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Little River Flood Line Mapping

Report to

Essex Region Conservation Authority

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28 June 1985

Essex Region Conservation Authority
360 Fairview Ave. W.
Essex, Ontario
N8M 1Y6

Attention: Mr. P. Hale,
General Manager

Flood Line Mapping
of Little River

Gentlemen:

We are pleased to submit our report in regard to the establishment of flood lines on Little River.

Our report presents the results of studies and investigations regarding the hydrology and hydraulic methodology used.

We would take this opportunity to thank all those who have assisted us and provided comments to us during the project. The opportunity to be of further service to the Authority is appreciated.

Please do not hesitate to call should you wish to discuss any aspect of our report.

Yours very truly,

MacLAREN ENGINEERS INC.

W. L. Knowles, P. Eng.
Vice President

/st

Lavalin

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A. INTRODUCTION

A.1 General Description of the Watershed

A general plan of the study area is shown in Figure 1. The Little River watershed provides drainage for approximately 60.8 sq.km.(23.5 sq.mi.). The water course channel is clean and weed-free. Overbank areas range from short grass to scattered brush and heavy weeds. The stream gradient at 0.06% is very mild, the floodplains are flat and artificially well drained. These factors, when compared to many other streams and rivers in south-central and south-western Ontario indicate that channel storage, and consequently flood peak attenuation would be substantially greater for the study watershed.

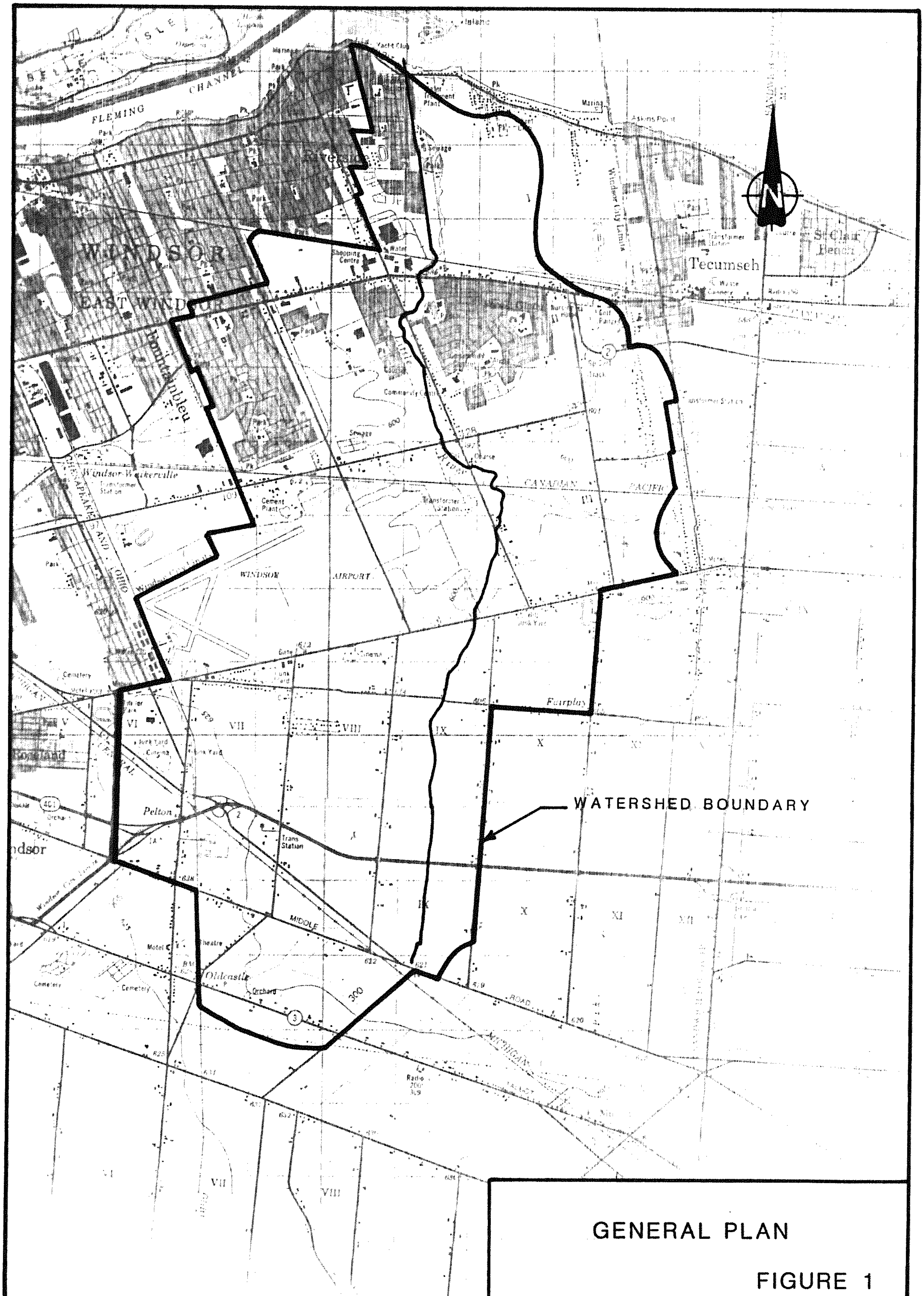
The dominate soils are Brookston clay and Brookston clay loam. Both are members of the Dark Grey Cleisolic Great Soil Group. They are dark clay and dark clay loam respectively over mottled clay then blue-grey compact gritty clay with few stones and have almost level topography with poor natural drainage.

Hydrologically, these soils are classified as being group C, according to the Soil Conservation Service HSC classification system.

Land use is interpretted from aerial photographs is as follows:

Residential	15%
Industrial	9%
Rural	76%

Physiographically, the area is entirely located within a clay plain.



GENERAL PLAN

FIGURE 1

B. METHODOLOGY

B.1 Hydrology

All floodplain mapping studies in southern Ontario (excluding perhaps areas within the eastern region) require the use of computer models for the determination of Regional storm flood flows and in many cases, the flood flow resulting from the 1:100-year storm rainfall.

These flood flows are determined, in the vast majority of instances, by the HYMO model. Much of the following discussion has been based on Collins and Moon Limited's 1981 report to the Ministry of Natural Resources.

The HYMO model was developed by Williams and Hann and is described in detail in a users` manual (Williams and Hann, 1973). The authors of the model originally thought of it as a structure within which hydrologic modelling could be conducted. The manual describes HYMO as a problem-oriented computer language. Despite this, most people use the acronym HYMO to describe the particular computer-model-calculation package developed by Williams and Hann 1973.

