ENERGY BALANCE MODELLING OF SNOWMELT IN A SUBURBAN ENVIRONMENT: A PROGRESS REPORT

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In southern Ontario, major runoff events in urban and suburban areas may occur during the snowmelt period, and especially during periods of rain on snow. However, many urban runoff models, and the drainage designs derived from them, have been formulated solely using data from convective rainfall events. Thus snowmelt has been largely neglected in urban hydrology, and although there are accurate means of predicting snowmelt generation (i.e. the energy balance approach), they have rarely been applied to an urban environment.

The heterogeneity of surface types in urban areas promotes complex patterns of snow accumulation since snow is often removed from impermeable surfaces such as roads, driveways and sidewalks, and is placed on lawns or removed from the basin entirely. During this movement the snow density may be substantially altered, which has important implications in terms of spatial variations of water equivalent available for runoff within urban areas. As a result of this snow removal, the areas that generate runoff under snowmelt may differ greatly from the runoff-producing areas under a rainfall event. Snowmelt runoff is generated on roofs and especially lawns, and whereas the infiltration capacity of lawns is often of secondary concern in urban hydrology, in the case of snowmelt it becomes the major determinant of runoff volumes. Roads and driveways, which during rainstorms generate most of the storm runoff, now serve to conduct meltwater from lawns and possibly roofs into the storm sewer system.

As a result of these variations in runoff source areas, differences might also be expected in the shape of the runoff hydrograph from an urban catchment depending on the nature of the input to the catchment (Figure 1). In the case of a rainfall event, the hydrograph quickly responds to variations in rainfall intensity, whereas snowmelt

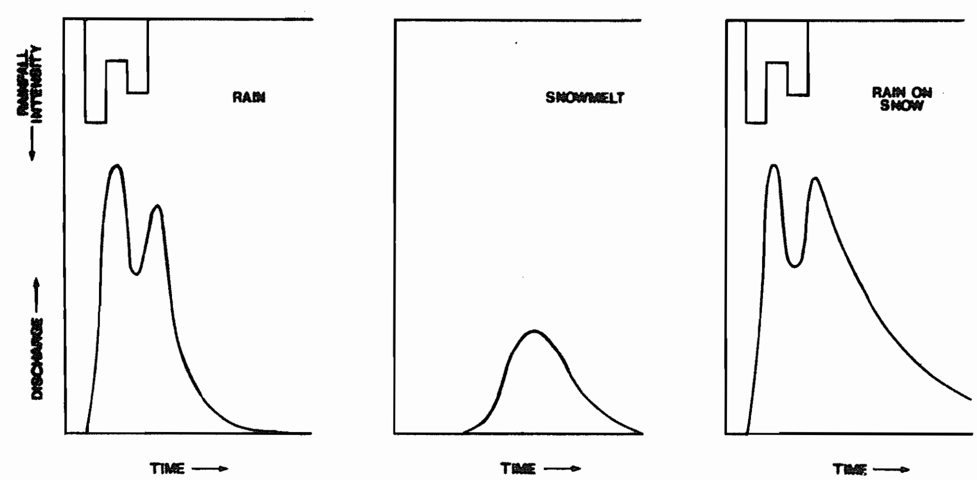

Figure 1: Runoff from urban catchments under different inputs

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produces a more sinusoidal hydrograph form (Jolly, 1972; Bengtsson, 1981). Because of the greater hydraulic efficiency of urban surfaces, the runoff pattern from urban basins might be expected to more closely reflect the pattern of melt in the pack than under natural basin conditions. Hydrographs resulting from rainfall occurring on a snow covered urban catchment display rapid fluctuations in discharge corresponding to changes in rainfall intensity, as well as increased runoff volumes and extended recession limbs due to snowmelt contributions.

