1.0 INTRODUCTION

1.1 STUDY OBJECTIVE

In view of development pressures along Bell Creek and potential for flooding, the Moira River Conservation Authority authorized Ecos Garatech Associates Ltd. to undertake a Flood Plain Mapping Study along the upper portion of Bell Creek within the City of Belleville.

The principal objectives of the study was the delineation of the Regulatory flood plain and associated fill line for approximately 8.3 kilometres along Bell Creek from the Canadian National Railway to north of Highway No. 401. In 1984 a Flood Plain and Water Management Study was completed by MacLaren Plansearch Inc. for the lower reaches and tributaries of Bell Creek. Due to the increase in expected development of the watershed these areas were re-evaluated during this study.

1.2 BACKGROUND INFORMATION

1.2.1 Watershed Description

The Bell Creek watershed drains an area of 23.3 km2. The watershed, located in the City of Belleville and the Township of Thurlow extends southerly for some 8.3 km to the Bay of Quinte (an arm of Lake Ontario). The point at which Bell Creek discharges into the Bay of Quinte is located in the south-eastern part of Belleville.

1.2.2 Study Area

The extent of the study included the main channel and tributaries of Bell Creek from its mouth at the Bay of Quinte to just north of the Highway No. 401 culvert crossing (top of the watershed).

1.2.3 Previous Investigations

In 1984 the Moira River Conservation Authority requested a study be completed on the lower Bell Creek area including the "tributary 1". This report entitled, "Flood Plain and Water Management Study, Bell Creek", was completed by MacLaren Plansearch Inc. This study provided the starting water surface elevations at the Bay of Quinte.

1.3 STUDY PROCEDURE

The Flood Plain Mapping Study of Bell Creek in the City of Belleville generally followed the project procedure outlined below.

Data Collection and Field Surveys

During the initial stages of the study, pertinent information was obtained from the Moira River Conservation Authority, the City of Belleville, the Township of Thurlow, the Ministry of Natural Resources, and Environment Canada.

In the months of October and November 1988, Ecos Garatech conducted the following field surveys:

(1) Field surveys to supplement the digital photogrammetric mapping.

(2) Field surveys to supplement dimensions of all hydraulic structures crossing the watercourse.

(3) Field surveys to verify the horizontal and vertical accuracy of the digital mapping.

Digital photogrammetric mapping was completed by Marshall, Macklin and Monaghan during 1988. Results of the field surveys to verify the accuracy are described in the Report on Inspection of Horizontal and Vertical Accuracy for Selected 1:2000 Scale Mapping, April 1989, Ecos Garatech Associates Ltd.

Flood Plain Mapping

The project Team requested Ecos Garatech to incorporate the Lower Bell Creek area into the Upper Bell Creek Flood Plain Mapping Study.

Information pertaining to cross-sections, channel inverts and gradients, hydraulic roughness, and bridge crossings were obtained from field surveys, construction drawings, surrounding surveys, previous investigations, and the Authority's Flood Risk Maps.

Water surface profiles were generated for the various flood events.

The results of the hydrologic and hydraulic analyses and the methodologies employed were subsequently approved by the Project Team comprising of the Conservation Authority, the Ministry of Natural Resources (Eastern Region) and a representative of the Federal - Provincial Flood Damage Reduction Program.

The flood plain resulting from the Regulatory flood and the corresponding fill lines were plotted on the Moira River Conservation Authority's Flood Risk Mapping, Sheet Nos. 1 to 8.

2.0 HYDROLOGY

2.1 GENERAL

In March of 1984, MacLaren Plansearch Inc. completed a report entitled "Flood Plain and Water Management Study - Bell Creek" (Ref.1), for the Moira River Conservation Authority.

In that report, the following information regarding hydrologic analyses and the determination of peak flows was provided:

1) The Regional Flood Frequency Analysis, whereby four streamflow stations (Demorestville Creek, Bloomfield Creek, Wilton Creek, and Shelter Valley Brook) were selected to be used for flood frequency analysis. The statistics from these stations were improved by combining the coefficient of skew of the study watersheds with that of thirty long-term WSC stations.

