R. M. Leith and **P. H. Whitfield,**[1] Environment Canada, #700 - 1200 West 73rd Ave., Vancouver BC, V6P 6H9, Canada

Some Effects of Urbanization on Streamflow Records in a Small Watershed in the Lower Fraser Valley, B.C.

Abstract

Times series of monthly, mean daily and maximum instantaneous streamflows were examined for changes which may be associated with urbanization within the Nicomekl watershed in the lower Fraser Valley of British Columbia, Canada. An adjacent watershed, the Salmon which has had much less urbanization, provided a comparison. In these low lying watersheds which receive heavy winter precipitation even slight increases in runoff could lead to increased flooding problems. Urbanization is relatively new in this area and though land use changes due to urbanization are not yet extensive, statistically significant increases in streamflow were detected. Continued urbanization causing increased runoff may generate increased flooding problems in the future.

Introduction

As Hipel *et al* (1977) have pointed out, a major challenge in hydrology is the detection, modeling, and description of the effects of man-induced or natural interventions, or alterations, on time series of hydrologic variables. In this study of two streams in the lower Fraser Valley of British Columbia, Canada, the intervention is change in landuse and landcover brought about by urbanization. The time series of hydrologic variables considered were monthly streamflows, annual maximum daily flows, and annual maximum instantaneous flows.

At the time of European arrival, the lower Fraser Valley was densely forested. At present what forest remains is second or third growth. European settlers established agriculture as the predominant landuse. As Moore (1990: 1) states, "Some of Canada's most important agricultural land and wildlife habitat is located in British Columbia's Lower Fraser Valley." Since 1970, the population of Greater Vancouver has been increasing rapidly and the effects of this increase are propagating into the Lower Fraser Valley. Moore (1990) indicates that between 1981 and 1986 the Lower Fraser Valley had one of the fastest growth rates in Canada (9.1%). The Lower Fraser Valley is a confined area, with mountains to the north and east, Georgia Strait to the west and the International Boundary with the United States of America to the south.

In this confined area, the effects of urban development have become a significant concern. The effects of urbanization upon hydrology has become a subject of worldwide concern (International Workshop on Integrated Water Resources Management in Urban and Surrounding Areas, 1994). A first step towards the assessment of the effects of urbanization upon the hydrology of a basin is the examination of the available streamflow data to ascertain whether there are detectable changes that may be related to urbanization (McCuen and Thomas, 1990). Exploratory data analysis techniques are used in our study, and as Eagleson (1979) pointed out, our results are not general as they do not incorporate climate, soil, and vegetal properties. This study is intended as an initial step in examining the effects of landuse change using more generalized water balance models. Intervention modeling of these data is reported in Leith and Whitfield (1996).

Data Assembly and Methods

Assembly of a time series of streamflow data that spans urbanization of a basin was difficult as hydrometric stations in British Columbia routinely have been discontinued when a basin suffered sufficient alteration (intervention) that the flow was deemed to have been changed from the "natural" regime. Fortunately, the Nicomekl River,

[1] Author to whom correspondence should be addressed

which flows through the City of Langley, has records before and during intense urbanization. There are streamflow records from an adjacent basin to the east, the Salmon River, and a major tributary of the Nicomekl, Murray Creek available for comparison. The geographical arrangement of the basins is shown in Figure 1. Table 1 provides the hydrometric station names, identifiers, and periods of record.

Three measures of urbanization are used in this study: census data, building permits, and air photos. Population data for Langley City and Langley District are plotted in Figure 2 and estimates of landuse and landcover made from air photos are summarized in Table 2. These estimates were made by delineating the drainage basins on air photos taken in 1967 and 1982. Each basin was divided into 1-kilometer squares, and each square was