. Storm-Runoff Volume Calculations in HYMO

The HYMO model calculates storm-runoff volume from a rainfall event using the Soil Conservation Service Curve Number method. This method of "direct" or "storm" runoff calculation has been widely used and accepted in the United States and Canada.

The Curve Number (CN) method was developed as a tool for the evaluation of the hydrologic effect of land use changes and of construction of runoff-control structures.

In the HYMO model, the SCS curve number method is extended to allow for the calculation of separate storm runoff amounts for each individual time step within a storm. While this goes beyond the original function of the CN procedure which was to calculate total storm runoff from a rain having a duration of twenty-four hours or less, it is a widely accepted practice.

It is noted that the model computations do not allow for minimum loss rates per time step period which, in turn, would be dependent upon the type of soil as this is assumed to be included with the use of the SCS curve number method.

In this study, therefore, and in accordance with the prescribed procedure of the Conservation Authorities Branch, Ministry of Natural Resources, storm runoff volumes have been computed on the following basis:

Runoff from Rainfall Frequency event	SCS Curve Number consistent with AMC II watershed condition	Assumed rainfall hourly distribution in accordance with SCS Type II (see Table 1)
Runoff from Regional Storm (Hazel) (see Table 1)	SCS Curve Number consistent with AMC III watershed	Rainfall hourly distribution as prescribed by the Ministry of Natural Resources and in accordance with the Essex Region Conservation Authority regulations. (see Table 1)

- Storm Runoff Hydrographs in HYMO

HYMO develops a storm runoff hydrograph for a sub-watershed by convoluting the runoff depths for each time step with a unit hydrograph for that sub-watershed. The unit hydrograph is developed as an instantaneous unit hydrograph in the presentation made in the HYMO user's manual, but then is treated as the time-step-duration unit hydrograph for computations. It is likely that there is little difference between the instantaneous unit hydrograph (IUH) and the time-step unit hydrograph for the steps of 0.5 hour or 1.0 hour.

The unit hydrograph for a sub-watershed has three analytic equations for different portions of its length. From the start to the point-of-inflection after the peak, it is represented by a two parameter gamma distribution equation. From the point of inflection to a time 2K after the inflection, the unit hydrograph has an exponential decay with time constant K. The remainder of the tail is fitted with a time constant 3K. The parameters of the gamma distrubution are such that if K and tp are known (tp is the time to peak of IUH), then the entire hydrograph shaped is determined.

The program allows for the entry of specified values for K and tp for each sub-watershed if they are known from flowrate records. If K and tp are unknown, the program provides estimating equations for K and for tp based on watershed properties. These regression-fitted equations were originally established for watersheds (0.5 to 25 sq.mi.) in the southern United States where overland runoff is large and frequent and where stream and land surface morphology are determined by this runoff. These equations have been widely accepted in Ontario and in numerous studies have been found to give realistic results for calibration events.

The HYMO model assumes that the runoff process is linear for each sub-watershed unit, ie., that magnitude of runoff in a period does not affect the time-distribution pattern of runoff.

We have shown on Figure 2 the delineation of the watersheds into sub-watersheds used to construct the computer model HYMO. In Table 2, we have summarized the physical characteristics of the sub-watersheds as to area, total fall, length of principal drainage channel, the HYMO parameters of tp, K and K/tp, and the weighted SCS curve number (CN) for AMC II and AMC III conditions.

. Streamflow Routing in HYMO

HYMO allows for the addition of storm runoff hydrographs where sub-watersheds discharge into a larger stream channel. Flows are routed downstream by a variable storage coefficient (VSC) method. This routing procedure introduces non-linearity in that for greater runoff events, the higher the flow, generally the greater the velocity and the less the time of travel.

The VSC routing procedure is, in fact, reservoir-type routing with the peak outflow rate coming at a time of equality of inflow and outflow during recession.

Also, within the HYMO model structure, routing can also be carried out using the storage index (SI) method. This method is also reservoir-type routing. Because of the wide, flat and low gradient floodplains the storage index routing method was used. The input parameters to the model relating outflow and storage volume in the routing reaches were developed using the hydraulic model HEC-2.

Baseflow Allowance in HYMO

There is no provision for baseflow in HYMO It is clear that overland runoff was the predominate source of streamflow in the watersheds for which it was developed initially. Hence, it was considered reasonable to start calculations with zero flowrate in all channels.

For the purpose of this study, we followed the Ontario convention of not including a baseflow allowance.
The assumption of zero flowrate in channels at the start of an

event will have some impact on downstream routing for the first few time steps. Since calculations show that the cannels fill rapidly from the first runoff, it is unlikely that the effects persist long enough to affect the timing or magnitude of flood peaks.

- Subsurface Runoff in HYMO

There is no explicit allowance for rapid subsurface storm runoff in HYMO. The choice of curve number may implicitly allow for this component in storm runoff volumes. Similarly, the choice of K may influence the shape of the unit hydrograph.

The model structure for Little River is shown in the Figure 3 schematic.

