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May 21, 1981

Rideau Valley Conservation Authority
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ATTENTION: Mr. O. Stirajs
General Manager

Dear Sir,

FLOODPLAIN MAPPING STUDY - TAY RIVER

We are pleased to submit twenty copies of our floodplain mapping report for the reach of the Tay River, from Glen Tay to the Tay Marsh. This report contains the text, photographs, figures, tables, and floodplain maps which document and illustrate our findings. The computer output sheets, previously submitted, are to be read in conjunction with the report. These sheets provide additional detailed information relating to flood flow rates, water surface elevations, and the extent of flooding.

The main results of the study can be summarized as follows:

1) Potential flooding problems that have been identified are generally associated with residential and commercial buildings within the floodplain — essentially those within the Town of Perth and environs.

2) Spill areas have been identified. Flood levels in the Tay River are not, however expected to be significantly reduced due to the presence of such spills.

3) The high flood levels to be anticipated in the River can be substantially attributed to the flat gradient of the channel. The presence of existing structures were not identified as contributing to significant backwater problems.

4) An assessment of regulation measures for Bob's Lake was carried out. This assessment indicates that a significant reduction of the Lake level, and attenuated downstream peak flood flow rates, can be achieved with the appropriate operation policy.

5) The operating policy of lowering the water level in the Tay Marsh does not appear to provide any significant flood reduction upstream in the built up area of Perth.

6) The potential formation of ice jams exists in the Tay River, at the entrance to the Tay Marsh. The major cause for such a jam would be the build up of ice floes against a stable ice cover in the Tay Marsh.

Appended to the report is the supplementary report on the analysis of the hydraulic capacity of the Tay River at the outlet of Christie Lake. This study shows that the high water elevation in Christie Lake, is not due to any channel obstructions but essentially because of the limited hydraulic capacity of the channel.

Yours very truly,
FENCO CONSULTANTS LTD.

D.J.W. Moncrieff, P.Eng.
Manager - Transportation Services

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Encl.

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SUMMARY

This report describes the results of a flood plain mapping study of the Tay River in the vicinity of Perth, Ontario. This report should be read in conjunction with flood plain maps of the Tay River from Glen Tay to the Tay Marsh. These flood plain maps show the one in one hundred return period flood levels and fill lines.

The Tay River watershed has an area of approximately 780 square kilometers (see Figure 1). It is located within the Canadian Shield and includes parts of Lanark, Leeds and Frontenac Counties. Approximately 10 percent of the catchment is covered by lakes. Bob's Lake is the major regulated water body in the watershed. This lake is regulated by Bolingbrook Dam which is operated by Parks Canada as part of the Rideau Canal System. Tay Marsh and Eagles Lake are also regulated by dams.

Land use within the watershed is predominantly rural in character. The Town of Perth is the only major urbanized area in the watershed. There is no indication that current land use patterns will change significantly in the near future.

Hydrologic calculations have been performed to estimate flood flow rates for a one in one hundred year return period flood. The methods used in these calculations have been single station data transfer, regional flood frequency analysis, the watershed classification method and single event simulation.

The single event simulation model enable various reservoir operating policies to be assessed so that the effects of regulating water levels in Bob's Lake and Tay Marsh can be evaluated.

The results indicated that regulation of Bob's Lake can result in significant reductions in the peak flood flow rate downstream of Bolingbrook Dam. The high water levels in Bob's Lake can also be reduced by proper operation. The policy for operation of Bob's Lake as outlined in the report "Study of the Operation of the Rideau - Cataraqui System" (Reference 1) appear to provide greater flood protection than operating policies used previously.

Regulation of Bob's Lake does not influence peak flood flow rates in Perth, if the flood is generated by a short duration (less than three days) snowmelt or rainstorm event. Flood flows at Perth resulting from longer duration events are, however,significantly influenced by the operation of Bolingbrook Dam.

The recommended design flow rate for the flood plain mapping at Perth is 150.4 m^3/sec. This was the flow rate from a simulated one in one hundred year snowmelt event with a duration of 2 days.

The hydraulic calculations show that the design flood would cause widespread flooding downstream of Perth. This area is currently undeveloped. Within the Town of Perth the risk of flood damage exists due to a number of residences and commercial buildings which are located within the flood plain. Upstream of Perth there are also several residences located within the flood plain.

