3.0 HYDRAULICS

3.1 HYDRAULIC MODEL

The floodline, or water surface elevation, for the Regulatory and the lower return frequency flood events is a function of the design flows and the ability of the channel, flood plain and river crossings to carry or pass these flows. In order to establish the water surface elevations at various locations in the study watershed, a detailed hydraulic analysis must be carried out. The channel and flood plain properties, as well as the characteristics of the various structures along the channel, must be considered in this analysis.

The hydraulic program used by Ecos Garatech to compute the water surface profiles was developed at the Hydrologic Engineering Center (HEC) by the U.S. Army Corps of Engineers and is commonly known as HEC-2.

The program computes and plots (by printer) the water surface profiles of river channels of any cross-section for either subcritical or supercritical flow conditions. It is capable of analyzing the effects of various hydraulic structures such as bridges, culverts, weirs, embankments and dams. Roughness coefficients can be specified by a number of methods to account for the change in roughness with the depth of flow or the actual location of the flow within the flood plain. Input to the program may be in either Imperial or Metric units.

A hydraulic model of the study reach was constructed by inputting specific cross-sections along the length of the flood plain into the model. These were taken from digital elevation models (DEM's), supplemented by field surveys and reconnaissance. The characteristics of the main channel and the flood plain, such as the hydraulic roughness, as obtained from field reconnaissance, were also included in the model. All river crossings and hydraulically significant structures and sections were also entered into the model to produce a physical representation of the study area.

The hydraulic model for the study (Upper Bell Creek) area, so established, may also be used to determine the capacity of various structures and channel reaches and to determine the effects of channel improvements, dykes and floodways on the water surface profiles.

In addition, the 1984 hydraulic model prepared by MacLaren was modified to reflect the updated flows generated in Section 2.

3.2 STARTING WATER SURFACE ELEVATIONS

The 1984 hydraulic model, from the Bay of Quinte to the Canadian National Railway crossing, has a starting water surface elevation of 75.03 m. This elevation is the maximum monthly mean water level for Lake Ontario in June (See table in Appendix E).

The hydraulic model for the Upper Bell Creek area starts approximately 200 m downstream of the Canadian National Railway crossing to the upstream side of Highway No. 401. The starting water surface elevation for this model was initiated at critical depth.

3.3 WATER SURFACE PROFILES

A detailed hydraulic model was constructed for the Upper Bell Creek area.

Upon completion of the hydrologic component of the study, water surface profiles associated with the Regulatory (100 year) flood and the 50, 25, 10, and 5 year flood events were computed using the developed hydraulic model in conjunction with the HEC-2 computer program.

The water surface profiles associated with the various flood events were also generated for the Lower Bell Creek area, using the modified 1984 hydraulic model.

3.4 SENSITIVITY ANALYSIS

A sensitivity analysis of the roughness coefficient, Manning's 'n' values, was undertaken in order to observe the potential change in the water surface profile of the 100 year flood within the Upper Bell Creek hydraulic regime.

The developed hydraulic model was modified to reflect a 10% increase and a 10% decrease in the 'n' values, and water surface profiles were re-generated.

A review of the results indicated that with a 10% variation of Manning's 'n' values, the change in the water surface elevations were less than 0.05 m. This minimal change would not alter the generated 100 year flood plain.

3.5 STRUCTURES

Floodwater unduly confined by structures can cause excessive water pondage. This may result in flooding of upstream properties, over-topping of roadways, excessive scour and erosion and, in severe cases, the loss of a structure. On the other hand, over-design of new structures for the sake of safety can add materially to the initial cost of the structure, and possibly increase downstream damages by increasing flood flows.

Reconnaissance and field surveys within the study limits (Upper Bell Creek) ascertained detailed information required to analyze the performance characteristics of the hydraulic structures. This information was used as computer input data, not only to determine the extent of flooding for the various flood events but also to analyze the performance of the individual structure.

Water surface profiles were generated with structures crossing the watercourse. The results of the hydraulic analysis for Upper Bell Creek, pertaining to water surface elevations, for the various return frequency flood events are presented in Table 3.1.

The resultant stage-discharge rating curves for the individual structure for Upper Bell Creek, are provided in the support document entitled "Bridge Data". The structure performance data are provided in Table 3.2.

The term "structure velocity" given in Table 3.2 is defined as the average velocity of the flow discharging through the structure for an effective flow area.

The resultant 100 year flood elevations for Lower Bell Creek are given in Table 3.3.