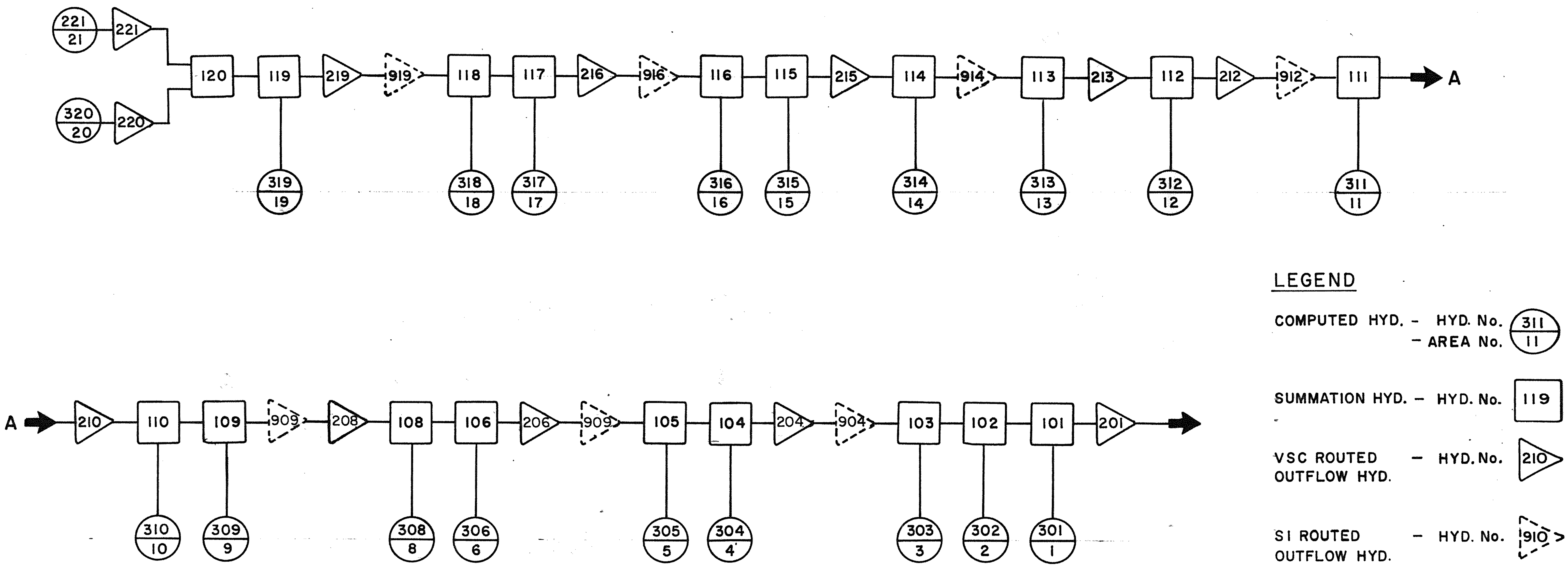
B.2 Topographic Mapping

The topographic mapping services were provided by Kenting Earth Sciences Limited. The 1:5000 scale orthophoto type mapping having one metre contours with 0.5 metre interpolated contours was based on 1:6000 scale air photographs taken April 11, 1984.

We have carried out a check of the various components of the topographic mapping as follows:

a) We confirm that the following materials and information has been provided by Kenting Earth Sciences Limited;

- An index map showing all horizontal ground control points provided.
- Two copies of a written report.
- Index map showing the proposed limits of the photogrammetric block and the general sheet layout for 1:5000 scale mapping.
- Point numbering system for horizontal control points.
- A list in duplicate of the final elevations of all vertical control points and bench marks.
- Originals of a set of plans showing the location of each vertical control point and each permanent and temporary bench mark.



LITTLE RIVER
HYMO MODEL FLOW CHART

FIGURE 3

- One set of contact prints of each annotated negative.
- One copy of the index and flight lines (1:50,000 scale).

b) We have undertaken a random visual inspection to confirm that the specified annotations and index have been provided regarding the aerial photography.

c) Spot elevations at bridges were checked by field survey procedures.

B.3 Flood Flows for Floodline Determination

We have summarized in the following tabulation (Table 3) the flood flows for the frequency event of 1:100 and for the regional storm under two channel conditions which reflect both the flows are contained by dikes.

Having regard for the calibration procedure, we concluded that standard hydrology procedures in Ontario that involved equating the runoff from a rainfall having a return frequency of 1:100 years to a flood flow having the same return frequency would yield inappropriately low flows for the determination of the 1:100 year flood line.

Consequently, we carried out a flood frequency analysis of the data for the Ruscom River gauge to obtain the 1:100 year flows as follows: (Figure 4)

Distribution	Flow CMS	Std. Error %
Gumbel I	135	17.9
Log Normal	147	26.0
3PLN	150	33.1
Log Pearson	142	33.2

Further, in 1981 the South-West Regional Engineer of the Ministry of Natural Resources carried out a study of the Ruscom River watershed. It was concluded that the 1:100 year flood flow at the WSC gauge would be 110 m3/s. This flow was developed through calibration of the HYMO model using recorded events and was supported by a regional regression analysis.

