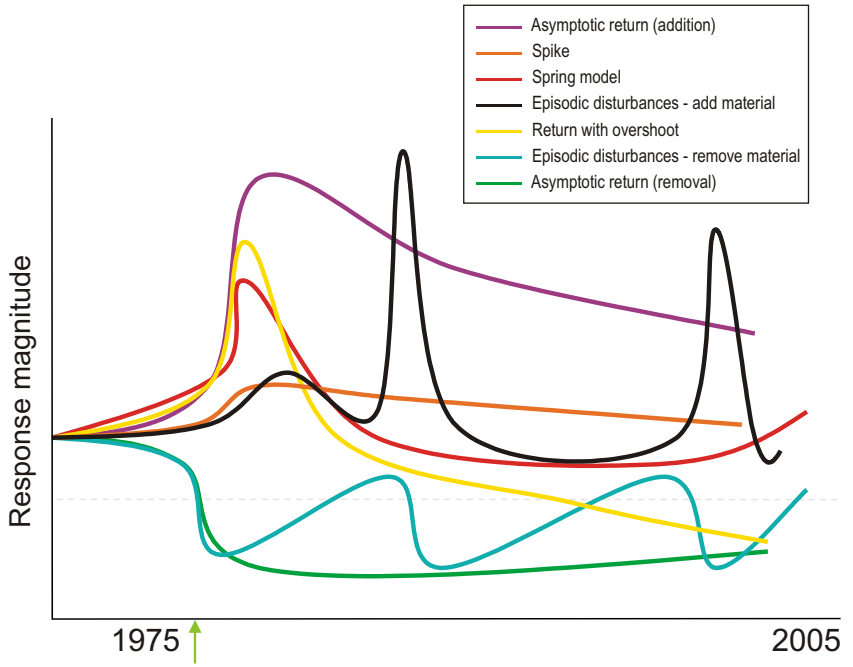

Figure 1. Hydrologic response trajectories.

ment experiments maintained over long periods provide a valuable source of information on the nature of post-disturbance response. While models can be valuable tools for exploring hydrologic changes associated with vegetation succession, they can only reveal the effects of the processes coded into them. Paired-catchment studies, on the other hand, have the potential to surprise us with unexpected responses. However, the interpretation of long-term paired-catchment analyses must be tempered with an understanding of how the treatment and control catchments may have differed through time due to differences in vegetation changes and response to climatic variations.

Key summary points

- Post-disturbance system response is not the same as recovery.
- There is a need to consider seasonal climate factors, forest age and type, and status and timing of disturbance in relation to predicted hydrologic response.

Contact

geojulia@comcast.net

Presentation:

The effects of lodgepole pine growth and stand management on snow accumulation and ablation in south-central British Columbia

R.D. Winkler and D.L. Spittlehouse

In a study of the effects of lodgepole pine growth and stand management on snow accumulation and ablation in south-central British Columbia, Winkler and Spittlehouse reported the following.

- Up to 40% less water accumulated as snow under the mature forest than in a clearcut opening. Ablation rates (loss of water from the snowpack through both sublimation and melt-water outflow) were most commonly reduced by 20–40%.
- The effects of clearcutting were moderated by the regrowth of lodgepole pine at 1000–2400 stems per hectare.
- Under 3-m tall lodgepole pine, snow accumulation was reduced by 8% relative to the open; at 5-m tall, both snow accumulation and ablation were reduced by up to 14%; and at 8-m tall, snow accumulation and ablation rates were up to 24% less than in the open.
- In a thinned stand, rates of accumulation and ablation were initially increased, but 6 years after thinning were 34% and 26% less than in the open, respectively. This was a more rapid reduction than that measured in the unthinned stand and is likely a result of well-developed and evenly distributed canopy cover relative to the somewhat more clumped stem distribution in the unthinned stand.
- These results are being used to develop "recovery" estimates for application in watershed development planning.

Contact

Rita.Winkler@gov.bc.ca

Presentation:

Annual water balance of forests, clearcuts, and regenerating stands

D.L. Spittlehouse

The forest canopy influences the balance of water inputs (precipitation) and outputs (evaporation and drainage) from the soil. Using measurements of precipitation interception and soil water content from four high-elevation lodgepole pine forests, three clearcuts, two 10-year-old stands, and one 25-year-old stand along with water balance model results, Spittlehouse reported the following.