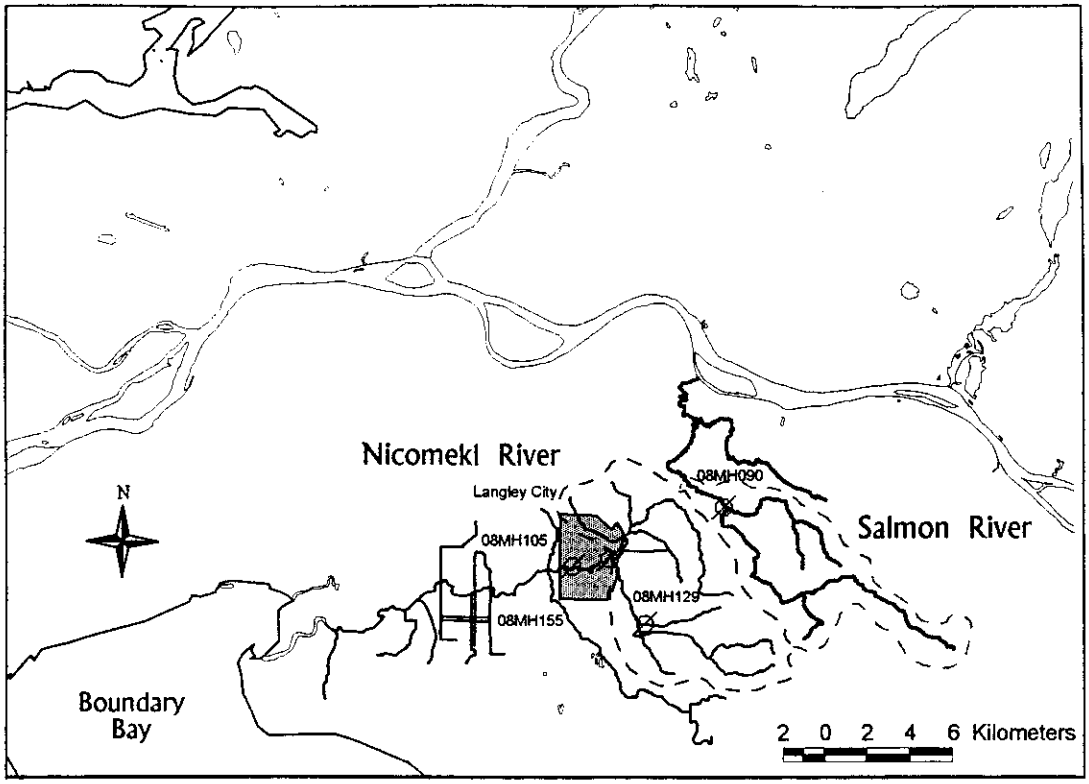

Figure 1. Location of the Nicomekl and Salmon basins in the lower Fraser Valley to the southeast of Vancouver. The Fraser River is shown to the north. The station identifiers are referenced in Table 1.

TABLE 1. Hydrometric Stations in Nicomekl and Salmon Watersheds.

Water Survey of Canada Station Identifier	Station Name	Drainage Area (km^2)	Period of Operation
08MH105	Nicomekl River below Murray Creek	64.5	April 1965–October 1984
08MH155	Nicomekl River at 203 Street, Langley	69.2	February 1985–present
08MH129	Murray Creek at 216 Street, Langley	26.2	March 1969–November 1983
08MH090	Salmon River at 72 Avenue, Langley	49	February 1960–September 1964 December 1968–present