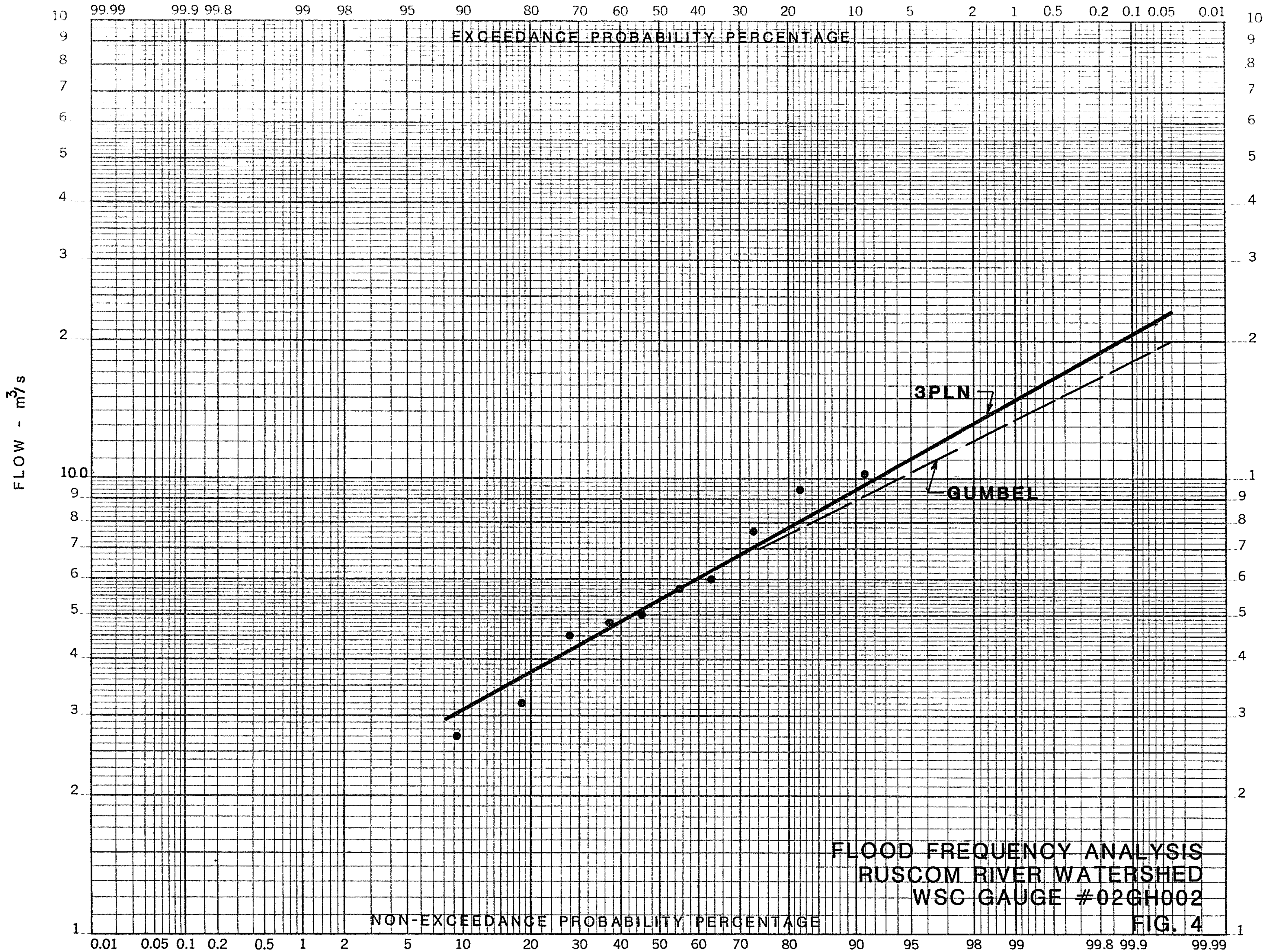

EXCEEDANCE PROBABILITY PERCENTAGE
NON-EXCEEDANCE PROBABILITY PERCENTAGE
FLOW - m³/s
3PLN
GUMBEL
FLOOD FREQUENCY ANALYSIS
RUSCOM RIVER WATERSHED
WSC GAUGE #02GH002

FIG. 4

With reference to the 1985 publication "Regional Flood Frequency Analysis for Ontario Streams - Volume 1, Single Station Analysis and Index Method" by S.M.A. Moin and M.A. Shaw, estimates of the 1:100 flood for the Ruscom River gauge would range from:

Q2	- Ruscom River determined from frequency analysis	=	55 m3/s
Q2	based on regional analysis	=	40 m3/s
Ratio of Q100/Q2 (Region 5)		=	2.35

100-year flood flow 94 m3/s to 129 m3/s

As regards the 1:100 year flood flow for Little River at the downstream point of the study area, (tributary area 60.8 km2) area, several estimates have been made as follows:

Method	1:100 yr. Little River Flood Flow
HYMO Modelling (Flood generated by 1:100 year rainfall)	46.6 m3/s
Regional Flood Index Method (1:100 yr)	2.35*A^0.775 = 56.7 m3/s
Transposition of Ruscom River flows based on foregoing publication	$Q\ Ruscom \times \left(\frac{60.8}{125}\right)^{0.775} =$ 0.572 Q Ruscom

For Q100 Ruscom	$94\ m^3/s \times 0.572$	=	Q100 LR =	$53.8 m^3/s$
For Q100 Ruscom	$110\ m^3/s \times 0.572$	=	Q100 LR =	$62.9\ m^3/s$
For Q100 Ruscom	$135\ m^3/s \times 0.572$	=	Q100 LR =	$77.2\ m^3/s$
For Q100 Ruscom	$150\ m^3/s \times 0.572$	=	Q100 LR =	$85.8\ m^3/s$

Another method that is suggested is based on the assumption that the flood flow generated from a runoff event for a particular watershed varies in direct proportion to the unit hydrograph parameters which are given by the relationship $\frac{BA}{tp}$

where - B is a watershed constant which in imperial units the ratio B to 1290 is the volume of runoff under the rising limb of the unit hydrograph.

A is the watershed area

tp is the time to peak of the unit hydrograph

Using the standard HYMO equations and relationships, we have determined that:

$\frac{BA}{tp}$ is proportional to A^0.733*SL^0.717

where SL = watershed slope

Direct application of this relationship to the Ruscom and Little River watersheds indicates that the Little River flood flow for the same runoff event would be:

$$\frac{(60.8)}{(125)}\hat{}0.733* \frac{(0.739)}{1.288}\hat{}0.717$$

ie. 39.0% of the Ruscom River flow

On this basis, the 1:100 year flood flow rate for the Little River would be as follows for the listed Q100 flows for the Ruscom River:

Q 100 Ruscom	Q 100 Little River
94 m3/s	37.2 m3/s
110 m3/s	43.6 m3/s
135 m3/s	53.5 m3/s
150 m3/s	59.4 m3/s

As regards the 1:100 year flow at the upstream point of the study area, the following several estimates have been made:

METHOD

1:100 year rainfall (HYMO modelling)	12.7 m3/s
Regional Flood Index Method 2.35 A^0.775 =	24.4 m3/s
Ratioing from the Ruscom River (Transposition of data)	Factor is 0.245 Q Ruscom

For Q 100 Ruscom		Q 100 Little River
= 94 m3/s	x 0.245 =	23.0 m3/s
= 110 m3/s	x 0.245 =	27.0 m3/s
= 135 m3/s	x 0.245 =	33.1 m3/s
= 150 m3/s	x 0.245 =	36.8 m3/s

In view of the foregoing and the several studies an analyses that have been carried out, we recommend that the 1:100 flood flow be based on the regional analysis equation

$$Q_{100} = 2.35 A^{0.775}$$

ie. Q 100 - downstream 56.7 m3/s
Q 100 - upstream 24.4 m3/s
Q 100 - intermediate points 2.35 A^0.775

B.4 Calibration of Models

Based on our analysis of the October, 1981 storm data presented in the Authority's Technical Documentation report, we have concluded that the storm of approximately 80 mm produced approx. 58 mm (2.3 inches) of runoff over a 4-hour period. Indeed, the measured volume of runoff excess for the Ruscom River gauge near Ruscom Station was approximately 60 mm (2.4 inches)

Based on our knowledge of the southwestern Ontario watersheds, a runoff of this magnitude would produce a significant runoff event - perhaps in the range rarer than 1:50 years. We were also aware that significant channel improvements including widening, deepening and cleaning had been carried out since 1981. Consequently, the existing channel conditions are much improved over those obtained in 1981. Further, since the improvements have been carried out there is now evidence of some degradation including siltation and vegetation growth on the banks.

We, therefore, carried out a series of backwater calculations assuming a 0.3m siltation of the channel and increasing vegetation growth yielding Manning's 'n' values ranging from 0.030 to 0.060. We have shown on Figure 5, the results of these calculations using the calculated 1:100 year flood flows at the locations where flood elevations were recorded for the October 1981 flood event.

Based on these analyses, we have carried out the determination of the 1:100 year flood elevations on the basis of some channel degradation from existing conditions. The assumed 'n' values are shown in Figure 5.