2) The regional analysis using the methodology outlined by Sangal & Kallio.

3) The synthetic unit hydrograph method, whereby, the computer program, HYMO, was utilized to generate peak flows from 12 hour duration rainfall events.

4) Four railroad embankments (three at the Canadian National Railway and one at the Canadian Pacific Railway) crossing the main channel and tributaries of Bell Creek were reservoir routed, to evaluate their potential in reducing peak flows. As a result of the evaluation, it was determined that these embankments were not significant in attenuating peak flows, and therefore, were not included in the final analysis. Discharge-storage information was obtained from the 1984 report, Table 3.4 (after page 3-9).

5) The results of the rainfall analysis (un-attenuated) were subsequently used as the design flows in the hydraulic analysis to determine the flood elevations along Bell Creek.

Based on the preceding, the hydrologic analysis for this study was carried out following this methodology. The methodology described in the above report was used to reflect any potential changes to the watershed parameters (CN, K and Tp) and thus, the peak flows.

Due to the changes in the future land use as a result of the expansion in the City limits, peak flood flows are expected to be higher. Consequently, EGA Consultants was authorized to undertake the following:

1) To prepare stage-discharge-storage curves for the railway structures.

2) To include reservoir routing in the hydrologic models to account for the available storage at the railway structures.

3) To re-run the hydrologic models for the Regulatory and the more frequent flood events, including the selected stormwater management plan.

2.2 PROCEDURES

The synthetic unit hydrograph method was used to determine the peak flood flows along Bell Creek.

Future land use plans from the City of Belleville (Ref. 2) and Thurlow Township (Ref. 3), in conjunction with the hydrologic soil groups, were utilized to determine the curve numbers (CN). Based on the land use, the percent imperviousness of the sub-catchments were estimated, and the times to peak (Tp) and recession constants (K) were adjusted in accordance to Figures 3.5 and 3.6 of Reference 1.

In addition, the stage-discharge-storage curve was determined for the CNR crossing Tributary 2 at the outlet of sub-catchment 308, due to the previous calculated storage curve being exceeded (see Appendix C for the delineation of the sub-catchments and the location of the tributaries).

The stage-discharge-storage curves for the following railway embankments were not exceeded as provided in the previous study, and therefore, the curves need not have to be re-calculated:

1) The CPR crossing the main channel at the outlet of sub-catchment 317.

2) The CNR crossing the North Tributary (main channel) at the outlet of sub-catchment 306.

3) The CNR crossing the East Tributary at the outlet of sub-catchment 304.

The stage-discharge-storage curve for the CNR crossing Tributary 2 is provided in Appendix D. For the other crossings identified above, refer to MacLaren's report.

Also, MacLaren's report recommended an on-stream detention pond at the outlet of sub-catchment 315 (at the old City limits) as a result of undertaking stormwater management alternatives.

The adjustments to the watershed parameters in conjunction with the stage-discharge-storage data were used as data input into the computer program, HYMO, to simulate the peak flood flows for the 100, 50, 25, 10 and 5 year 12-hour duration storm events.

2.3 HYDROLOGIC PARAMETERS

A) Soils and Land Use

The hydrologic soil cover complex numbers (CN), or curve numbers, is a function of the soil types and land use classifications. The soil types were categorized into their respective hydrologic soil groups (Ref. 4, 5, 6 and 7). The proposed land use for the Bell Creek watershed was obtained from zoning by-laws of the Township of Thurlow (Ref. 3) and land use plans in the City of Belleville (Ref. 2). The proposed land use within the Bell Creek watershed is illustrated in Figure 2.1, and provided in Table 2.1.

The soil groups and land use were combined into hydrologic soil cover complex numbers. The resulting curve numbers are given in Table 2.2, which also compares the curve numbers determined by MacLaren.

