Approaching Watershed Modelling

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The new *Forest and Range Practices Act* will likely increase people's interest in the ability of watershed models to assess the potential effects of forest management on water resources in a watershed (results-based) context. Hydrologic simulation, however, is not a tool that forest planners commonly use due to the complexity involved—complexity of watershed processes and management strategies, of past and present human disturbances, of cumulative watershed processes, and, more importantly, of many models themselves. Despite these barriers, the planning community's interest in modelling is increasing. This article introduces terminology and provides links to watershed modelling applications in British Columbia. Information about what scale is appropriate or what distinguishes micro- and macro- scale models are not discussed.

What Are Models?

Models are simplifications of reality that reflect our understanding of the processes they represent. Hydrologic models simulate the movement and storage of water within a catchment. Models are often used to generate scenarios and sometimes predictions (e.g., flood forecasting). Some models are based solely on empirical equations while others are built on more complex, physically based principles. "As with any tool, the answers they give are dependent on how we apply them, and the quality of these answers is no better than the quality of our understanding of the system" (Butcher *et al.* 1998). Whether the model is empirically or physically based, its parameters must generally be derived from measurement or, more often, calibrated (fit) to a watershed. This calibration involves adjusting parameter values so that differences between the input data and modelled outputs are minimized. Once a model is calibrated, its output should be tested or "validated" on a portion of data not used for calibration. The requirement of model calibration can present a significant barrier to operational model applications when little or no catchment-specific data are available.

Data Requirements

The type and amount of data required for watershed-scale simulation vary by hydrologic model and intended application. Whether a model is data-intensive or simplistic, it is often desirable to have high quality data. The record length (amount), however, can be short if the data sufficiently represent wet, normal, and dry years. The availability of data will often dictate the type of model that can be used. For this reason, a well-designed monitoring program is a common prerequisite of any simulation exercise. An important barrier to some model applications (i.e., those wishing to generate representative output), however, is the sparse network of climate and hydrometric stations in British Columbia, particularly at high elevations.

Model Use

Watershed models have the potential to generate probable future conditions (scenarios) given a range of forest management options or forecast events (e.g., flood, drought). Changes in water quantity, and less frequently in water quality, can also be explored through simulation. Often, results can be integrated with other models (e.g., climate change models) or geographic information systems. Examples of research applications of watershed simulation of forest management effects in British Columbia are provided in Table 1.

In Approaching Modelling

"Modelling is useful for many purposes, but it may not always be the best tool for a given situation" (Butcher *et al.* 1998). Defining the management problem and setting realistic expectations for the modelling process will help the non-expert determine if watershed simulation is an appropriate tool. This step contributes to development of appropriate, realistic scenarios that can be used to address the problem. Further assessment of whether adequate data exist to address the problem is the next logical step.

Once it is decided that simulation is an appropriate tool, then a model must be selected. A common goal of model selection is to balance between an acceptable level of uncertainty in results and efficiencies in time or other resources needed to run a model. All models are created for a specific purpose, which must match the intended use of the model. For example, a model designed for research may not always be appropriate as a management tool. Non-experts may not understand the difference between a model that produces scenario results and one that makes absolute predictions, or the subsequent differences in reliability of results. Sometimes models cannot be used outside an intended hydrologic regime (e.g., snowmelt- vs. rain-dominated hydrologic regime) as hydrologic assumptions built into a model may lead to errors.

Excessive data demands can often limit the practicality of some models. A few modellers abide by Occam's Razor, a philosophical rule that states that the simplest of competing

Table 1. British Columbia examples of hydrologic simulation applications in forested watersheds