In our opinion the model results are fairly and reasonably consistent with the observed results.

B.5 Hydraulics

Using the flood flows determined, water surface elevations were computed using the U.S. Army Corps of Engineers Model HEC-2, 1976, updated to April 1980.

Input data for the model included:

- cross-section information taken from the 1:5000 scale topographic mapping supplemented by field survey input for underwater cross-section data.
- bridge cross-section data based on detailed field surveys. Photographs of all 16 bridges and structures were also taken.
- channel and overbank roughness factors (Manning's n) based on field reconnaissance data. Because of the generally wide floodplain, and low values of the product of velocity time hydraulic radius, we used Manning's 'n' (0.200) for the overbank areas.

Starting water level elevation downstream of the CN bridge was determined from previous backwater work by M.M. Dillon Limited.

Starting water elevations used -

Regional storm	178.4 m
1:100	177.0 m

The expansion/contraction coefficients used in the modelling were:

	Contraction	Expansion
Channel	0.3	0.5
At Bridges	0.6	0.8

and are in accordance with the recommendations of the U.S. Army Corps of Engineers as made at the seminar on advanced water surface computations using HEC-2 computer program sponsored by the Ministry of Natural Resources, March, 1980.

We have summarized in Table 4, the flood elevation for each of the 1:100 and regional storm flood events for each reach and cross-section and structure used in the computations.

We have plotted on the 1:5000 topographic maps the resulting floodplain under 1:100 year flow and as well have shown the hydraulic profile on Figure 5.

B.6 Data Submitted Under Separate Cover

- one complete set of final cronaflex maps
- five complete white print sets of mapping
- two complete sets of input/output data of all computer modelling - hydrology and hydraulics
- photographic record and survey information relating to each bridge
- hydraulic profiles for each reach for the 1:100 year flood and the calibration event.

PRINCIPAL REFERENCES/DATA SOURCES

- 1:25,000 scale topographic mapping - Surveys and Mapping Branch, Department of Energy, Mines and Resources
- Physiography of Southern Ontario, Chapman and Putnam Ontario Research Foundation, University of Toronto Press, 1966
- Historical Streamflow Summary - Ontario, Environment Canada, Inland Waters Directorate, Water Resources Branch, Water Survey of Canada, Ottawa, 1980.
- Soil Survey of Essex County, Report No. 11 of the Ontario Soil Survey, Canada Department of Agriculture and Ontario Department of Agriculture, 1963.
- Rainfall Data, Environment Canada, Atmospheric Environment Service for Windsor A.
- Handbook of Applied Hydrology, Ven Te Chow (editor-in-chief) McGraw-Hill Book Company, 1967.
- Design of Small Dams, United States Department of the Interior Bureau of Reclamation, 2nd Edition, 1973.
- National Engineering Handbook, Hydrology, Section 4, U.S. Department of Commerce, August 1972.
- Watershed Model Calibration Methodology Study, Collins and Moon Ltd. and Dr. Hugh Whiteley, July 1981.

- Specific data reviewed included:

  1. Plans for modifications at the 2nd Concession Drain.
  2. Plans (as-built) of the bridge at Forest Glade Drive.
  3. A profile of Little River from Lauzon (north) to Forest Glade Drive with a proposed dredging grade.
  4. E. C. Row Expressway culvert construction.
  5. Plan of Municipal Drains in Windsor.
  6. Plan of Little River Drain Sandwich South Township.
  7. Polonia Culture & Recreation Centre Flood Study
  8. Salvation Army Flood Study
  9. Little River Farms Ltd. Flood Study
  10. Polonia Park Development Flood Study
  11. Lauzon Parkway Bridge Across Little River Hydrology Report
  12. Site Specific Floodline Study for Vidican Holding Co. Ltd.
  13. Little River Dykes Engineering Study
  14. Technical Documentation of the October 1, 1981 Flood.

TABLE 1

RAINFALL AMOUNTS AND DISTRIBUTION

A. RAINFALL AMOUNTS

Storm	Regional	1:100
Point Rainfall	211 mm	106.5 mm
Amount	8.31"	4.19"

B. RAINFALL DISTRIBUTIONS

i) 12-Hour Hurricane Hazel

Time Interval (hrs)	36-37	37-38	38-39	39-40	40-41	41-42	42-43	43-44	44-45	45-46	46-47	47-48
Percent of total rainfall	3	2	3	6	8	6	11	6	6	25	18	6

ii) Frequency Rainfall Events - 24 hour Duration

Time Interval (hrs)	0-2	2-4	4-6	6-8	8-9	9.0-9.5	9.5-10.0	10.0-10.5	10.5-11.0
Percent of total rainfall	2.2	2.6	3.2	4.0	2.7	1.6	1.8	2.3	3.1

Time Intervals (hrs)	11.0-11.5	11.5-11.75	11.75-12.0	12.0-12.5	12.5-13.0	13.0-13.5	13.5-14.0	14-16	16-20	20-24
Percent of total	4.8	10.4	27.6	7.2	3.7	2.7	2.1	6.0	7.2	4.8

TABLE 2 - LITTLE RIVER WATERSHED - PHYSICAL CHARACTERISTICS

Sub Watershed	Area sq.km	Height m	Length km	K/tp	tp hrs.	K hrs.	WEIGHTED CN II	CN III
A01	5.65	0.9	4.2	4.75	7.00	33.28	88	95
A02	0.44	0.9	2.4	6.42	2.25	14.41	92	97
A03	1.19	3.0	2.4	3.65	1.72	6.29	84	93
A04	3.26	3.0	3.7	3.46	3.14	10.86	80	91
A05	3.29	6.1	3.9	2.80	2.37	6.64	81	92
A06	3.32	6.1	3.5	2.73	2.22	6.07	78	90
A08	1.35	3.0	2.9	3.77	2.04	7.68	80	91
A09	1.89	3.0	3.4	3.72	2.51	9.33	79	91
A10	0.41	3.0	1.3	3.67	.80	2.95	80	91
A11	1.76	4.6	3.4	3.31	2.04	6.76	85	94
A12	6.73	7.6	5.3	2.52	3.30	8.34	79	91
A13	2.05	3.0	2.6	3.38	2.11	7.12	78	90
A14	1.84	3.0	2.7	3.51	2.14	7.49	78	90
A15	1.37	2.4	2.4	3.82	1.99	7.60	78	90
A16	2.07	2.4	3.5	3.98	2.96	11.76	78	90
A17	2.20	6.1	5.1	3.29	2.59	8.52	78	90
A18	1.45	4.6	3.2	3.38	1.86	6.30	78	90
A19	6.24	6.1	4.7	2.64	3.26	8.62	78	90
A20	7.67	3.0	5.3	3.27	5.11	16.69	78	90
A21	6.60	1.5	4.0	3.88	5.63	21.86	78	90
Total =	23.47					Ave. CN =	80	91