B) Rainfall Depths and Distribution

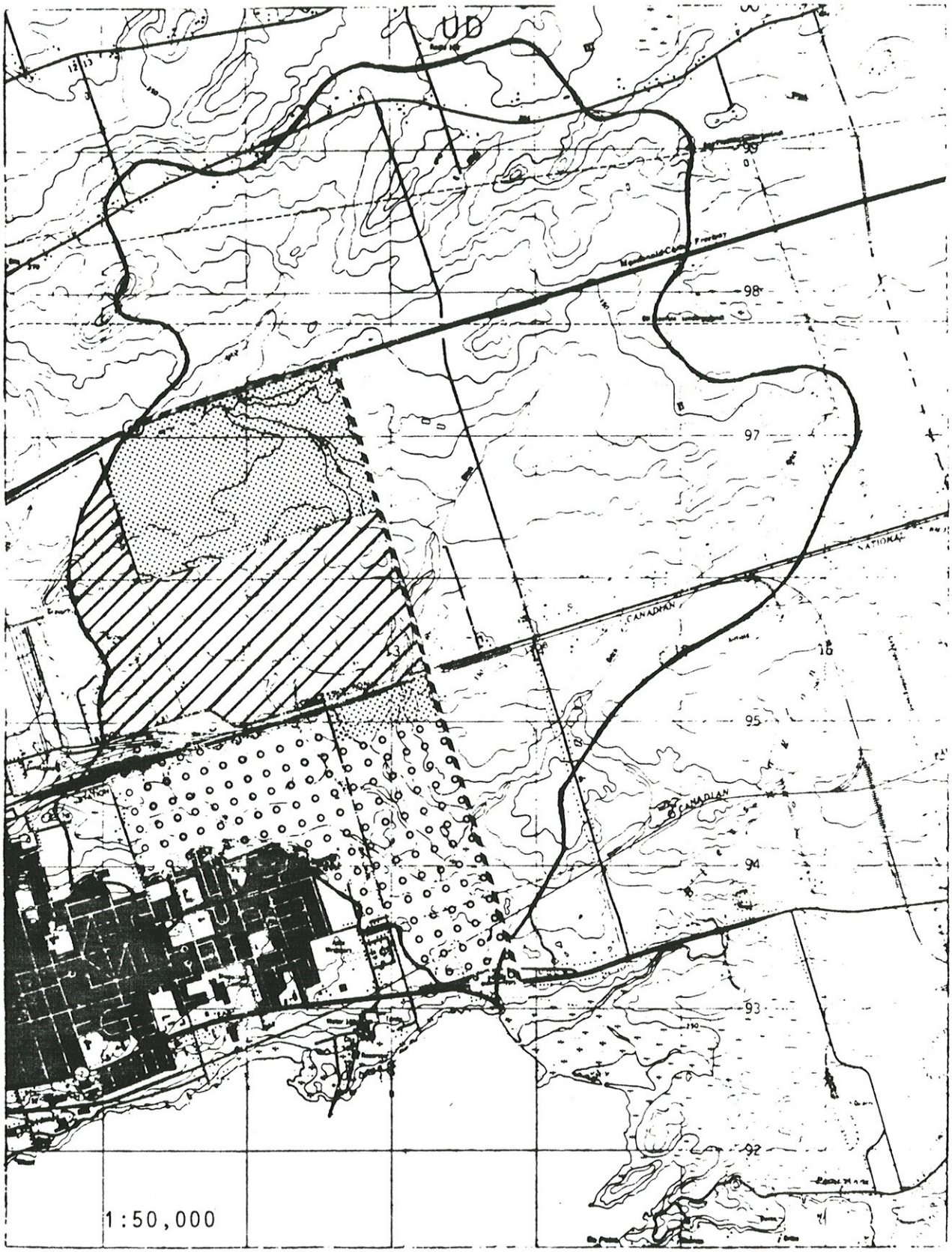
The 12 hour design rainfall depths for the various storm events were obtained from Table 3.1 of MacLaren's report. The design rainfall depths were distributed using the 12 Hour SCS Type II distribution.