Model	BC applications (only)	Application	URL or report
DHSVM: (US) http://www.hydro.washington.edu/Lettenmaier/Models/DHSVM/index.htm	Redfish Creek		Whitaker, A., Y. Alila, J. Beckers, and D. Toews. 2003. An application of the Distributed Hydrology Soil Vegetation (DHSVM) model to the Redfish Creek Watershed Experiment in southeastern B.C. using internal catchment data. Hydrological Processes 17:199–224. Whitaker, A., Y. Alila, J. Beckers, and D. Toews. 2002. Evaluating peak flow sensitivity to clear-cutting in different elevation bands of a snowmelt-dominated mountainous catchment. Water Resources Research 38(9):1172–1188.
http://www.forestry.ubc.ca/people/alila.htm	Upper Penticton Creek		(All publications in press or in preparation).
	Carnation Creek		(All publications in press or in preparation).
HSPF (US) http://water.usgs.gov/software/hspf.html	Carnation Creek	Water quantity	Hetherington, E.D., B. Walsh, and M. Leytham. 1995. Calibration of HSPF hydrologic simulation model using Carnation Creek experimental watershed data. In Proceedings, Mountain hydrology: peaks and valleys in research and application. B.T. Guy and J. Barnard (editors). May 16–19, 1995, Canadian Water Resources Association, Vancouver, B.C., pp. 47–54.
UBC Watershed Model (BC)	Upper Penticton Creek	Water chemistry under different forest cover	Hudson, R.O. and M.C. Quick. 1997. A component based water chemistry simulator for small subalpine watersheds. Canadian Water Resources Journal 22(3):299–325. Available from: http://www.for.gov.bc.ca/rco/research/hydroreports/tr004.pdf
http://www.civil.ubc.ca/home/ubcmodel/main.htm	Gray Creek	Hydrologic recovery	Hudson, R.O. 2000. Assessing snowpack recovery of watersheds in the Vancouver Forest Region. B.C. Ministry of Forests, Vancouver Forest Region, Nanaimo, B.C. Forest Research Technical Report TR-004: Hydrology. Available from: http://www.for.gov.bc.ca/rco/research/hydroreports/tr022.pdf
	Russell Creek	Determination of conditions that would lead to rain-on-snow	Hudson, R.O. 2002. The effects of forest harvesting and regeneration on peak streamflow in a coastal watershed. B.C. Ministry of Forests, Vancouver Forest Region, Nanaimo, B.C. Forest Research Technical Report TR-022 (Hydrology).
	Capilano, Coquitlam, Cheakamus, Elaho, Englishman, Lillooet	Climate change/ water quantity	Whitfield, P.H., C.J. Reynolds, and A.J. Cannon. 2002. Modelling streamflows in present and future climates—examples from Georgia Basin, British Columbia. Canadian Water Resources Journal 27(4):427–456.

theories is preferable to the more complex. This rule favours models that have the fewest assumptions both in representation of hydrologic processes and in data interpretation for a given application. For example, based on process, a complex, physically explicit snowmelt model is more likely to be accurate than a simple temperature degree-day model (data permitting) because it uses fewer assumptions of physical processes. Yet, the simpler degree-day model is often more accurate because, as a variable, temperature can be distributed across a watershed with a higher degree of confidence (i.e., fewer assumptions) than is needed to distribute radiation, humidity, wind speed, precipitation, etc., over the same watershed (S. Hamilton, pers. comm., 2003). As such, data availability and model complexity must be considered when selecting an appropriate model.

Further Resources

The topic of hydrologic simulation is enormous and much information exists on the many models available, their technical aspects, and computer/data requirements. However, information is relatively limited for non-modellers. We recommend the following resources as starting points for those interested in watershed modelling.

Butcher, J., L. Shoemaker, J.T. Clements, and E. Thirolle. 1998. Watershed modeling online training module. U.S. Environmental Protection Agency, Watershed Academy Web. Available from: http://www.epa.gov/watertrain/modeling/

Westervelt, J. 2000. Simulation modeling for watershed management. Springer-Verlag, New York. 190 p.

Recommended reviews of the suitability of the various watershed models for forestry and other applications:

Alila, Y. and J. Beckers. 2001. Using numerical modelling to address hydrologic forest management issues in British Columbia. Hydrological Processes 15:3371–3387.

Alila Y., A. Whitaker, D. Toews, and P. Calvert. 1998. Hydrological modelling to assess the consequences of forest management scenarios on peak flows, Kootenay, British Columbia. In Proceedings, Mountain to sea: human interactions with the hydrologic cycle. Canadian Water Resources Association, June 10–12, 1998, Victoria, B.C., pp. 67–71.

Pike, R. 1998. Current limitations of hydrologic modeling in B.C.: an examination of the HSPF, TOPMODEL, UBCWM and DHSVM hydrologic simulation models, B.C. data resources and hydrologic–wildfire impact modeling. M.Sc. thesis. University of Victoria, Victoria, B.C. 129 p.

Singh, V.P. (editor). 1995. Computer models of watershed hydrology. Water Resources Publications, Highlands Ranch, Colorado. 1130 p.

Singh, V.P. and D.K. Frevert (editors). 2001. Mathematical models of small watershed hydrology and applications. Water Resource Publications, Littleton, Colorado. 972 p.