The present study sought to examine these phenomena in more detail, by examining the snowmelt generated by suburban and rural areas, and by testing the application of the energy balance approach to snowmelt runoff prediction in these two environments. The study was conducted in a suburban area of Peterborough, Ontario (Figure 2), which consists of a suburban subcatchment nested within a largely rural watershed. Information was collected on snow accumulation and distribution within the suburban and rural catchments prior to the melt of 1984. Within the rural portion of the basin, water equivalent measurements were made for open and wooded sites. Within the suburban catchment 15 house lots were randomly selected and front yard, back yard and driveway snowbank source areas were identified and sampled. In addition, the geometries and water equivalents of roadside snowbanks within the catchments were also measured. Secondly, the components of the complete snowpack energy balance were determined for the melt period. Hourly values of solar radiation, net radiation and albedo were measured at the Trent University Weather Station, 10 km northeast of the study area. Sensible and latent heat fluxes were calculated according to the procedure outlined by Price and Dunne (1976), employing measurements from the Weather Station. Precipitation measurements were made at the Peterborough Airport, 5 km south of the catchments. Thirdly, runoff was measured for the suburban catchment and the entire basin during the melt.

Snow accumulation during the winter of 1983-84 afforded a unique opportunity to study two distinct melt periods, each of which resulted in complete loss of the pack. The first melt period commenced February 3 and stopped February 24, with a total duration of 22 days, while the second melt period began on March 15 and ended April 2, with a length of 19 days. Complete snow surveys of the component surface types within the catchments were made prior to each melt period and the results are shown in Figures 3 and 4. Prior to the first melt, there were roughly equal water equivalents on all the surface types except the driveway snowbanks. The variability of the point water equivalents over a surface type were roughly similar from one surface to another. This pattern was in marked contrast to the spatial distribution of water equivalents at the start of the second melt. There were quite distinct differences in mean water equivalents between several of the accumulation environments, with greater water equivalent depths in the woods due to intense drifting during early March. In addition the variability of the individual water equivalent values about the mean was much greater for some surface types than others. It is anticipated that these differences in snow accumulation patterns will be reflected in the patterns of melt for the two periods.

Ongoing research based on the data collected includes gross comparisons of melt data to runoff data, comparisons between urban and rural runoff responses under snowmelt conditions, the development of an energy balance model for snowmelt in a suburban environment, and a comparison of this approach with simpler methods of snowmelt prediction, such as degree-day indices.

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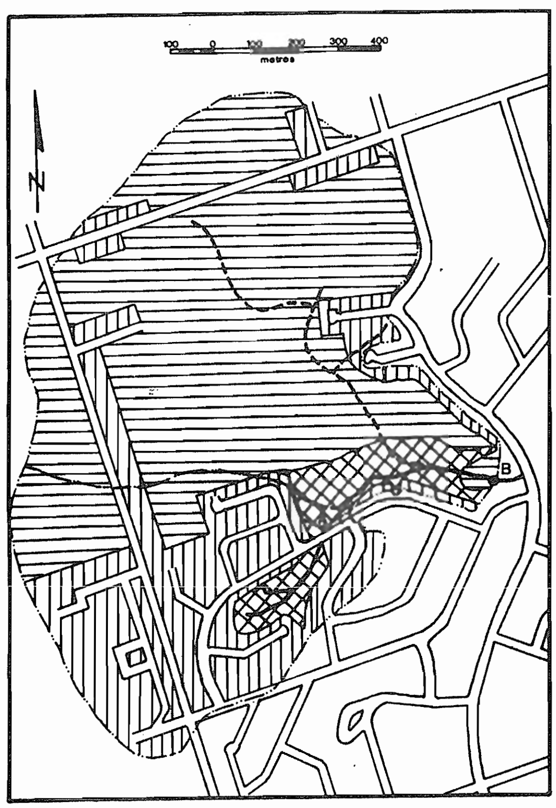

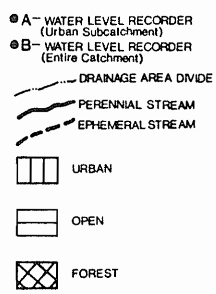

	ha	%
ENTIRE CATCHMENT	96.9	100.0
open	54.6	56.3
forest	6.6	6.8
urban	35.7	36.9
SUBURBAN CATCHMENT	33.5	100.0
open	6.1	18.3
forest	2.2	6.4
urban	25.2	75.3
REMAINING PORTION	63.4	100.0
open	48.4	76.4
forest	4.4	7.0
urban	10.5	16.6