- The mature forest intercepted 25%, the 25-year-old stand intercepted 18%, while the 10-year-old stand intercepted less than 10% of incoming precipitation.
- Biweekly average evaporation rates (including transpiration) were approximately 2 mm per day for moist forests and clearcuts. Soil drying, however, reduced the rate of evaporation in the clearcuts to less than half of that in the forest by mid-summer.

Continued on page 12

Continued from page 11

- Forest cover removal increased the output of water available for streamflow by 50% for the clearcut, 30–40% in the 10-year-old stand, and 5–15% in the 25-year-old stand.

Contact:

Dave.Spittlehouse@gov.bc.ca

Presentation:

Recovery of stand-level hydrologic processes following forest harvesting in coastal watersheds: Developing and testing an empirical model

B. Floyd, R. Hudson, I. Dodd, M. Hrachowitz, M. Weiler, and Y. Alila

An ongoing study is being used to develop/refine a predictive empirical model of hydrologic recovery in coastal rain-on-snow environments. Recovery curves produced by the model were based on snow course, rainfall, throughfall, and stemflow measurements from high- and low-elevation sites. While testing of the model at Russell Creek on Vancouver Island is ongoing, the authors provided the following preliminary key messages.

- The model can be adjusted based on elevation and the size of the event to provide reasonable estimates of interception recovery in harvested stands in rain-on-snow environments.
- Interception recovery ranged between 40 to 100% for stands between 10 to 17 m in height, with the amount of recovery depending on size and type of storm.
- The snowmelt lysimeter network in Russell Creek watershed was adjusted in summer 2006 to better capture the throughfall variability within forest stands (e.g., extended the length of each lysimeter to 7.5 m, installed stem flow gauges at each site, rewired the cameras to improve energy efficiency).
- Additional rain-on-snow events will be captured during 2006–2008 to increase the sample size, thus further testing and refining the model.
- Currently we cannot link interception recovery with hydrologic recovery; thus, future research will attempt to incorporate this interception recovery model into a distributed hydrological model to assess hydrologic recovery in harvested watersheds.

Contact:

Floydb@interchange.ubc.ca

Poster:

Scaling leaf area index and rainfall interception for projection of hydrologic recovery after disturbance in lodgepole pine

B. Brabender and U. Silins

This poster reported on alternate approaches to scaling effective leaf area index (LAIe) and rainfall interception storage capacity (S) using commonly available forest growth and yield data. Brabender and Silins found:

- LAIe ranged from 0.03 to 2.24 (m^2/m^2) in lodgepole pine stands 1–133 years old.
- The LAIe was linearly related to total annual stand volume growth ($r^2 = 0.83$); thus, change in annual volume growth rate is a good predictor of changes in stand LAIe as stands establish, develop, and mature.
- Canopy rainfall interception storage capacity (S) ranged from 1 to 4 mm (30–115 years old, LAIe 1.8–3.2 m^2/m^2) that amounted to 23–37% total growing season rainfall interception loss.
- Stand leaf area was a poor predictor of storage capacity (S), but gross stand volume was strongly related to interception storage capacity ($r^2 = 0.90$), likely because tree boles and branches play a greater role in interception storage than leaf area in these stands.

Contact:

Brendan.Brabender@gov.bc.ca or uldis.silins@ualberta.ca

Poster:

Hydrologic response of headwater streams to alternate harvesting practices

F.D. Beall and C.C. Krezek

This poster summarized the results of an experiment conducted in the Turkey Lakes watershed, a hardwood forest located in central Canada. The study examined 5 headwater basins before and after treatment with different harvesting practices (i.e., clearcut, selection, and shelterwood systems), two of which were reference basins. The authors reported enhanced summertime baseflow in the clearcut basin as reflected in the reduction in zero-flow days (from 39 to 0 days per year) in 2 years following harvest. The number of zero-flow days returned to pre-harvest levels within 4 years of treatment. The authors noted the difficulty in evaluating hydrological response during periods of climatic extremes.

