CORRECTION OF WINTER PRECIPITATION VALUES FOLLOWING A CHANGE OF GAUGE EXPOSURE

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ABSTRACT

This paper, based upon results from a two-year winter precipitation study in central New Brunswick, discusses several methods of correcting precipitation data for undercatch. The set of correction options considered range from a simple gross seasonal correction factor to a more complex formula based on individual storm events and form of precipitation. Inasmuch as these techniques rely upon dual-gauge comparison and on-site wind and temperature records, they are limited by their site specificity. However, the potential for broader application is explored by classifying sites according to gauge exposure and by comparing results from the use of on-site wind data with that from a distant station. The need for development of a conceptual formula for precipitation adjustment that quantifies site factors, uses available climatological records, and incorporates existing gauge performance data is advanced.

INTRODUCTION

The poor performance of unshielded precipitation gauges during windy conditions involving solid precipitation has been well chronicled by many investigators (Rechard and Wei, 1980; Goodison, 1978; Struzer, 1965). In Central New Brunswick, researchers at the Nashwaak Experimental Watershed Project found their ability to estimate changes in annual water yield following clearcutting seriously hampered by suspected undercatch of the unshielded standpipe gauges in the treatment watershed. The gauges, initially sheltered within small forest clearings, became exposed when forest cover was removed as part of the experimental treatment (Dickison and Daugharty, 1983).

The experimental design of the project employed the traditional paired watershed project approach (Hewlett and Nutter, 1969). The treatment (Narrows Mountain Basin) and control (Hayden Basin) watersheds, while not contiguous, are only two kilometres apart and share similar physiographic characteristics (Figure 1). Annual precipitation averages 1280 mm, about one-third of which is snow, with a permanent snowpack usually lasting from late November to early May. The mean annual temperature is 3.3°C.

PHYSICAL NETWORK

The backbone of the precipitation network consisted of eleven unshielded standpipe storage gauges for year-round operation, six in the control watershed, four in the treatment watershed, and one at a headquarters station sited approximately midway between the two basins. All gauges except that at the headquarters station were located within small forest clearings (diameter:height ratio 2:1). In addition, there were two Alter-shielded Sacromento storage gauges, a Fischer and Porter recording gauge, two tipping-bucket gauges (one in each basin) and standard Atmospheric Environment Service (AES) gauges operated at all sites during the period May-October.

The precipitation and discharge relationships between the control and treatment watersheds were defined during the seven-year calibration period (1972-78). Commercial clearcutting of Narrows Mountain Brook (NMB) basin began in the early summer of 1978 and was completed by January, 1979. A riparian strip 65 m wide along the main stem of NMB, comprising 8% of the basin area, was left unharvested.

PRECIPITATION DEFICIT

While preliminary assessment of the runoff changes following clearcutting indicated a first-year increase of water yield in the order of 15% (Dickison <u>et al</u>., 1981), larger than normal annual precipitation differences between the two watersheds in the years since

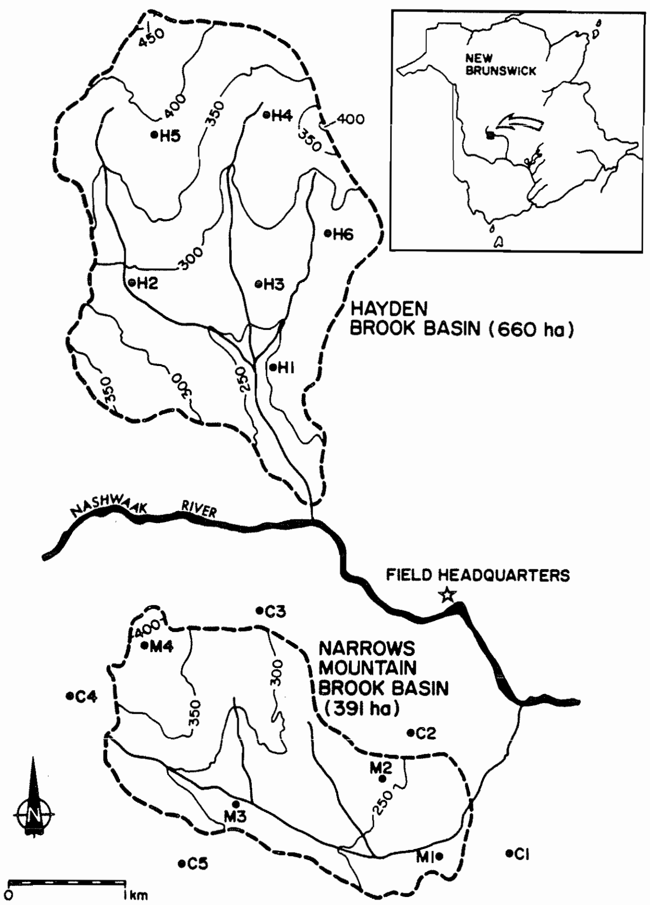

Figure 1. Map of the Nashwaak Experimental Watershed Project showing locations of precipitation stations.

the treatment led to a questioning of this estimate (Table 1).