TABLE 3.1

WATER SURFACE ELEVATIONS
UPPER BELL CREEK
CITY OF BELLEVILLE AND THURLOW TOWNSHIP

Location and Cross-section Number	Water Surface Elevations (m) 100 Year Flood	50 Year Flood	25 Year Flood	10 Year Flood	5 Year Flood
Main Channel					
1	87.01	86.98	86.93	86.88	86.81
161	87.51	87.47	87.42	87.36	87.30
Canadian National Railway and County Road No. 18					
268	88.98	88.83	88.63	88.37	88.19
557	89.03	88.90	88.75	88.60	88.52
804	89.87	89.82	89.77	89.69	89.63
Farm Crossing					
868	90.18	90.15	90.13	90.08	90.05
889	90.41	90.38	90.34	90.30	90.25
1217	91.91	91.88	91.85	91.79	91.76
1443	93.04	93.01	92.99	92.95	92.92
1532	93.32	93.30	93.28	93.24	93.21
1862	93.92	93.89	93.86	93.80	93.76
2285	94.68	94.65	94.62	94.57	94.54
2545	95.46	95.43	95.41	95.36	95.31
2788	96.22	96.20	96.19	96.16	96.14
3060	96.73	96.70	96.68	96.63	96.60
3384	98.21	98.18	98.15	98.11	98.07
Highway No. 401					
3555	101.09	100.67	100.48	100.28	100.12
3631	101.38	101.06	100.90	100.76	100.68
3870	102.61	102.59	102.58	102.56	102.54
4134	104.78	104.77	104.75	104.73	104.70
4431	107.18	107.15	107.13	107.10	107.07

TABLE 3.1 (Cont'd)

WATER SURFACE ELEVATIONS
UPPER BELL CREEK
CITY OF BELLEVILLE AND THURLOW TOWNSHIP

Location and Cross-section Number	Water Surface Elevations (m) 100 Year Flood	50 Year Flood	25 Year Flood	10 Year Flood	5 Year Flood
Tributary 3					
92	94.11	94.07	94.05	94.01	93.98
Farm Crossing					
117	94.43	94.42	94.41E	94.39	94.29E
286	94.63	94.61	94.58E	94.55	94.53
414	95.03	95.01	94.99	94.96	94.94
628	96.34	96.32	96.29	96.25	96.21
Mitchell Road					
665	96.63	96.62	96.60	96.58	96.55E
694	96.75	96.73	96.71	96.68	96.64E
779	97.07	97.04	97.02	96.98	96.95
932	97.77	97.75	97.72	97.68	97.65
Farm Crossing					
948	98.01	97.99	97.96	97.93	97.89
1169	98.61	98.59	98.57	98.55	98.52

E - Estimated

TABLE 3.2

STRUCTURE PERFORMANCE DATA

Location	Flood Event (yr)	Discharge (cms)	Structure Velocity (m/s)	Class of Flow	% Weir Flow Over Roadway Embankment	Total Head Loss (m)
Main Channel						
Canadian National Railway	100	16.8	3.80	LF	—	1.21
	50	14.8	3.66	LF	—	1.07
	25	12.7	3.48	LF	—	0.92
	10	10.1	3.22	LF	—	0.72
	5	8.21	3.01	LF	—	0.58
County Road No. 18	100	16.8	1.24	PF-WF	88	0.01
	50	14.8	2.62	PF-WF	27	0.11
	25	12.7	2.54	PF	—	0.12
	10	10.1	2.52	LF	—	0.14
	5	8.21	2.57	LF	—	0.18
Farm Crossing	100	17.8	2.38	PF-WF	94	0.53
	50	15.6	2.40	PF-WF	93	0.55
	25	13.4	2.39	PF-WF	94	0.57
	10	10.5	2.25	PF-WF	92	0.59
	5	8.40	2.09	PF-WF	94	0.61
Highway No. 401	100	4.86	2.74	PF	—	3.16
	50	4.25	2.82	PF	—	2.86
	25	3.65	2.73	LF	—	2.73
	10	2.85	2.53	LF	—	2.64
	5	2.26	2.36	LF	—	2.60

TABLE 3.2 (Cont'd)

STRUCTURE PERFORMANCE DATA

Location	Flood Event (yr)	Discharge (cms)	Structure Velocity (m/s)	Class of Flow	% Weir Flow Over Roadway Embankment	Total Head Loss (m)
Tributary 3						
Farm Crossing	100	4.93	1.24	PF-WF	90	0.20
	50	4.32	1.23	PF-WF	90	0.22
	25	3.72	2.77	PF-WF	46	0.24
	10	2.93	1.80	PF-WF	31	0.28
	5	2.34	2.23	PF-WF	15	0.23
Mitchell Road	100	4.93	1.43	PF-WF	89	0.39
	50	4.32	1.32	PF-WF	84	0.40
	25	3.72	1.30	PF-WF	72	0.40
	10	2.93	1.28	PF-WF	66	0.41
	5	2.34	1.19	PF-WF	50	0.46
Farm Crossing	100	4.93	2.04	PF-WF	95	0.15
	50	4.32	2.11	PF-WF	95	0.15
	25	3.72	1.89	PF-WF	96	0.16
	10	2.93	1.62	PF-WF	88	0.19
	5	2.34	1.76	PF-WF	81	0.19

Abbreviations:

LF-WF - Low flow and weir flow condition.
The water level is below the low chord of the structure and is flowing over the roadway embankment.