The design rainfall depths are appended in Appendix B.

C) Recession Constants, Times to Peak and Watershed Parameters

The ratio of the recession constant (K) to the time to peak (Tp) of the unit hydrograph is a function of the watershed parameter (B).

The present conditions K and Tp values (Table 3.2 of Ref. 1) were used as the basis in the updating of the values. Based on the proposed land use, the percent imperviousness within each sub-catchment was estimated. The K and Tp values were then updated to reflect the effect of urbanization, in accordance to Figures 3.5 and 3.6 of MacLaren's report. The results of the updated K, Tp and B values are given in Table 2.3.



- Residential
- Restricted Industrial
- Gen. Industrial
- City Limits

Figure 2.1 Proposed Development Areas - Bell Creek

TABLE 2.1

PROPOSED LAND USE

BELL CREEK

Sub-catchment Area I.D.	Future Change in Land Use % of Sub-catchment Area	
301	15	from rural to industrial
302	8	from rural to industrial
303	0	(no development)
304	0	(no development)
305	70	from rural to industrial
306	74	from rural to industrial
307	100	from rural to industrial
308	96	from rural to industrial
309	4	from rural to residential
310	95	from rural to industrial
311	99	from rural to residential
312	90	from rural to industrial
313	70	from rural to residential
	30	from rural to industrial
314	90	from rural to residential
315	0	(no change)
316	0	(no change)
317	36	from rural to residential
318	0	(no change)
319	50	from rural to residential
320	90	from rural to industrial

TABLE 2.2

COMPARISON OF CN VALUES

Sub-catchment Area I.D.	Drainage Area (km2)	CN Values MacLaren Future	CN Values Updated Values
301	2.95	79	85
302	2.59	83	85
303	2.93	78	86
304	3.29	83	83
305	1.35	79	89
306	1.16	82	90
307	0.62	86	88
308	1.42	73	87
309	1.86	86	86
310	0.41	88	89
311	0.41	90	90
312	0.60	85	91
313	0.78	88	90
314	0.36	87	89
315	0.36	83	89
316	0.167	83	89
317	0.60	86	88
318	0.25	74	80
319	0.10	87	88
320	0.142	82	90

Note: Underlined values were changes due to proposed development at the time of the MacLaren report (1984).

TABLE 2.3

HYDROLOGIC MODELLING PARAMETERS

FUTURE CONDITIONS

Sub-catchment Area I.D.	Drainage Area (km2)	Future				
		CN Values	% Impervious	K	Tp	B
301	2.95	85	9	3.66	1.77	196
302	2.59	85	5	2.52	1.35	202
303	2.93	86	0	2.81	1.59	206
304	3.29	83	0	2.54	1.44	205
305	1.35	89	42	0.32	0.64	580
306	1.16	90	43	0.32	0.64	580
307	0.62	88	57	0.22	0.44	580
308	1.42	87	57	0.27	0.53	580
309	1.86	86	1	3.33	1.50	170
310	0.41	89	57	0.19	0.32	485
311	0.41	90	35	0.50	0.55	350
312	0.60	91	54	0.20	0.39	570
313	0.78	90	43	0.48	0.53	350
314	0.36	89	32	0.50	0.41	280
315	0.36	89	26	2.93	0.92	123
316	0.167	89	28	0.47	0.41	290
317	0.60	88	13	1.08	0.56	192
318	0.25	80	26	0.29	0.29	320
319	0.10	88	45	0.12	0.24	580
320	0.142	90	50	0.13	0.25	580

Note: Future conditions based on the new current Official Plan and Zoning By-Laws.

2.4 RESULTS

The updated hydrologic parameters (K, Tp and CN values) of the Bell Creek watershed were assembled as computer data input and analyzed utilizing the computer program, HYMO, for the 12-hour duration 100, 50, 25, 10 and 5 year storm events. A watershed schematic of the HYMO computer model is illustrated in Figure 2.2.