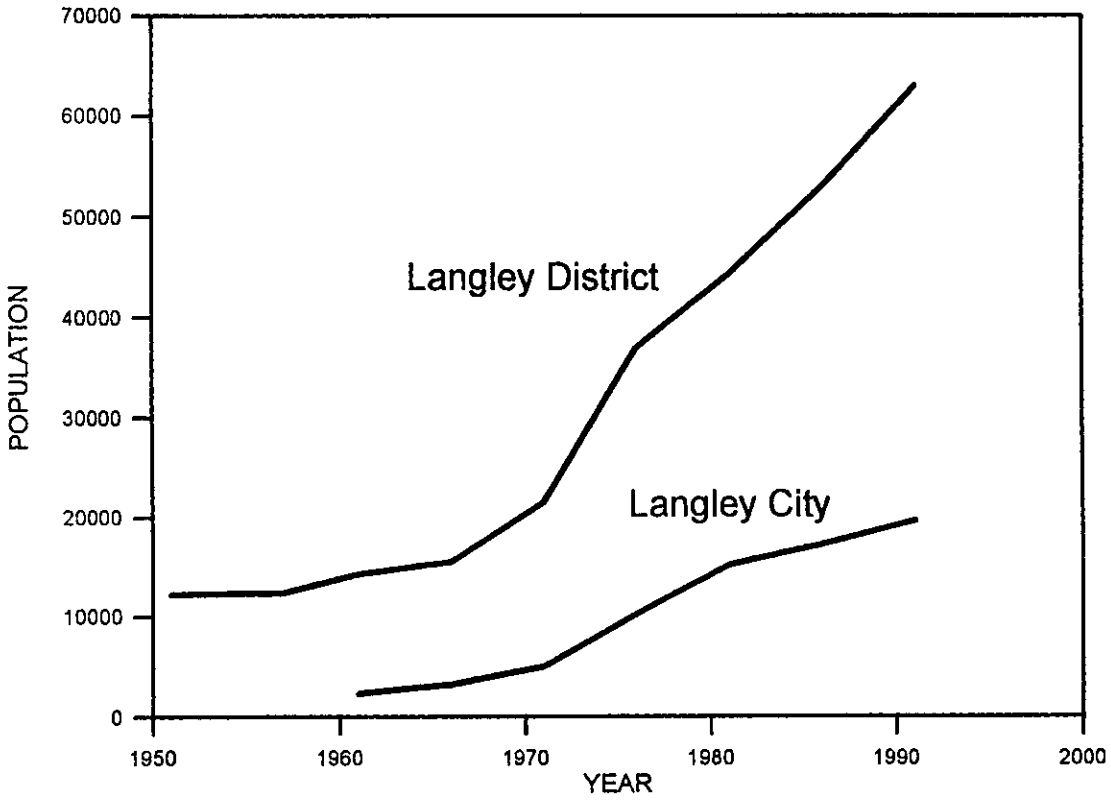

Figure 2. Population growth in Langley City and Langley District between 1950 and 1990.

TABLE 2. Landuse and landcover in the study area in 1967 and 1982.

	Nicomekl Basin			Murray Basin			Salmon Basin		
Year	Forest	Agric.	Urban	Forest	Agric.	Urban	Forest	Agric.	Urban
1967	34%	64%	1%	44%	56%	0%	51%	46%	3%
1982	24%	68%	8%	34%	63%	3%	34%	58%	7%

classified according to the predominant land use land cover within the square.

Monthly runoffs from the Nicomekl River below Murray Creek (08MH105) gauging station were plotted against monthly runoff from the Salmon River. Runoff is the volume of streamflow discharge over a period of time divided by the drainage area of the basin. Using runoff as the hydrologic response adjusts for differences in drainage areas. Monthly runoffs from two time periods, the first 1968-1972 before intense urbanization and the second 1980-1984, during and after intense urbanization were compared. The start of the intense urbanization was estimated from the rate of population increase, Figure 2, and the peak in building permits in 1979 and 1980. Air photos were available only in 1967 and 1982 so the beginning of rapid increase in urbanization could not be estimated from this data.

To produce homogeneous independent sequences, seasonality and serial dependence were removed from the Nicomekl and Salmon River monthly runoffs. Seasonality was removed by subtraction of the appropriate monthly mean (i.e. we subtracted the overall July mean from each July value) and serial dependence was removed using the lag one correlation coefficient (i.e. the correlation between one month and one follow-

ing). The result of this is to produce a series which has no seasonal pattern and no auto-correlated structure. Regression equations were developed for the 1968-1972 and the 1980-1984 periods. These equations were then tested to determine if the regression parameters were statistically distinct.

Maximum Daily and Maximum Instantaneous flows for the Nicomekl, Salmon, and Murray were input to a Flood Frequency Program, Kite (1991). Ten year floods, i.e. peak flows with a return period of ten years or a probability of exceedance less than or equal to 0.1 in any year, together with 95% confidence intervals were estimated for 2 parameter log normal and 3 parameter log normal distributions. Estimates were made by maximum likelihood and the method of moments. The 10-year flood was investigated, as five to eight observations were available so the extrapolation is small.

In November 1984, the gauging station on the Nicomekl River below Murray Creek (08MH105) was closed and in February of 1985, a station was relocated down stream to 203 Street, Langley (08MH155). To ascertain whether changes were brought about by the relocation of the gauging station, the observed peak flows from the new station were adjusted by the drainage area ratio (64.5/69.2) so that they could be compared with data from the previous location.

Results and Discussion

From the analysis of air photos the increase in urban area for the Nicomekl basin from 1965 to 1982 was 7%, 3% of which was in the Murray Creek tributary. The remaining 4% was largely concentrated in the City of Langley. The urbanization in Murray Creek was mainly small distributed housing developments, while in the City of Langley urbanization consisted of large housing developments, light industrial activity, and extensive parking lots in a concentrated area.