A number of spill areas exist. Three spill zones are located downstream of Glen Tay where water would flow from the Tay River across the flood plain to Grants Creek. Another spill zone exists north of the C.P.R. tracks at Long Swamp. Despite these spill areas the amount of flood water flowing in the Tay River is not expected to be significantly reduced.

The major cause of flooding appears to be due to the flat gradient of the Tay River and the fact that there is no deep valley to contain the floods. Structures in waterways were not identified as causing flood problems.

It has been reported that ice jams occasionally occur in the reach of river between Perth and the Tay Marsh. These jams may be caused by chunks of ice lodging on islands, in bends of the river or on a more stable ice cover in Tay Marsh.

The water level in Tay Marsh is lowered every Fall in order to provide additional flood protection to the Town of Perth. This policy has been reviewed as part of this study. The hydrology calculations indicate that the attenuation of flood waves in Tay Marsh is similar regardless of whether the water level is lowered or at the normal summer operating level. The hydraulic analysis indicates that the flood elevations in Perth are related to the flood flow rate and are not influenced by water levels in Tay Marsh. It was not possible to identify any significant flood reduction as a result of lowering the water level in the Tay Marsh for the winter.

It is recommended that a former policy of not lowering the water level in the Tay Marsh be reinstated. The potential benefits of this approach are as follows:

1. The ice cover on the Tay River will be formed at a higher elevation. This will increase the hydraulic capacity of the river when an ice cover exists. It will also delay the break up of the ice cover in the spring and thus may reduce the risk of ice jams.

2. It may reduce maintenance problems caused by bull rushes freezing at the roots, becoming dislodged in the spring and accumulating at Beveridge Dam.

3. It may improve the habitat for the mammals and amphibians which inhabit the marsh. It is alleged, for example, that the practice of lowering water levels in the winter has reduced the population of frogs and other marsh inhabitants.

The analysis of the hydraulic capacity of the Tay River downstream from Christie Lake has been documented in a separate letter report submitted to the Authority. The investigation showed that there are no obstructions in the channel restricting the flow. The limited capacity of the channel to receive the flood flows causes the high water levels at Christie Lake. Appendix V contains a copy of this report.

INTRODUCTION

The Rideau Valley Conservation Authority has retained FENCO CONSULTANTS LTD. to carry out a floodplain mapping study of the Tay River in the vicinity of Perth, Ontario. Figure 1 shows the Tay River watershed and the reaches of the River which were studied in detail.

Scope

The scope of the project may be summarized as follows:

1) Collect and review background information related to the project such as,"as-built" drawings, flow data and previous reports.

2) Coordinate the services of a mapping contractor to obtain topographic maps of the floodplain between Glen Tay and Tay Marsh.

3) Carry out field surveys and reconnaissance of the River to establish bridge dimensions, obtain soundings and to check the topographic mapping.

4) Prepare a hydrology study to determine the 1 in 100 year design flood.

5) Establish water surface elevations for the Design Flood using computer program HEC-2.

6) Plot the floodlines on the topographic maps.

7) Evaluate the outlet of Christie Lake to identify any channel restrictions.

8) Appraise the operation policy of Beveridge Dam to determine if the current policy reduces flood risks in Perth.

9) Prepare a technical report outlining the findings of the study.

In addition to the above, an analysis to estimate the hydraulic capacity of the Tay River downstream of Christie Lake was performed. The purpose of this investigation was to identify any natural or man-made restrictions in the channel which may be contributing to flooding and ice damage problems occurring along the shores of Christie Lake. The documentation of this study is presented in Appendix V of this report.

The results of the above study, carried out in accordance with the Terms of Reference prepared by the Rideau Valley Conservation Authority are presented in this report and on the floodplain maps.

WATERSHED CHARACTERISTICS

General

The Tay River watershed covers an area of approximately 780 square kilometres. The catchment includes parts of Lanark, Leeds and Frontenac Counties, as shown in Figure 1.