Table 1. Summary of November-April precipitation (mm), 1972-85.

		HB	NMB	NMB-HB
	1971-72	551.0	517.4	-33.6
	1972-73	810.1	802.7	-7.4
	1973-74	742.6	683.4	-59.2
Pre-harvest	1974-75	536.0	547.3	11.3
	1975-76	746.4	774.3	27.9
	1976-77	594.1	565.4	-28.7
	1977-78	621.3	602.9	-18.4
	1978-79	758.4	671.1	-88.3
	1979-80	599.1	525.3	-73.8
	1980-81	665.4	556.2	-109.2
Post-harvest	1981-82	652.4	563.8	-88.6
	1982-83	—	—	—
	1983-84	868.5	568.5	-118.0
	1984-85 (30 Nov-28 Feb)	200.0	178.2	-21.8

December-April precipitation in the first four post-treatment seasons was consistently less than predicted (Dickison and Daugharty, 1983). Although precipitation differences did exist in the pre-harvest years, they were not great. Hayden Brook (HB) basin received slightly more precipitation than NMB but the mean difference for seven pre-harvest winter seasons was only 15 mm. Since clearcutting, however, single season differences have averaged 100 mm, with NMB consistently recording less precipitation than HB.

The hypothesis was formulated that precipitation differences between the watersheds resulted from gauge undercatch due to exposure of the experimental network. That catch differences (relating to gauge efficiency) were primarily a winter phenomenon was tested by Blais (1985). Eliminating all events which displayed a detectable pattern of spatial distribution, he analysed 112 rainfall occurrences in NMB and HB during the 1979-84 period and found essentially no significant difference. This confirmed that the precipitation deficit was occurring solely during the season of solid precipitation, or as a result of a consistently biased storm pattern.

METHOD

In order to estimate the magnitude of the winter-season deficit of the exposed NMB watershed, another network of gauges was established in the forested perimeter around the experimental basin (Figure 1). The goal was to achieve estimates of basin precipitation similar to those obtained by the original network prior to its exposure. Consequently, unshielded standpipe storage gauges were used and they were sited within forest clearings close enough to the basin boundary to be considered representative yet far enough away to be free from wind-related edge effects.

Two checks were made to test for network comparability. Firstly, Blais (1985) had already demonstrated that there was no significant difference between the summer-time catch of NMB and HB networks. He also showed that clearcutting had not affected the catch relationship between standpipe gauges (2 m above ground) and AES rain gauges (only 30 cm above ground where wind speeds are near zero). Finally, he graphed 1984 standpipe and AES gauge summer season catches of exposed and sheltered NMB networks. There was almost no difference in catch between similar gauge types in these two networks. The excellent network correspondence for May-October values, while not in itself proof of year-round agreement, offers encouraging support for that assumption.

Secondly, if the precipitation recorded by the new network was comparable to the association established between the control and treatment watersheds prior to the clearcut, this would be evidence that the new NMB network is a reasonable surrogate for the original.

Table 2. Comparison of winter season precipitation totals of the three networks.

	Exposed NMB (mm)	Sheltered NMB (mm)	Difference (%)	HB (mm)
1983-84 (5 Dec-22 May)	568.5	638.2	12.0	686.5
1984-85 (20 Nov-23 Feb)	178.2	194.5	9.1	200.0

Table 3. Measured and corrected winter precipitation (mm), 1978-85. (Direct comparison).

	HB	NMB		NMB-HB
		Measured	Corrected	Corrected
1978-79	759.4	671.1	741.5	-14.9
1979-80	599.1	525.3	580.5	-18.6
1980-81	665.4	556.2	614.6	-50.8
1981-82	652.4	563.8	622.9	-29.5
1982-83	—	—	—	—
1983-84	686.5	568.5	638.2	-48.3
1984-85	200.0	178.2	194.5	-5.5

RESULTS

During the two years of the study the original networks of the two basins had the same relationship as they did for the first four years after clearcutting, whereas the relationship between the HB network and the newly created NMB network followed the pattern established prior to the cut (Table 2). Thus the average catch of the new network is a close approximation of what the gauges of the old network would have caught had they still been protected within forest clearings. This relationship may therefore be used as a basis for making adjustments to aberrant data.

Correction Options

Having established network representativeness several options exist for correction or adjustment of post-clearcut precipitation data. They are:

i) Direct network comparison,
ii) Individual gauge assessment,
iii) Storm-by-storm and grouped-events correction.