TABLE 3. Regression Coefficients for deseasonalized and deserialized monthly runoffs.

Time Period	Regression Coefficient	Probability
1968–1972	1.037	<0.01
1980–1984	1.144	<0.01

In the Salmon basin, urban area increased 4%, mostly small housing developments distributed throughout the watershed. The forest cover was reduced by 17%, so the Salmon basin has had landcover changes during the study period. Thus, it was not a static control. Table 3 provides the regression coefficients for the deseasonalized deserialized Nicomekl monthly runoffs as functions of the deseasonalized deserialized Salmon monthly runoffs. The intercepts were not significantly different from zero.

From an F-test, the regression coefficients are significantly different from each other at the one percent significance level. The change in slope indicates an increase in the monthly runoffs for the Nicomekl River relative to the Salmon River, as indicated in Figure 3.

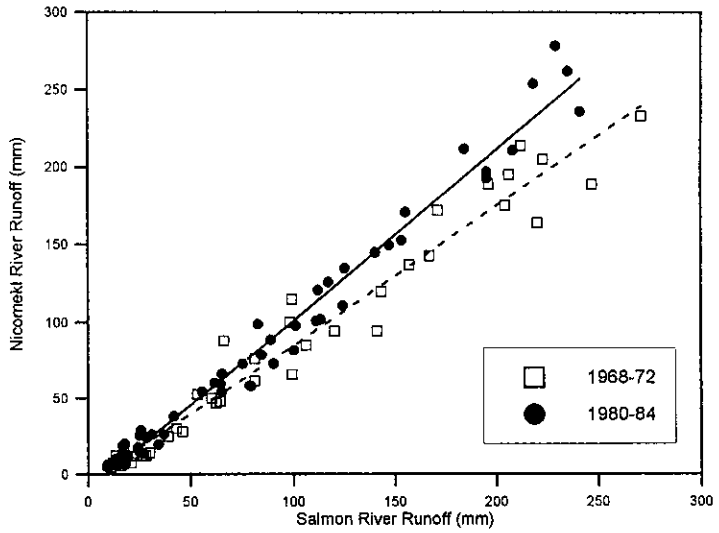

Figure 3. Relationship between monthly runoffs for Salmon and Nicomekl Rivers before intense urbanization (1968-72) and after (1980-84).