Tributary streams to the Tay River include Grants Creek, which joins the Tay upstream of Perth, and Jebbs Creek which joins immediately upstream of Tay Marsh. Lakes within the watershed cover more than 10 per cent of the total catchment area. Many of these lakes are regulated. The largest of the lakes, Bob's Lake, and Tay Marsh are controlled by dams operated by Parks Canada for the Rideau Canal System. Water level in Eagle Lake is controlled by a dam operated by the Ministry of Natural Resources.

Land Use

Land use within the Tay River watershed is predominantly rural. Some wooded pastures and crop lands exist in the eastern portions of the watershed while swamps and forests characterize the western portion of the catchment.

The Town of Perth is the only major urbanized area within the watershed. This town, located in the lower portion of the watershed, covers an area of some 530 hectares.

Cottages are located along the shores of most of the lakes and other small settlements are scattered throughout the watershed.

Information obtained from various planning agencies indicates that present land use patterns are not expected to change significantly in the foreseeable future. The existing undeveloped nature of the Tay River watershed was therefore used in calculating anticipated runoff.

Geology and Soils

Geology and soils data were obtained from "Soil Surveys" of Frontenac, Lanark and Leeds Counties.

The Tay River watershed is located within the Canadian Shield. The bedrock is predominantly Precambrian composed of igneous, metamorphic and some metamorphosed limestone. Cambrian rock (limestone) exists in a portion of the catchment near Perth.

The soils are predominantly sandy loams of the Monteagle and Tweed series. The depth of soil cover is generally shallow and rock outcrops are common. Clay loams are found in the vicinity of Perth. Soils, which may be classified as "muck", occur throughout the watershed where poorly drained land forms exist. Figure 2 shows the location of the various soil types within the watershed.

Flood Problems

Flooding problems within the study area, according to reports from local municipal authorities, have not caused significant property damage. However, large areas of low land adjacent to the river are inundated at times. This has raised concerns about possible flood damage if development occurs within the flood zone. Thus, this study is being carried out to determine the limits of flooding so that proper control and zoning bylaws can be enacted.

Local residents have reported that ice jams occur upstream of the Tay Marsh. Flooding has been attributed to these jams.

The water level in Beveridge Dam has been lowered every fall in an attempt to reduce flood risks in Perth. There has been some controversy over the effectiveness of this procedure in lowering flood levels. It is alleged that this lowering of the water level in Tay Marsh has reduced the population of amphibians in the marsh. Also Rideau Canal maintenance personnel feel that lowering the water level in the Tay Marsh during the winter may be contributing to the blockage of Beveridge Dam by bulrushes.

Cottagers have expressed concern about flooding and ice damage along the shore of various lakes within the watershed. Most of these complaints have come from owners on Christie Lake.

HYDROLOGY

The hydrologic characteristics of the watershed were evaluated to establish the 100 year flood flow rate in the Tay River. A number of methods were used to calculate the flow rate. The following paragraphs describe the methodology utilized to establish the design flow rate for the 100 year flood.

Single Station Data Transfer

Flood flow estimates were derived by transposing flood flow estimates from adjoint watersheds to the Tay River. Relationships defining flow rate as a function of flood frequency are available for gauging stations on the Mississippi, Rideau and South Nation Rivers. This data is documented in the report entitled "Magnitude and Frequency of Floods in Southern Ontario", (Reference 12).

The instantaneous peak flow rates for the above rivers were transferred to the Tay River at Perth using the following expression

$$Q2 = Q_1 \left(\frac{A_2}{A_1}\right)^{0.75} \qquad (1)$$

where:

Q_2 = peak flow rate in the Tay River
Q_1 = peak flow rate at the gauging station
A_2 = area of watershed tributary to the Tay River
A_1 = area of watershed tributary to the stream gauge.

The index of 0.75 in equation 1 was selected on the basis of information contained in "Design Flood Estimation for Medium and Large Watersheds" (Reference 8).

The results of this analysis are shown in Table 1. There is a relatively wide variation in the results that were obtained using this method. Application of the data from the Mississippi River results in lower flow rates than that from the information obtained from the Rideau River or the South Nation River. This difference is attributed to the fact that the South Nation River is located in the St. Lawrence Lowlands while the Mississippi River is located in the Canadian Shield. Watersheds in the Canadian Shield tend to have lower peak flow rates.

Regional Flood Frequency Analysis

Two methods of Regional Flood Frequency Analysis were used to estimate 100 year flood flows in the Tay River.