Direct Network Comparison

The average seasonal catch difference between the new (sheltered) and the original (exposed) gauges for the two years of study was 10.5%. This value may be applied as a correction factor to post clear-cut November-April precipitation data recorded by the NMB network (Table 3). Corrected precipitation totals are all brought within the previously established limits of the original relationship.

Individual Gauge Assessment

The performance of each gauge of the original network may be analyzed in relation to all other gauges. The record of a gauge that deviates significantly from the others is examined, and if no reason for the difference other than reduced catch efficiency occasioned by exposure is indicated, then the record of that gauge could be omitted and the seasonal and annual totals recalculated using only the data set from the remaining gauges.

A possible candidate for this treatment might be M4, a gauge located near the top of windswept Narrows Mountain. Although moderately protected by scattered groves of residual trees, this gauge recorded 30% less precipitation during the 1983-84 season than its counterpart at lower elevation and somewhat less than another standpipe gauge deliberately exposed on a low windswept ridge. Incongruously, however, during the 1984-85 season which was characterized by less than normal snowfall and lower mean storm wind speeds, M4 caught slightly more than the network average.

Omission of M4 data only reduces the average difference between the two NMB networks to 10%, which would still be applied as a correction factor to the basin average following the exclusion of M4 data from that average. This procedure does not yield materially different results from the first method and there are certain problems associated with it. Firstly, discarding the M4 record leaves a large block of the basin virtually unrepresented and reduces the intra-basin network to only three stations. Secondly, there is evidence that the area represented by this higher elevation station may be a zone of greater precipitation and omitting the M4 data would fail to take this into account.

It seems that during winters of relatively high wind speed M4 records less than the basin average, and during winters of light winds it measures as much or more precipitation. A correction procedure involving M4 data which does not take into account gauge exposure, mean storm wind speed and precipitation form, would not be appropriate.

Storm-By-Storm and Grouped-Events Correction

One of the weaknesses of the two previous correction procedures is that, given the variability of the weather from one season to the next, two years is a short period to provide comparisons for precipitation correction. As gauge catch efficiency is largely a function of wind speed, air temperature and precipitation form, a procedure that enables precipitation values to be adjusted on the basis of actual weather conditions during storm periods should improve the accuracy of these precipitation estimates. Reliability of such a procedure would depend largely upon obtaining good conversion co-efficients for gauge catch efficiency and having accurate temperature and wind speed data. This correction method has not been applied to our data, but a description of the approach is in order.

Temperature. Daily temperature records are available from a hygrothermograph at the headquarters station and these could be matched to storm periods using the recording precipitation gauge to classify events as to precipitation type. A temperature of 1.5°C may be used to separate solid and liquid precipitation, based on an analysis of 2400 occurrences of precipitation at the Fredericton airport during the period 1978-82. Standpipe gauges were read only monthly during the winter so apportionment of monthly totals on a storm-to-storm basis would need to rely on the recording gauge data.

Wind. Wind records are not available during the winter prior to December, 1983, but 2-m and 10-m anemometers have been maintained at an open site within NMB for the past two winters. An anemometer had also been operated at H6 in the control watershed from May to October 1972-80 and regression was used to determine monthly wind speed relationships with the Fredericton airport station 60 km southeast (Steeves, B.G., pers. comm.). The October relationship (r=0.896) may be extrapolated to the winter season to estimate daily wind speed totals for the Nashwaak. Employing this relationship involves a risky and critical assumption, however the ratio of storm-day hourly mean wind speeds to monthly hourly means derived by this method are within the normal range found by Bogdanova (1966). The ratio will be further tested for selected storms during the 1983-84 and 1984-85 season using actual Nashwaak/Fredericton wind data.

If testing supports application of the ratio, mean wind speeds for major events will be calculated for at least two post-treatment seasons. Precipitation events will be grouped according to precipitation form (solid or liquid) and mean storm wind speed. Finally the appropriate conversion co-efficient will be applied to correct the data.

Conversion Co-Efficients. Conversion co-efficients will be derived from the performance curve of the experimental unshielded standpipe gauge located at the same site as the wind equipment (Figure 2). However comparison of mass monthly curves of the four original gauges of NMB with the experimental gauge reveal that, with the exception of M4, the sites do not have exposure characteristics comparable to the experimental site (Figure 3). Application of the conversion factor, unless an adjustment can be made for site specific wind conditions, would yield greater than actual estimates for these other stations.