NOTES: tp = 1.44 A**0.289 L**0.726 H**-0.46
K = 5.95 A**0.107 L**1.025 H**-0.777

Wtd. Cn based on hydrologic type and land use as follows:

Land Use	Soil Type = C CN = as above
1. Residential	15%
2. Commercial/Industrial	09%
3. Rural/Open Space	76%

TABLE 3 - FLOOD FLOWS - LITTLE RIVER

HYMO MODEL SUMMARY - * FLOWS(CMS) USED IN HEC2 MODEL

Sub-Watershed Area	Hydrograph No.		Regional Storm I	II	Calculated 100YR
A21	321		9.42	9.42	
	221		9.31	9.31	
A20	320		14.94	14.94	
	220		14.31	14.31	
	120		23.63	23.63	
A19	319		19.30	19.30	
	119		40.78	40.78	
	219	*	38.71	38.71	24.40
	919		0.00	33.70	
A18	318		5.77	5.77	
	118		41.94	35.34	
A17	317		7.01	7.01	
	117		47.26	38.94	
	216	*	47.17	38.91	27.70
	916		0.00	38.03	
A16	316		5.17	5.17	
	116		51.56	40.92	
A15	315		4.83	4.83	
	115		55.01	43.07	
	215		53.34	42.87	
A14	314		6.50	6.50	
	114	*	57.44	46.18	32.30
	914		0.00	44.77	
A13	313		7.49	7.49	
	113		62.57	47.45	
	213	*	62.45	47.43	34.00
A12	312		21.53	21.53	
	112		81.61	64.97	
	212	*	81.53	64.92	39.50
	912		0.00	60.42	
A11	311		7.01	7.01	
	111		86.99	63.56	
	210		86.34	63.44	
A10	310		2.57	2.57	
	110		87.36	63.81	
A09	309		5.77	5.77	
	109	*	92.39	67.35	42.80
	909		0.00	66.90	
	208		91.29	66.73	
A08	308		4.75	4.75	
	108		94.88	68.88	
A06	306		13.41	13.41	
	106		105.16	76.07	
	206	*	104.79	75.95	46.40
	906		0.00	75.87	
A05	305		13.01	13.01	
	105		115.54	86.17	
A04	304		8.71	8.71	

Sub-Watershed Area	Hydrograph No.	Regional Storm I	Regional Storm II	Calculated 100yr
	104	123.86	94.49	
	204	* 123.67	94.49	51.30
	904	0.00	92.00	
A03	303	4.92	4.92	
	103	127.57	95.00	
A02	302	1.04	1.04	
	102	128.53	95.90	
A01	301	5.97	5.97	
	101	134.45	101.88	
	201	* 133.66	101.71	56.70

I - Confined by dikes

II - Existing conditions

TABLE 4 - COMPUTED FLOOD ELEVATIONS (METERS)

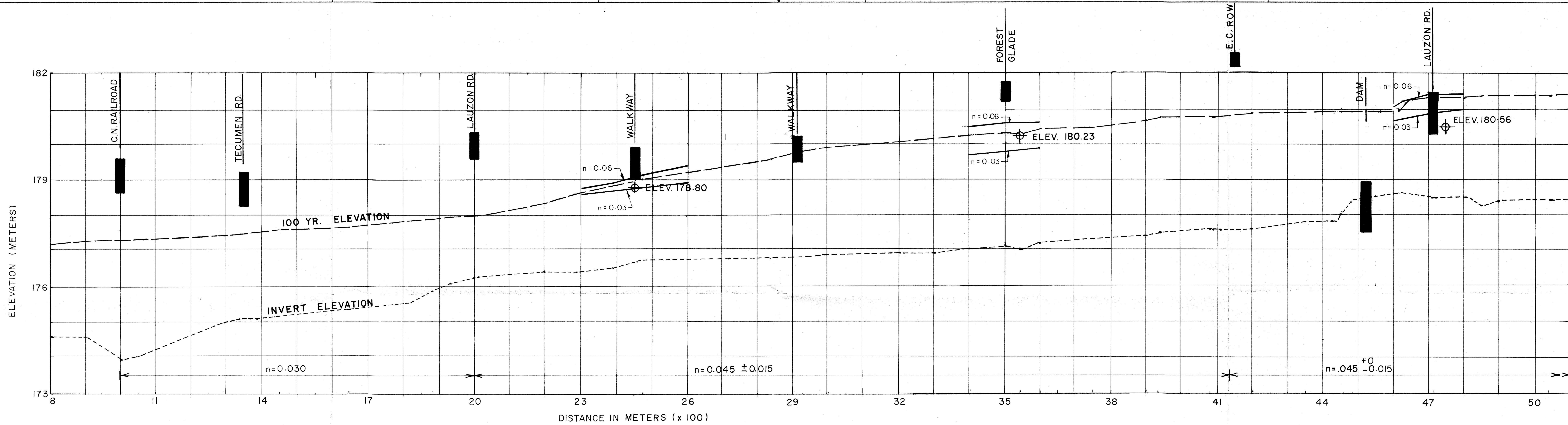
SECTION NO.	STRUCTURE	MINIMUM ELEV.	REGIONAL FLOW	STORM ELEV.	1:100 yr. FLOW	Event ELEV.
3000		174.0	101.8	178.40	56.7	177.00
5000		174.0	101.8	178.45	56.7	177.10
6000		174.0	101.8	178.48	56.7	177.16
8000		174.3	101.8	178.55	56.7	177.27
9001		174.3	101.8	178.58	56.7	177.32
10002	ST-1	173.6	101.8	178.60	56.7	177.35
10113		173.6	101.8	178.68	56.7	177.37
10304		173.7	101.8	178.77	56.7	177.40
10500		173.8	101.8	178.77	56.7	177.41
12901		174.6	101.8	178.80	56.7	177.48
13502	ST-2	174.8	101.8	178.81	56.7	177.50
13683		174.8	101.8	178.96	56.7	177.54
13904		174.8	101.8	178.97	56.7	177.57
14500		174.9	92.1	179.03	51.3	177.67
16400		175.1	92.1	179.06	51.3	177.75
18300		175.3	92.1	179.08	51.3	177.83
18850		175.6	92.1	179.08	51.3	177.84
19401		175.8	92.1	179.09	51.3	177.89
20002	ST-3	175.9	92.1	179.13	51.3	178.04
20123		175.9	92.1	179.14	51.3	178.07
22004		176.0	92.1	179.38	51.3	178.39
22950		176.0	75.9	179.53	46.4	178.66
23901		176.1	75.9	179.57	46.4	178.85
24502	ST-4	176.2	75.9	179.61	46.4	178.95
24533		176.2	75.9	179.61	46.4	179.00
24704		176.2	75.9	179.62	46.4	179.03
28301		176.3	75.9	179.84	46.4	179.56
29102	ST-5	176.4	75.9	179.91	46.4	179.67
29133		176.4	75.9	179.97	46.4	179.67
29304		176.4	75.9	179.99	46.4	179.70
30000		176.5	75.9	180.05	46.4	179.80
32000		176.6	75.9	180.26	46.4	180.07
33000		176.6	75.9	180.34	46.4	180.16
34001		176.7	66.9	180.43	42.8	180.26
35002	ST-6	176.8	66.9	180.48	42.8	180.32
35183		176.8	66.9	180.56	42.8	180.33
35404		176.8	66.9	180.56	42.8	180.35
36000		176.9	66.9	180.57	42.8	180.38
37500		177.0	66.9	180.62	42.8	180.47
39001		177.1	66.9	180.72	42.8	180.62
40302	ST-7	177.2	66.9	180.82	42.8	180.72
40323		177.2	66.9	180.82	42.8	180.73
40824		177.2	66.9	180.84	42.8	180.73
40845		177.2	66.9	180.84	42.8	180.75
41106		177.3	66.9	180.88	42.8	180.79
42000		177.3	60.5	180.98	39.5	180.86
43501		177.5	60.5	181.00	39.5	180.89
44302	ST-8	177.5	60.5	181.02	39.5	180.91
44323		177.5	60.5	181.02	39.5	180.92
44704		177.7	60.5	181.03	39.5	180.93
45100		177.9	60.5	181.03	39.5	180.94
45601		178.2	47.5	181.08	34.0	180.97