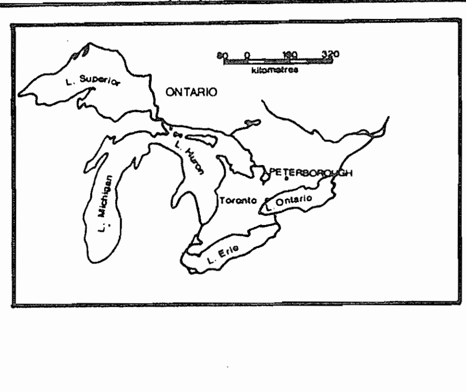

Figure 2: Study area location

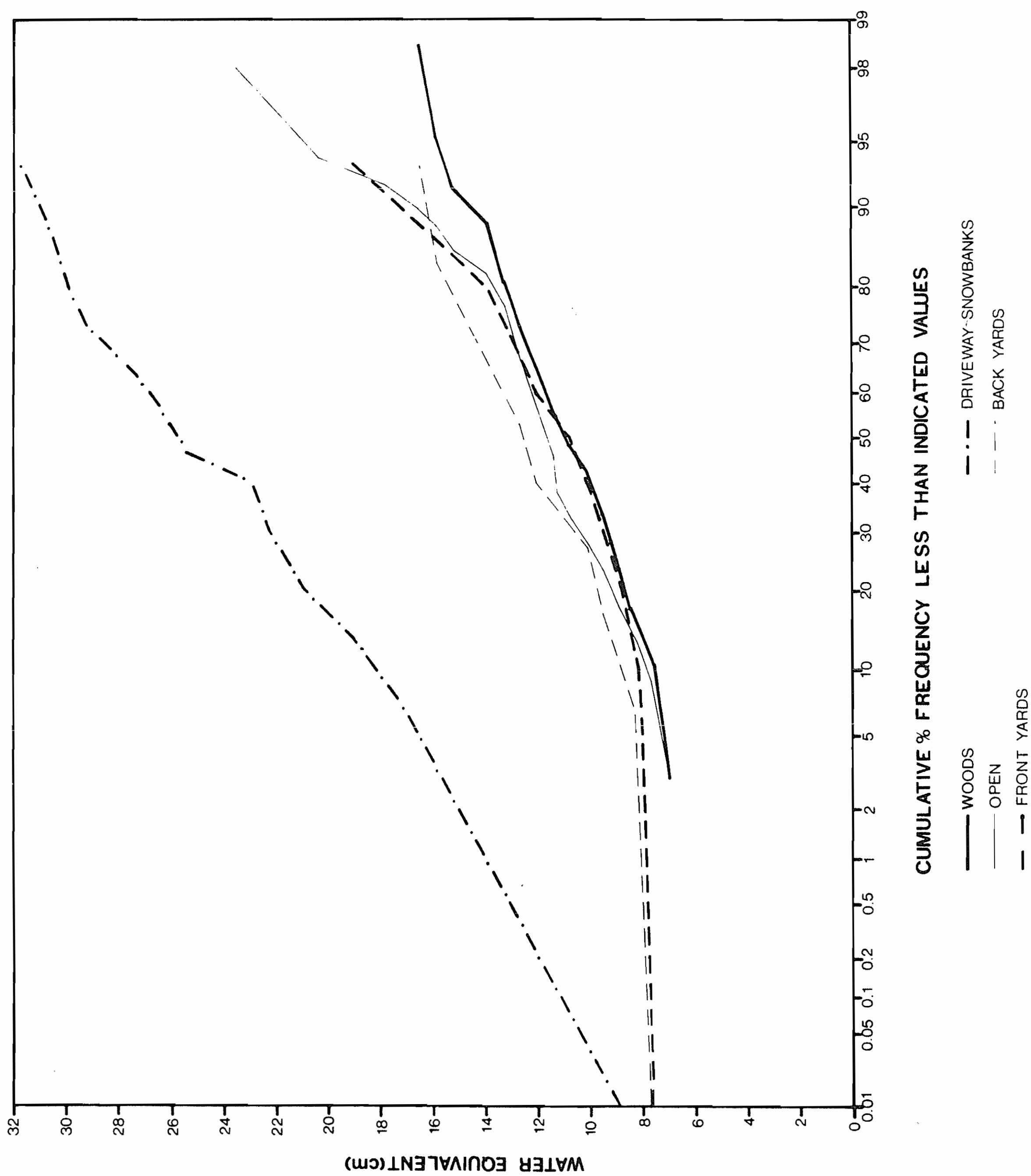

Figure 3: Water equivalent cumulative frequency curves for the 3 February snow survey.