In spite of the number of variables which must be estimated and the uncertainty re-

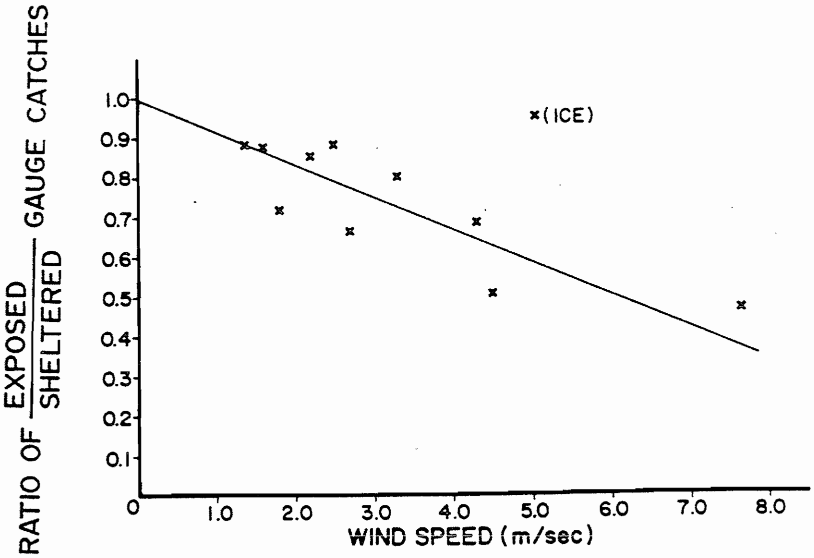

Figure 2. Catch ratios for a fully exposed standpipe gauge (near M2), compared to standpipe gauges at sheltered sites (C1 and C2), with variation in wind speed, for individual storms during winters of 1983-84 and 1984-85.

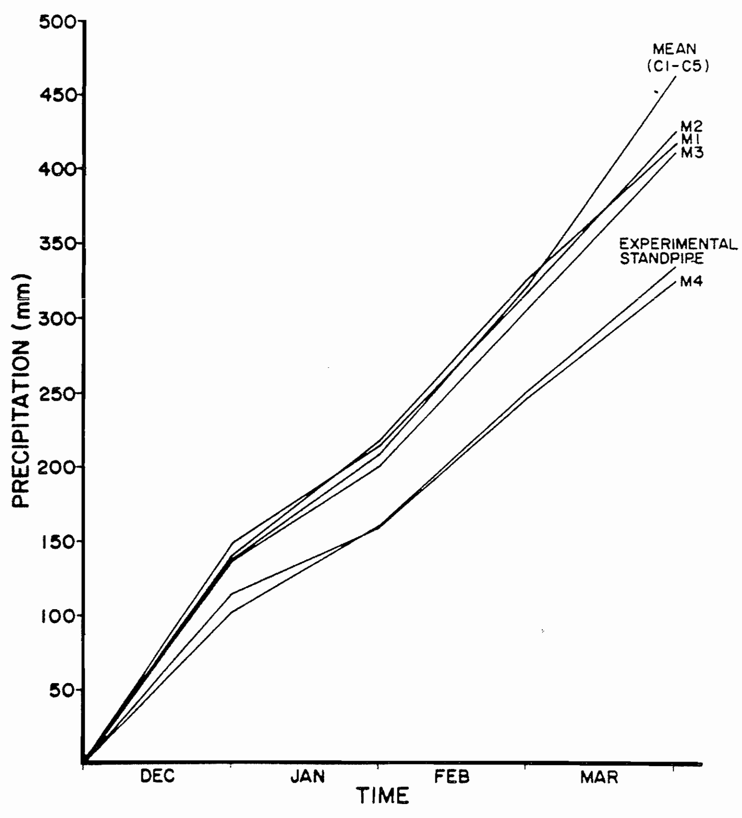

Figure 3. Mass curves of 1983-84 winter precipitation for standpipe gauges at sheltered (C1-C5), exposed (M1-M4), and experimental sites in Narrow Mountain Brook basin.

garding exposure factors of individual gauges, this is a procedure which is potentially more sensitive than the other two approaches. Its limitations result from quality of data collected, rather than the time period of the study.

DISCUSSION

The impracticality of establishing a sheltered gauge or network for comparative purposes at every station where exposure-related undercatch is suspected and the cost and difficulties inherent in gathering adequate data to confidently carry out individual event corrections suggest that attention be directed to development of an analytical or semi-empirical approach to correction of monthly, seasonal or annual precipitation totals.

Agreement among researchers regarding the major factors affecting gauge catch (wind speed, gauge configuration, site exposure and precipitation type) is widespread. The difficulty is that these factors are interrelated and separation of their independent effect is difficult. For example, the strong dependence of Hamon's B co-efficient and the conversion factor K upon wind, temperature and gauge type causes these values to vary widely, necessitating separate calculations for each type of gauge and snowfall (Sevruk, 1980).

However, sufficient testing of gauges and gauge-shield combinations has been conducted under such a wide range of conditions and sites that it may now be possible to independently calibrate these variables and model their separate and combined effects.

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