PF-WF - Pressure flow and weir flow condition.
The water level is above the low chord of the structure and is flowing over the roadway embankment.

PF - Pressure flow condition.
The water level is above the low chord of the structure but not over the roadway embankment.

LF - Low flow condition.
The water level is below the low chord of the structure.

TABLE 3.3

100 YEAR WATER SURFACE ELEVATIONS
LOWER BELL CREEK
CITY OF BELLEVILLE AND THURLOW TOWNSHIP

Location and Cross-section Number	100 Year Water Surface Elevations (m) MacLaren's	EGA's
Main Channel		
1.0	75.03	75.03
3.0	75.42	75.52
Abandoned Rail Crossing		
6.0	75.68	75.76
8.0	76.31*	76.36*
Highway No. 2		
11.0	77.34	77.29
13.0	77.76	77.80
Kingston Road		
16.0	78.60	79.01
17.0	79.35	79.41
19.0	80.36	80.40
Canadian Pacific Railway		
22.0	81.22	81.46
24.0	81.23	81.47
27.0	81.65	81.68
29.5	82.69	82.72
202.0	83.39	83.43
203.6	84.59	84.64
205.0	85.46	85.55
207.0	85.82	85.91
208.5	86.59	86.63

* - critical depth

TABLE 3.3 (Cont'd)

100 YEAR WATER SURFACE ELEVATIONS
LOWER BELL CREEK
CITY OF BELLEVILLE AND THURLOW TOWNSHIP

Location and Cross-section Number	100 Year Water Surface Elevations (m) MacLaren's	EGA's
Tributary 1		
30.0	82.38	82.16
31.0	82.80	82.76
34.0	84.32	84.24
301.0	85.23	85.14
302.8	85.50	85.38
304.0	86.69	86.48
304.6	87.24	87.18
306.0	88.24	88.35
307.0	88.46	88.66
321.0	88.85	89.07
Tributary 2		
220.0	85.87	85.97
230.0	85.88	85.98
East Tributary		
2016.0	83.64*	83.62*
2020.0	84.05*	84.02*

* - critical depth

3.6 RESERVOIR ROUTING

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 (see also Sections 2.1 and 2.2).

Although the Canadian National Railway structures were reservoir routed, the outflow is governed by the hydraulic capacity of the structures of County Road No. 18, which is located immediately upstream of the railway.

The hydraulic analysis undertaken for the Canadian National Railway and County Road No. 18 produced a water surface elevation of about 89.0 m upstream of the structures.

Reservoir routed results gave an elevation of about 89.03 m for the Canadian National Railway structure crossing the main channel, and an elevation of about 89.13 m for the Canadian National Railway structure crossing Tributary 2.

3.7 RESULTS

The extent of flooding within the study area of Upper Bell Creek, as a result of the Regulatory (100 year) flood was plotted on the Moira River Conservation Authority's Flood Risk Maps, Sheet Nos. 1 to 8.

For the Lower Bell Creek area, the 100 year lake flood elevation of 76.20 m was superimposed on the backwater simulations at the Bay of Quinte. The backwater effect of 76.20 m ends at about 70 m downstream of Highway No. 2.

The results of the hydraulic investigations for Upper Bell Creek are:

(1) The Manning's 'n' sensitivity analysis demonstrated that a 10% deviation in the values would not significantly alter the simulated Regulatory flood plain.

(2) The Canadian National Railway and Highway No. 401 structures can discharge the various flood events, without weir flow occurring over the roadway embankment.

(3) The bridge structure of County Road No. 18 can discharge, without weir flow occurring over the roadway embankment, up to the 25 year flood event.

(4) Weir flow over the roadway embankment will occur at all the culvert crossings (three Farm Crossings and Mitchell Road).

(5) For the 100 year flood event, the total head loss through the structures varied from 0.01 m at County Road No. 18 to 3.16 m at the Highway No. 401 crossing.

(6) In reviewing the flood plain of Upper Bell Creek, it was estimated that 9 buildings are within the 100 year flood plain.

The results of the hydraulic analyses, the 1:2000 scale digital mapping illustrating the Regulatory (100 year) flood plain and the methodologies employed were subsequently approved by the Project Team.