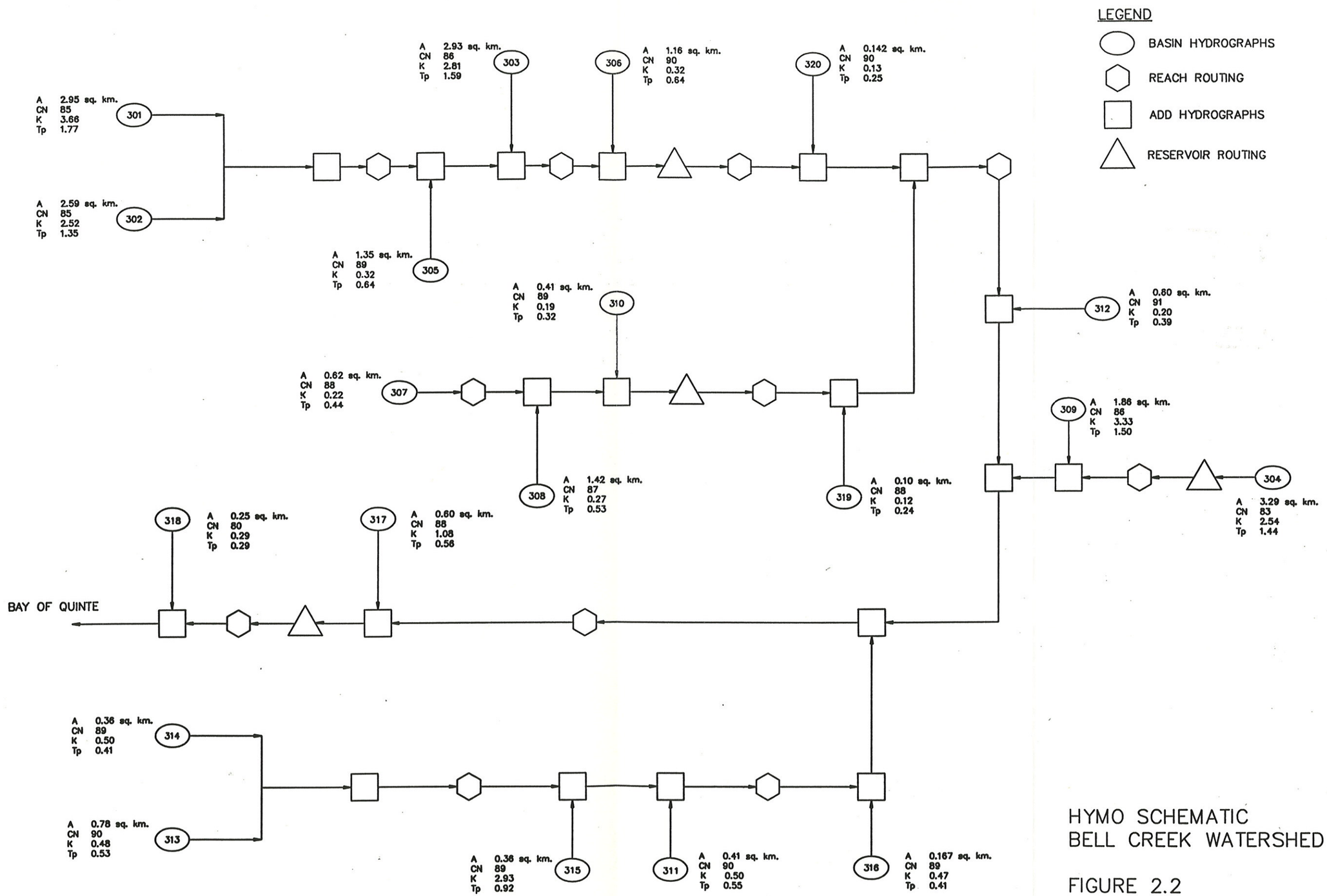
The results of the simulation, incorporating reservoir routing at the railway structures, for the 100 year storm event are provided in Table 2.4. The future conditions (1984 Official Plan and Zoning By-Laws) peak flows generated by MacLaren, without reservoir routing, are also given in Table 2.4 for comparison. As expected, higher flows were generated from those areas where the proposed land use has changed from rural in the 1984 study to residential and/or industrial in the present study (See Table 2.1). The railway embankment crossing Tributary 2 at the outlet of sub-catchment 308 reduces the 100 year peak flow by about 60%. The other structures have less than 10% reduction in the 100 year peak flow.