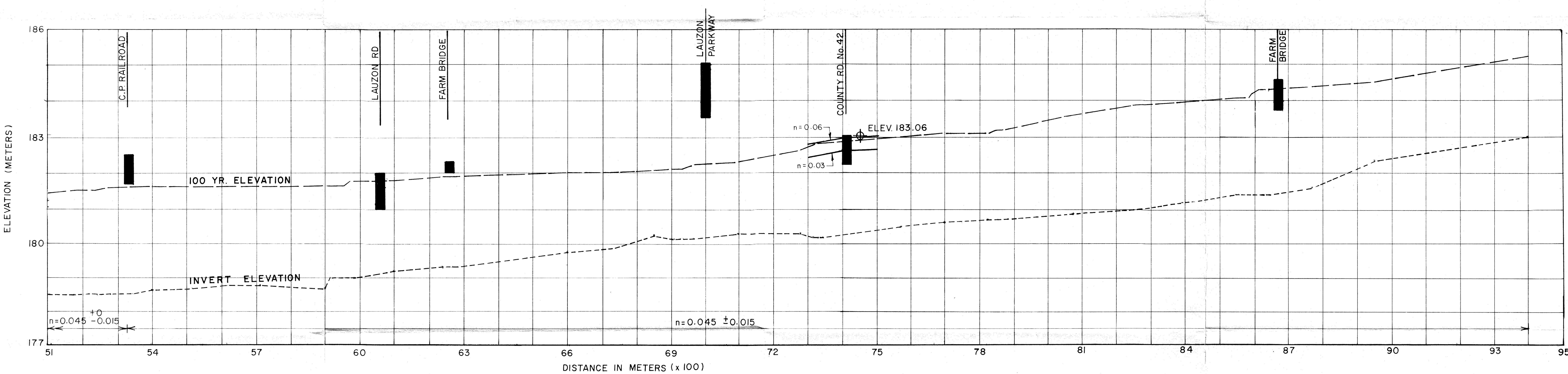
SECTION NO.	STRUCTURE	MINIMUM ELEV.	REGIONAL FLOW	STORM ELEV.	1:100 yr. FLOW	Event ELEV.
46102	ST-9	178.4	47.5	181.08	34.0	180.99
46203		178.4	47.5	181.51	34.0	181.19
46304		178.4	47.5	181.52	34.0	181.32
47100		178.3	47.5	181.53	34.0	181.34
48000		178.3	47.5	181.53	34.0	181.36
48500		178.2	47.5	181.56	34.0	181.40
49000		178.2	47.5	181.57	34.0	181.42
50350		178.2	47.5	181.60	34.0	181.48
51701		178.2	47.5	181.63	34.0	181.54
52302	ST-10	178.2	47.5	181.64	34.0	181.56
52403		178.2	47.5	181.64	34.0	181.56
52804		178.2	47.5	181.72	34.0	181.62
54000		178.3	44.8	181.74	32.3	181.64
55200		178.4	44.8	181.77	32.3	181.67
56150		178.5	44.8	181.77	32.3	181.68
57100		178.5	44.8	181.78	32.3	181.68
59000		178.7	44.8	181.79	32.3	181.70
59201		178.7	38.1	181.80	27.7	181.71
59602	ST-11	178.7	38.1	181.80	27.7	181.72
59703		178.7	38.1	181.92	27.7	181.83
59804		178.7	38.1	181.92		

7.7 181.83

61000		178.8	38.1	181.94	27.7	181.85
62301		179.0	38.1	181.98	27.7	181.91
62602	ST-12	179.0	38.1	181.98	27.7	181.91
62643		179.0	38.1	182.02	27.7	181.92
62804		179.0	38.1	182.02	27.7	181.93
66000		179.4	38.1	182.08	27.7	182.01
67250		179.5	33.7	182.10	24.4	182.03
68501		179.7	33.7	182.13	24.4	182.08
69002	ST-13	179.9	33.7	182.15	24.4	182.12
69023		179.9	33.7	182.15	24.4	182.12
69214		179.9	33.7	182.17	24.4	182.16
69235		179.9	33.7	182.17	24.4	182.17
69736		179.9	33.7	182.32	24.4	182.29
71000		179.9	33.7	182.35	24.4	182.34
72801		179.9	33.7	182.50	24.4	182.61
73102	ST-14	179.9	33.7	182.51	24.4	182.63
73223		179.9	33.7	182.91	24.4	182.84
73404		179.9	33.7	182.96	24.4	182.87
75800		180.2	33.7	183.02	24.4	182.99
77000		180.3	33.7	183.08	24.4	183.10
78201		180.4	33.7	183.20	24.4	183.09
78502	ST-15	180.4	33.7	183.26	24.4	183.19
78553		180.4	33.7	183.34	24.4	183.20
78704		180.4	33.7	183.35	24.4	183.23
80600		180.5	33.7	183.54	24.4	183.57
82500		180.7	33.7	183.71	24.4	183.82
83950		180.9	33.7	183.84	24.4	183.96