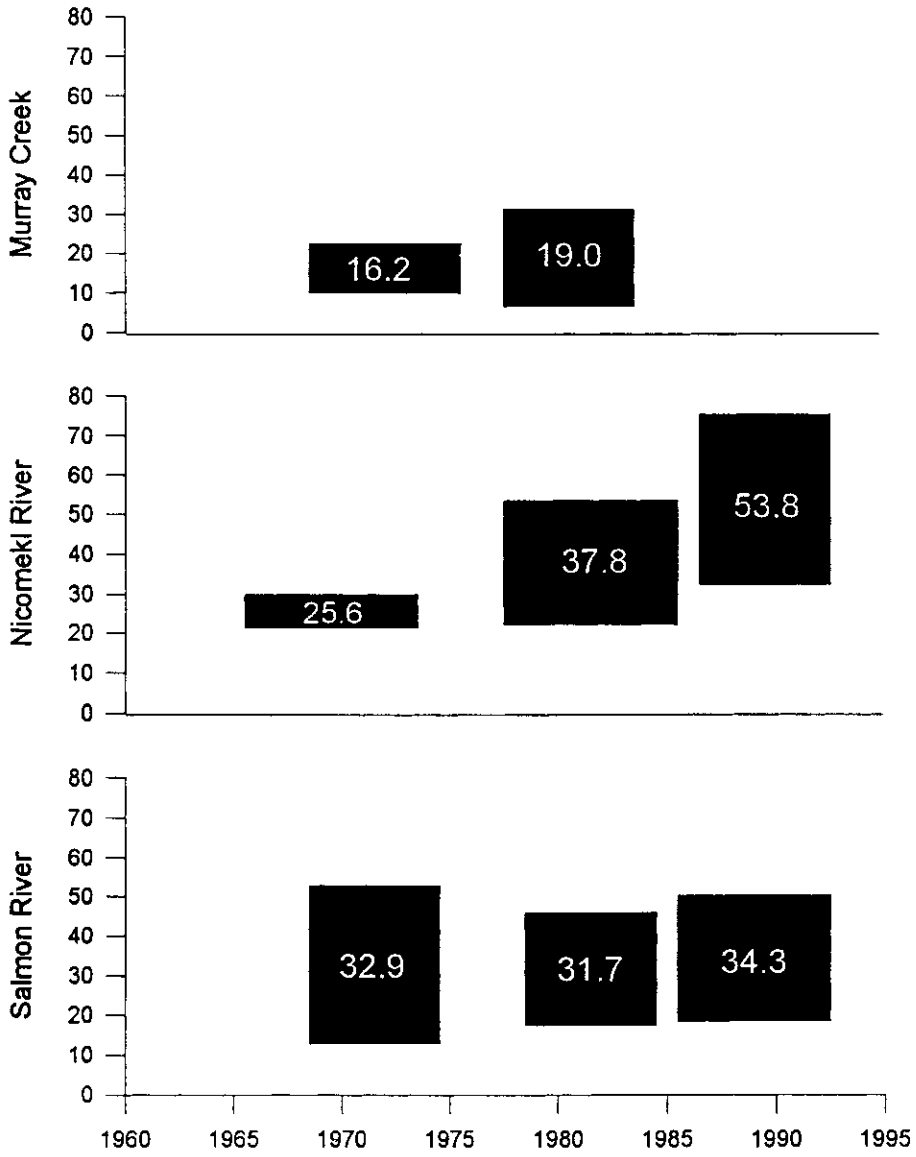

Figure 4. Estimates of 10-year maximum daily flood for Murray Creek, Nicomekl River, and Salmon River over the period of urbanization. The estimated flood is indicated by the number in the bar, the width of the bar gives the time period for data used in making the estimate and the vertical length of the bar shows the 95% confidence internal for the estimate.

From sequences of maximum daily flows, estimates of 10 year floods made using the two parameter log normal distribution are shown in Figure 4. The vertical bars in Figure 4 provide 95% confidence intervals with the estimated 10 year floods shown in numerals within the bar. Results for the three parameter log normal distribution were similar to those of the two parameter and are not shown. For Murray Creek, the estimated 10 year flood does not change significantly between the periods 1969-1975 and 1978-1983. The Nicomekl River below Murray Creek shows a significant

increase from 25.6 cubic meters per second (cms) in 1968-1972 to 37.8 cms in 1978-1984. After the gauge was relocated, there was a marginally significant increase to 53.8 cms. The estimated flood for the Salmon River does not change significantly for any of the periods 1968-1972, 1978-1984, and 1985-1992.

Considering maximum instantaneous flows, the Salmon River does not show any significant change in the estimate of 10 year flood, Figure 5. The Nicomekl River (08MH105) shows no change to 1984, but the 1984 maximum instantaneous flow is missing and the 1984 maximum daily flow is the highest on record. In the period 1985-1992