Contact:

fbeall@nrcan.gc.ca

Poster:

Bed temperatures in relation to hyporheic exchange patterns in a headwater stream, and response to forest harvesting.

S.M. Guenther and R.D. Moore

Many studies have reported that reducing canopy cover over streams increases stream temperatures throughout the summer as a result of exposing the stream to solar radiation. The response of streambed temperatures to forest harvesting and interaction with hyporheic exchange patterns, however, has not been stud-

ied in detail. In a study of two paired reaches in a coastal mountain headwater stream, the authors' analysis of pre- and post-harvest data showed that:

- Daily maximum stream temperature increased by up to 6°C, while daily maximum bed temperature only increased by up to 2°C.
- Areas of downwelling flow in the stream reach exhibited higher bed temperatures than areas of upwelling flow.

Logging-related changes in bed temperatures therefore do not appear to be as large as those for surface water, and are greatest in areas of downwelling hyporheic flow.

Contact:

guenther@geog.ubc.ca

Presentation:

The sensitivity of rainfall-based runoff models to network density

M. Hrachowitz, R. Hudson, B. Floyd, M. Weiler, and Y. Alila

The presentation provided an overview of the initial phases of the development of a physically based distributed hydrologic simulation model in the Russell Creek watershed on Vancouver Island. The presentation focussed on the supplementation (i.e., increased density) of the existing hydro-meteorological network to better represent the spatial distribution of temperature, precipitation, and other meteorological parameters. The authors used several techniques to evaluate the performance of the enhanced network that included.

- comparison of temperature and precipitation variability to actual measurement accuracy to determine optimal instrument network density;
- comparison of standard (common default approach) lapse rates from index sites to measured temperature gradients; and
- calculation of basin average rainfall plus rain-on-snow melt with decreasing network density to determine optimum network density.

Contact:

markus.hrachowitz@ubc.ca

Poster:

The effects of overstory mortality on snow accumulation and ablation

P. Teti

This poster presented an overview of a new research project addressing how changes in stand structure related to mountain pine beetle are affecting snow accumulation and melt. The study area is actually a network of 34 plots clustered in 6 groups in the BC Interior between Fraser Lake and Bonaparte Lake. Stand characteristics and snow ablation rates are being measured in recent clearcuts, partially recovered clearcuts, recently attacked pine stands, and pine stands attacked 20 years ago. The large size of the network requires long travel times for ground-based snow measurements so aerial photography is being tested as a method for determining snow-free dates and measuring the stand traits that regulate snow interception and melt rate.

Contact:

Pat.Teti@gov.bc.ca

Poster:

Evaluation of rehabilitation methods for controlling erosion on wildfire sites

K. Giest and D.F. Scott

In this poster, Giest and Scott describe an active research project examining the efficacy of several methods to reduce soil erosion after wildfire. Four treatments under investigation include straw mulch, chipped tree mulch, needle fall, and seeding. These treatments, along with untreated controls, are being studied at 5 locations in the Southern Interior of British Columbia that were burned by wildfire in 2003. The authors reported the following early results:

- The mulch and needle-fall treatments effectively reduced erosion relative to the control (no treatment).
- Seeding does not appear to reduce soil loss significantly.
- The results confirm that as ground cover increases, soil erosion decreases.
- Since the plots are only exposed to natural rain events, the treatments have not been tested against all storm intensities.

Contact:

david.scott@ubc.ca

Presentation:

The role of water-repellent soils in the hydrological consequences of wildfire in BC

D.F. Scott, P. Jordan, M. Curran, and D. Dobson

The lead author presented an overview of the hydrologic consequences of wildfires that occurred in southern British Columbia in 2003. Before the post-wildfire events, evidence of water-repellent soils causing flooding had not been recorded in the southern BC Interior. The risk of flooding was thought to be limited because of the low probability of large rainstorms of high intensity and the highly permeable soils. Immediately after the 2003 wildfires, water-repellent soils in some of the burned areas were observed. As a result of these water-repellent conditions, a series of flood, debris flood, and debris flow events off burned sites occurred in the fall of 2003 and spring/summer of 2004. The results of the study indicate that it is important to measure soil wettability after wildfire as part of a proper assessment of the risk of erosion. Ongoing research is looking at site factors that might be used to pre-

Continued on page 14

Continued from page 13

dict where repellency and erosion are more likely to occur, and will also measure the persistence of repellency after wildfire.