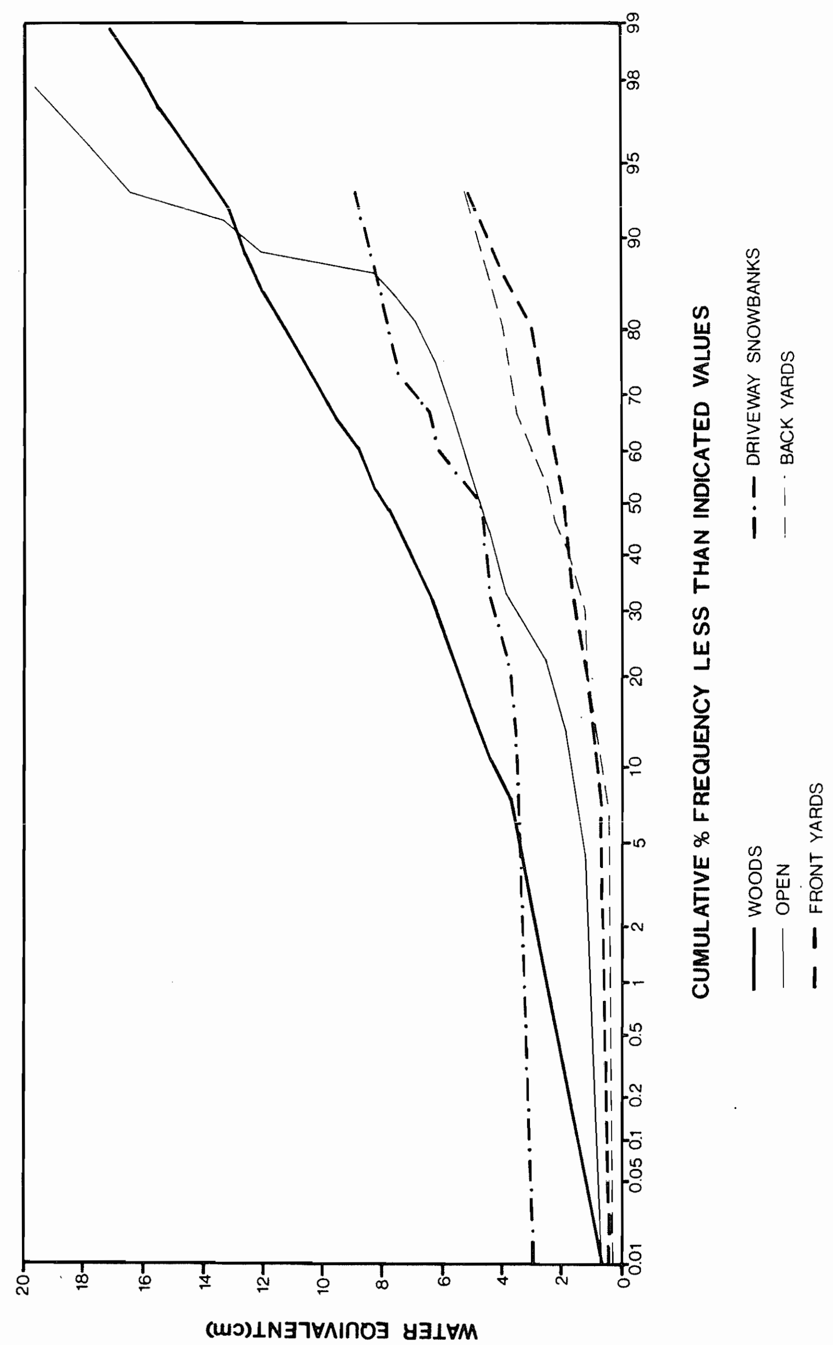

Figure 4: Water equivalent cumulative frequency curves for the 14 March snow survey.