A method developed for the Canadian Shield between Capreol and Armstrong and described in the report entitled "Flood Frequency Analysis, CN Mainline Capreol to Armstrong", (Reference 6) was employed. This method uses the index flood method to calculate flow rates and takes into account the watershed slope, watershed area and water surface area of lakes.

The second method is described in the report "Magnitude and Frequency of Floods in Southern Ontario" (Reference 12). The index flood method is also employed, although watershed area is the only parameter considered in the analysis.

The results are indicated in Table 1. There is relatively close agreement between the two methods.

Watershed Classification Method

The watershed classification method is described in "Design Flood Estimation for Medium and Large Watersheds" (Reference 8). This method uses the following equation to relate flow rate to watershed area:

$$Q_{25} = C\ A^{0.75} \qquad (2)$$

where:

Q_{25} = flow rate associated with a twenty five year return period

C = a coefficient selected to reflect the watershed classification

A = watershed area

The watershed classification is determined from watershed characteristics such as soil type, land use, slope, amount of retention in the watershed and a precipitation index.

The flow rate associated with a one hundred year return period is estimated by multiplying the twenty five year flow rate by a factor. The method for determining the ratio of one hundred year peak flow to twenty five year flow is described in Reference 8.

Two approaches were used in applying this method. It was assumed that the watershed was a Class "A" type of basin (Canadian Shield) and that it was a Class "B" type of basin (Southern Ontario-St. Lawrence Lowlands). These results indicate that flow rates for the Class "B" type of basin were approximately double the flow rates calculated for a Class "A" type of basin.

Single Event Simulation Model

Flood flow hydrographs for the watercourse were computed using unit hydrograph techniques outlined in the "SCS National Engineering Handbook" (Reference 17). This involved the following steps:

1. The watershed was subdivided into subcatchments as shown on Figure 3.

2. The area, length, elevation differential, area of lakes, and the percentage of the subcatchment area in each soil type - land use category was measured for each of the areas. The land use data from the "Rideau Valley Conservation Report" (Reference 11) was used together with soils information contained in the "Soil Surveys" for Frontenac, Lanark and Leeds Counties. (Reference 14, 15, 16).

3. Curve numbers which reflect the infiltration characteristics of the various soils types and land uses were selected. The curve number of each soil type and land use are shown in Table 2.

4. Using the previously compiled data, the time of concentration was estimated for each of the subcatchments using the Kirpich Formula. A number of other methods for computing the time of concentration were also tested. The method noted above was used because it is widely applied in Ontario for this type of project and our subsequent calculations indicated that the predicted flow rates were not particularly sensitive to the method used to compute the time of concentration. Compositive curve numbers were computed using weighted

averages of the curve number for each soil type and land use located within each subcatchment. Table 3 shows the values that were measured, for each subcatchment, together with the computed time of concentration (Tc) and composite curve numbers for each of the areas.

5. A schematic diagram of the watershed is shown in Figure 4. This shows the connections between the subcatchments, lakes and channels which were modelled.

   It should be noted that in some cases two lakes were assumed to act as one unit. An example of this is Bob's Lake and Crow Lake. Above elevation 162.20 metres the two lakes are joined together. Another example is Pike Lake and Crosby Lake which are connected by a short navigable channel.

   Channels were modelled when they were of sufficient length to have a travel time which was greater than approximately one hour. These consist of Grants Creek and Tay River between Christie Lake and Tay Marsh. The other channels in the watershed have travel times less than one hour. These include Tay River between Eagle Lake and Bob's Lake; Tay River between Bob's Lake and Christie Lake; and Jebb's Creek. It was considered impractical to attempt to model these short channels. The numerical errors introduced by attempting to model a short channel may be greater than approximations involved in not modelling the channel.

   The version of HYMO used for this study utilized the SCS dimensionless unit hydrograph technique to model runoff from the subcatchments. The Convex Method was used for channel routing. Reservoir routing was carried out using the Storage-Indication Method.

6. Eagle Lake, Bob's Lake, Christie Lake, Pike Lake, Otty Lake and Tay Marsh were modelled as reservoirs in the single event simulation model. Thus, for each reservoir, rating curves which define flow rate and storage as a function of elevation were defined.