Contact:

david.scott@ubc.ca

Presentation:

Predicting the effects of forest harvesting using a conceptual streamflow model: Evaluation using a paired-catchment approach

R.D. Moore and D.G. Hutchinson

The use of conceptual models to simulate the effects of forest harvesting and other forest disturbances has not been tested experimentally. This presentation described the suitability of using a conceptual model (HBV-EC) to predict the hydrologic effects of salvage harvesting 30% of Camp Creek following a mountain pine beetle outbreak in the mid-1970s. The authors calibrated the HBV-EC model to the pre-harvest conditions at Camp Creek, then perturbed the landscape to simulate streamflow following forest harvesting. Harvesting-related streamflow changes inferred from the model results were compared with those calculated from a paired-catchment analysis of streamflow observations for Camp (treatment) and Greata (control) creeks. The authors found that:

- The pattern of deviations between observed and predicted Camp Creek peak flows suggested that peak flows had recovered toward pre-harvest levels about 15–20 years after harvest.
- The magnitude and seasonal pattern of modelled changes in monthly flows agreed reasonably with those from the paired-catchment analysis.
- The modelled magnitudes of peak flow changes were also similar to those estimated from the paired-catchment analysis.
- The model requires further development to represent the effects of complex stand conditions (e.g., dead trees, regenerating forests) on water and energy fluxes.

Contact:

rdmoore@geog.ubc.ca

Poster:

Long-term monitoring results: Channel wood production rates in small, steep stream channels, Columbia River Basin

C. Chesney

This poster summarized the results of a long-term monitoring project examining the functional roles of wood in small, steep stream channels. Over 5800 trees, 2400 channel wood pieces, and 300 sediment wedges were monitored, as were rates of tree fall, and production rates of fallen wood (fluvial and terrestrial). Over 4 years of monitoring at 18 sites in the Yakima River basin, the author reported the following:

- 33% of fallen trees became channel wood.
- 67% of fallen trees became terrestrial wood.
- The tree fall rate was approximately 0.5% per year.
- The conversion rate of standing trees becoming channel wood that is hydraulically active, within the channel's bankfull wetted perimeter, was 0.0167%.
- 78% of zone 1 and 2 channel wood came from trees rooted within 8 m of the channel edges with most of the wood being above and near the channel (currently not hydraulically active).

Contact:

CRSNWISSP@aol.com

Presentation:

Harvesting effects on soil and creek nitrogen in high-elevation forests of Southern Interior BC

G. Hope, R. Winkler, D. Spittlehouse, and M. Feller

There is little known regarding post-harvest responses of both soil and stream nitrogen (N) in high-elevation forests in south-central British Columbia. This project details the linkages between forest harvesting, soil nitrogen cycling, and stream nitrogen based on studies conducted in the Upper Penticton Creek watershed experiment (i.e., 241 Cr., 240 Cr., and Dennis Cr. basins) and at the Sicamous Creek Silvicultural Systems study. Stream N has been measured from late April to late October since 1993. For the last 4–5 years, available soil ammonium (NH_4), nitrate (NO_3), soil solution N below the rooting zone, and soil moisture content have been measured throughout the growing season in both harvested and uncut forested areas. In the studies, the authors found that:

- Nitrate concentrations increased in Dennis Creek (primarily near periods of peak flows) 2 and 3 years after 50% of the watershed was harvested.
- Nitrate concentrations remained at or below detection levels in 241 Creek following 30% harvest of its watershed, and in 240 Creek, in which no logging has occurred.
- Available soil ammonium was significantly elevated in the clearcuts versus the uncut forest in the first 2 years post-harvest.
- Increases in soil solution concentrations of ammonium and organic N, but not nitrate, were observed in the second year after harvest in the clearcuts.
- The patterns of soil N changes are similar to those observed in the Sicamous Creek research study, a nearby, wetter, high-elevation research site.
- Losses of all forms of N from the root zone were extremely small (<0.1% of total) compared with the estimated total soil nitrogen content.

Contact:

Graeme.Hope@gov.bc.ca