In addition, an on-stream detention pond was included in the simulations at the outlet of sub-catchment 315 along Tributary 1. Table 2.5 provides the routed peak flows at key locations along Bell Creek. A 100 year inflow of 6.84 cms was reduced to 3.81 cms after going through the proposed detention pond on Tributary 1.

The results of the peak flows for the various storm events at the mouth of Bell Creek are provided in Table 2.6.

The results of the hydrologic analysis and the methodologies employed were approved by the Project Team.

The generated peak flood flows were subsequently utilized in the hydraulic assessment of Bell Creek.



HYMO SCHEMATIC
BELL CREEK WATERSHED

FIGURE 2.2

TABLE 2.4

COMPARISON OF 100 YEAR PEAK FLOWS

FUTURE CONDITIONS

BELL CREEK

Location	100 Year Peak Flows (cms) MacLaren's	EGA's
Tributary 2 industrial (Outflow 307)	2.58	4.00
Tributary 2 at CNR* (Outflow 308)	N/A	(13.71) 5.56
Tributary 2 at Confluence with Main Branch (Outflow 319)	5.48	5.65
North Tributary at CNR* (Outflow 306)	N/A	(17.81) 16.84
North Tributary below CNR Embankment (Outflow 320)	12.88	16.91
Main Branch above Confluence with Tributary 1 (Outflow 312)	15.76	22.56
Eastern Tributary at CNR* (Outflow 304)	N/A	(5.12) 4.83
Eastern Tributary above Confluence with Main Branch (Outflow 309)	7.66	7.14
Tributary 1 at old City Limits (Inflow 316)	9.17	6.84
Tributary 1 above Confluence with Main Branch (Outflow 316)	10.38	8.28
Main Stream below CPR Crossing* (Outflow 317)	27.03	(34.71) 31.99
Bell Creek at Bay of Quinte (Outflow 318)	27.20	32.13

Notes: * - Denotes location of reservoirs.
Flows in brackets are inflows into reservoirs.

TABLE 2.5

100 YEAR PEAK FLOWS

FUTURE CONDITIONS WITH DETENTION POND

BELL CREEK

Location	Backwater 100 Year Peak Flows (cms)
Tributary 2 industrial (Outflow 307)	4.00
Tributary 2 at CNR* (Outflow 308)	(13.71) 5.56
Tributary 2 at Confluence with Main Branch (Outflow 319)	5.65
North Tributary at CNR* (Outflow 306)	(17.81) 16.84
North Tributary below CNR Embankment (Outflow 320)	16.91
Main Branch above Confluence with Tributary 1 (Outflow 312)	22.56
Eastern Tributary at CNR* (Outflow 304)	(5.12) 4.83
Eastern Tributary above Confluence with Main Branch (Outflow 309)	7.14
Tributary 1 at old City Limits** (Inflow 316)	(6.84) 3.81
Tributary 1 above Confluence with Main Branch (Outflow 316)	4.39
Main Stream below CPR Crossing* (Outflow 317)	(34.45) 31.68
Bell Creek at Bay of Quinte (Outflow 318)	31.78

Notes: * - Denotes location of reservoirs.
** - Denotes location of SWM detention pond.
Flows in brackets are inflows into reservoirs.

TABLE 2.6

PEAK FLOOD FLOWS

AT THE MOUTH OF BELL CREEK

Return Period (yrs)	Peak Flood Flows (cms)	
	No SWM Pond	With SWM Pond
5	17.60	17.07
10	21.20	20.68
25	25.53	25.09
50	28.77	28.32
100	32.13	31.78

Note: Refer to Table 2.5 for location of SWM Pond.