It was necessary to consider four different operating policies for the reservoirs in order to assess the response of the watershed to reservoir management. These four policies are described below:

Operating Policy 1

Stop logs were assumed to be at the Fall - Winter operating level of (elevation 161.37 m) for Bob's Lake described in the report "Study of the Operation of the Rideau - Cataraqui System" prepared for Parks Canada by Acres Consulting Services Ltd.

Stop logs at Eagle Lake and Beveridge Dam were assumed to be removed. Tay Marsh was assumed to be at the winter level of 129.65 metres.

It was assumed that no changes in stop log position were made during the flood event.

Operating Policy 2

It was assumed that all of the stop logs were in position. Thus, all reservoirs were at their summer water level. This is a very conservative assumption but it is useful to test the sensitivity of the watershed response to various operating policies.

Operating Policy 3

The stop log positions for this case were the same as for Policy 1 at the start of the flood event. However, it was assumed that as the water level in Bob's Lake increased, additional stop log's were added at Bob's Lake so that the outflow was relatively constant until the top stop logs were installed (The simulated outflow from Bob's Lake while being filled was 2.55 m^3/s.).

Operating Policy 4

The assumed stop log position at Eagle Lake and Beveridge Dam were the same as those for Policy 1.

The assumptions made at Bob's Lake were the same as Policy 3 except that the initial stop log elevation was at the bottom of the conservation zone (elevation 160.15 m). It was assumed that stop logs were added as required to provide a nearly constant outflow (The simulated outflow while Bob's Lake was filling varied from 3.0 m^3/s to 8 m^3/s.).

This policy is representative of the recommendations outlined in Acres report where it is suggested that Bob's Lake be lowered in the late winter period, based on runoff volumes forecast from snow surveys.

A portion of subcatchment 9 is below Otty Lake; however it was considered to contribute to Otty Lake and the outflow was routed through the lake. This was done because at the time of the field visit a beaver dam existed at the outlet of Jebb's Creek and it appeared to control water levels back to Otty Lake.

With respect to Policy 1 through 4, it was assumed that no changes were possible in the rating curves for Christie, Otty and Pike Lakes. Thus, only one rating curve was defined for each of these lakes regardless of the operating policy used.

Tables 4 through 9 show the rating curves for the above lakes.

7. The rainfall quantities for the study area were determined from rainfall intensity duration frequency data published by the Atmospheric Environment Service for the rain gauge at Cornwall, Ottawa and Smiths Falls.

Rainfall volumes for different durations of the 100 year storm are presented in Table 10. The rainfall distribution used for the 24 hour event is shown in Table 11. The same distribution was used to model 12 hour and 48 hour rainfall events except that the time base was adjusted accordingly.

The snowmelt quantities were estimated from an analysis of temperature and precipitation data from meteorological stations at Cornwall, Ottawa and Smiths Falls. The details of this analysis are given in Appendix IV. Five models were used to predict snowmelt given temperature and precipitation data for durations of one to ten days. Extreme value probability functions were fitted to the data to predict 2, 5, 10, 25, 50 and 100 year snowmelt volumes for the five different models and the different durations.

The Cornwall data for Model 3 (the UBC Snowmelt Model) was used for this study. The Ottawa data was not available at the outset of the study. However, subsequent analysis of the Ottawa data provided results which were nearly identical to the Cornwall data. The Smiths Falls data was found to give results which were lower. This was attributed to the fact that the period of record at Smiths Falls is much shorter than the period of record at the other two stations. A comparison of predicted snowmelt quantities at Cornwall, Ottawa and Smiths Falls using Model 3 is presented in Figure 5.

The snowmelt quantities for a 100 year return period and different durations are shown in Table 10. The snowmelt was assumed to vary sinusoidally throughout the day as described in Reference 4. A dimensionless distribution for a 24 hour period is shown in Table 12.

8. Twenty-five runs of the HYMO model were made. The purposes for the numerous runs are:

i) To test which event duration causes the highest peak flow rate.

ii) To estimate the sensitivity of predicted peak flow rates to different reservoir operating policies.

iii) To determine if summer rainfall or snowmelt events cause the largest peak flow rates.

iv) To assess changes in peak flow rate due to changes in assumed antecedent moisture conditions.

v) To study the effects of varying time steps used in some of the simulations. A summary of the various runs, the assumptions and the results are shown on Table 13.