SECTION NO.	STRUCTURE	MINIMUM ELEV.	REGIONAL FLOW	STORM ELEV.	1:100 yr. FLOW	Event ELEV.
85401		181.1	33.7	183.97	24.4	184.07
85702	ST-16	181.1	33.7	183.96	24.4	184.08
85803		181.1	33.7	184.17	24.4	184.17
86104		181.1	33.7	184.43	24.4	184.34
86400		181.4	33.7	184.44	24.4	184.35
87700		181.6	33.7	184.46	24.4	184.39
89500		182.0	33.7	184.55	24.4	184.54
94000		182.7	33.7	185.10	24.4	185.21





⌖ RECORDED OCT. 1, 1981 HIGH WATER LEVEL (m) GSC

No	REVISIONS	DATE	INTLS

MICROFILM ROLL No. DR-

DRAWN BY REW	DESIGNED BY E.E.
CHECKED BY E.E.	APPROVED BY E.E.

MacLaren Engineers
MacLAREN ENGINEERS INC. Lavalin

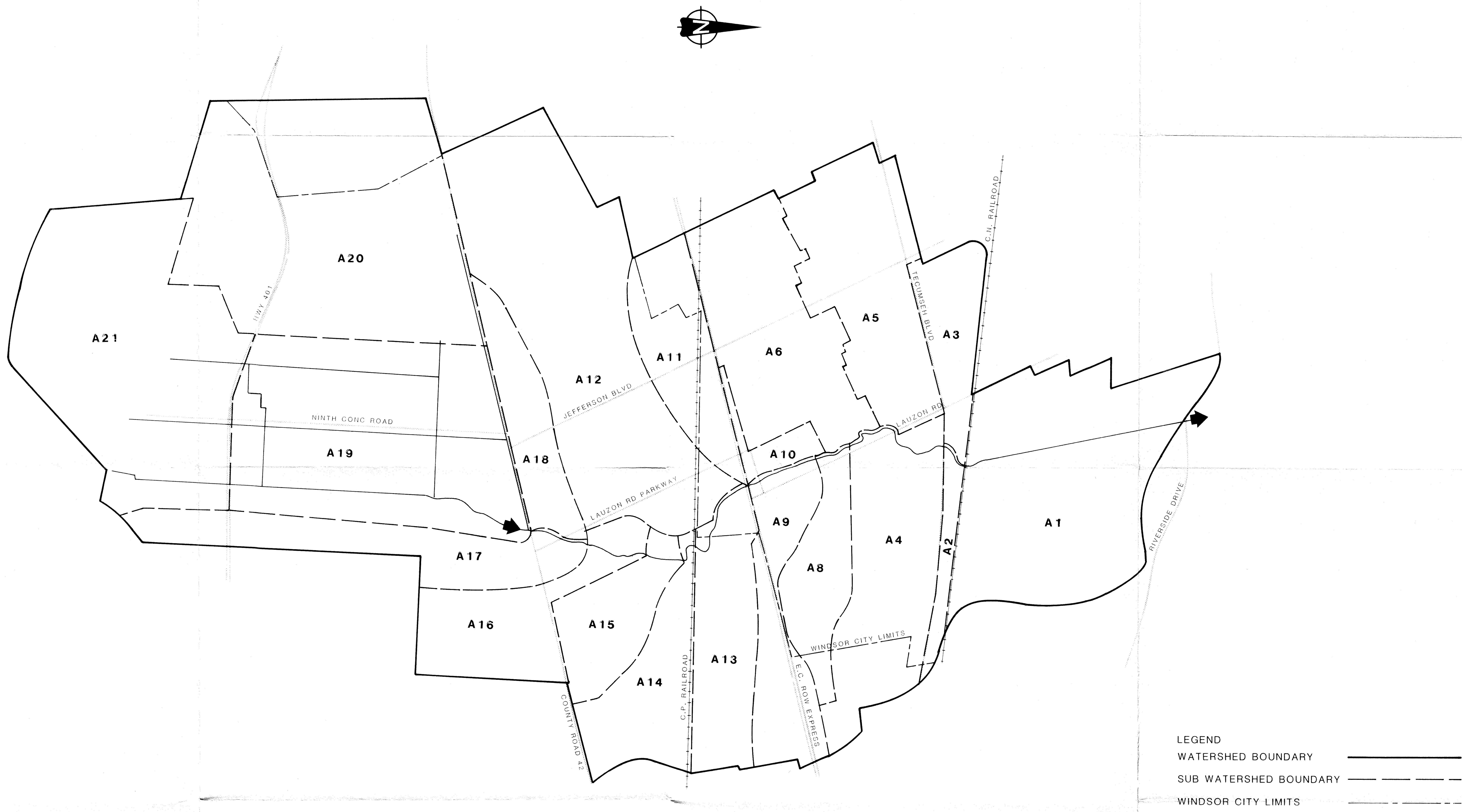
ESSEX REGION CONSERVATION AUTHORITY
LITTLE RIVER FLOODLINE MAPPING

HYDRAULIC PROFILE OF LITTLE RIVER
FOR 1:100 YEAR FLOOD FLOW

DATE	SCALE
SEPT. 1986	HOR. 1: 600 VERT 1: 6

FIGURE 5

FILE 42141-A1



No.	REVISIONS	DATE	INTLS

MICROFILM ROLL No. DR-

DRAWN BY | DESIGNED BY | CHECKED BY | APPROVED BY

MacLaren Engineers

MacLAREN ENGINEERS INC — Lavalin

ESSEX REGION CONSERVATION AUTHORITY
LITTLE RIVER FLOODLINE MAPPING

WATERSHED / SUB WATERSHED DELINEATIONS

DATE: SEPT. 1986
SCALE: 1:25000

FIGURE 2

FILE 42141-1-A1-