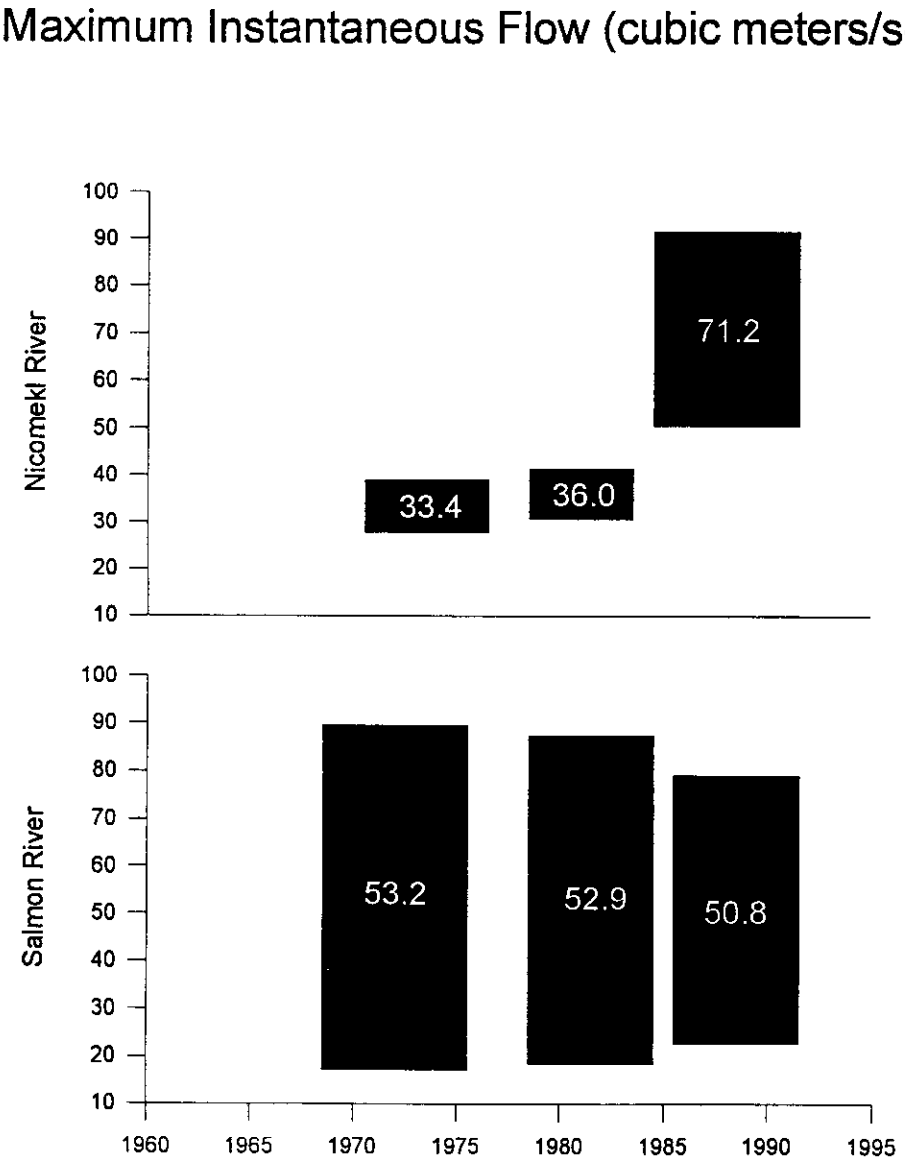

Figure 5. Estimates of the 10-year maximum instantaneous flood for Nicomekl River and Salmon River over the period of urbanization. . The estimated flood is indicated by the number in the bar, the width of the bar gives the time period for data used in making the estimate and the vertical length of the bar shows the 95% confidence interval for the estimate.

there is a significant increase in the estimate of 10 year maximum instantaneous flood.

Despite the adjustments to flows to account for the increase in contributing area, moving the gauge on the Nicomekl River has significantly altered the maximum daily and maximum instantaneous flows. The area added to the basin, although small, is intensely urbanized including parking lots and commercial development.

Conclusions

In the Nicomekl drainage, there have been significant increases in monthly stream flow and 10 year maximum instantaneous flood since 1967. These changes have occurred at the same time as intense urbanization in concentrated areas within the basin. Although there has been some development in the Murray Creek and Salmon River basins there does not appear to have been significant changes in maximum daily or maximum instantaneous flows in these basins. The distributed nature of urban growth in these basins is thought to be the fundamental difference from the Nicomekl basin. The changes to the Nicomekl flow regime have taken place in that part of the basin, which does not include Murray Creek. These results suggest that even a small amount of concentrated urbanization can significantly alter flow regimes.

Literature Cited

Eagleson, P.S. 1979. The annual water balance. Journal of Hydraulics Division, Proceedings of the American Society of Civil Engineers 105:HY8 923-941

Hipel, K.W., A.I. McLeod, and E.A. McBean. 1977. Stochastic modeling of the effects of reservoir operation. Journal of Hydrology 32:97-113.

Integrated Water Resources Management in Urban and Surrounding Areas. 1994. International Workshop, Gelsenkirchen, Federal Republic of Germany

Leith, R.M., and P. H. Whitfield. 1996. Intervention modelling of effects of urbanization on a small watershed in the Lower Fraser Valley, B.C. Canadian Water Resources Journal 21:387-392.

Kite, G. 1991. Hydrologic Applications: Computer Programs for Water Resources Engineering. Water Resources Publications, Littleton, Colorado.

McCuen, R.H., and W.O. Thomas Jr. 1990. Flood frequency analysis techniques for urbanizing watersheds. Pages 35-46 *In*: M. Jennings (ed.) Symposium Proceedings on Urban Hydrology, Denver, Colorado. American Water Resources Association.

Moore, K.E. 1990. Urbanization in the Lower Fraser Valley, 1980-1987. Technical Report Series Number 120. Canadian Wildlife Service. Environment Canada.

Received 27 July 1999
Accepted 16 November 1999