Results of Hydrology Analysis

The main recommendations and findings of the hydrology analysis are summarized in the following paragraphs.

Based on our analysis of the results from the single event simulation model and the other methods of analysis, we recommend that the flow rate of 150.4 m^3/sec be used for floodplain mapping of the Tay River in Perth, Ontario. This value was predicted from a single event simulation of a 2-day snowmelt event. The flood hydrograph for two locations near Perth are shown in Figure 6.

Higher flow rates were indicated in some of the simulations, however these higher flow rates and the associated assumptions were not selected for the design flow rate after comparisons were made with the results of the single station data transfer and the regional flood frequency analysis. The higher flow rates appeared to be typical of what would occur in a watershed within the St. Lawrence Lowlands. The Tay River is located in the Canadian Shield, thus lower peak flow rates would be anticipated.

The operation of Beveridge Dam does not affect the design flood flow rate in Perth. However, correct regulation of the water level in Bob's Lake can reduce peak flow rates within the watershed. This is particularly true when the flood event has a long duration. For example, if a 10 day snowmelt event were to occur and Bob's Lake had not been drawn down prior to the event (Operating Policy 2) the peak flow rate predicted at Perth is 220 m^3/sec. If Bob's Lake was drawn down prior to the event (Operating Policy 4) the peak flow rate predicted at Perth is 115 m^3/sec.

Operation of Bolingbrook Dam at Bob's Lake does not seem to have as pronounced an effect if short events are causing the flooding. The peak flow rate predicted at Perth with a 2-day snowmelt event is approximately 150 m^3/sec regardless of the assumed operating policy.

The single event simulation results indicate that the attentuation of the flood wave in Tay Marsh is independent of the various operating policies that were modelled in our study.

HYDRAULIC ANALYSIS

The water surface elevations were established in the reach of the Tay River from Tay Marsh to Glen Tay for the 100 year flood. The following paragraphs describe the methodology used to determine the flood limits for the flood plain maps.

Field Surveys and Reconnaissance

Field surveys and reconnaissance of the Tay River from Glen Tay to Beveridge Dam were carried out. During these surveys the following activities were accomplished:

1. The dimensions of all bridges, culverts and dams located along the river were measured.

2. Inspection of the flood plain for any natural obstructions and establishment of roughness coefficients was completed.

3. Soundings of the river were made so that the low flow channel could be modelled.

4. A geodetic survey to establish the elevation of structures and to confirm topographic map information was performed.

5. Photographs of the bridges, culverts, dams and typical reaches of the river were obtained. Copies of these photographs are in Appendix I.

Backwater Calculations

Water surface elevations were calculated using computer program HEC-2. (Reference 9). Cross-sections describing the geometry of the flood plain was obtained from topographic maps. The geometry of the low flow channel at each cross-section was obtained by interpolation of field collected data. Sections describing the bridges and other structures were also derived from field survey information.

The flow rates along the river for the design flood were obtained from the single event simulation model described earlier. The design flow rate represents a flood with a return period of once in a hundred years.

The downstream water surface elevation used for calculation of the flood lines assumed that all of the stop logs were in place at Beveridge Dam. This is the normal summer operating condition of the dam.

This operating condition was assumed after a number of calculations were performed to determine how sensitive the computed flood water elevation in Perth was to changes in water levels at Beveridge Dam. Multiple backwater calculations were performed with flow rates ranging from 75 m^3/s to 300 m^3/s in the reach from the Perth basin to Beveridge Dam. One set of these calculations was performed with all of the stop logs at Beveridge Dam removed. The second set of calculations assumed that the stop logs were in place. Comparing water levels at the Perth Basin indicates that the water level would be lower by a very small amount if the stop logs at Beveridge Dam were removed. These differences are, however, considered to be insignificant. For example, with a flow rate of 75 m^3/s the difference in water surface elevation was 0.08 metres. The difference in water surface elevation was 0.02 metres with flow rates greater than 100 m^3/s.

The above results indicate that flood water elevations downstream of Perth are governed largely by flow resistance and the fact that the relatively flat River gradient of 0.00013 metres per metre does not impart a large driving force. It can also be concluded that lowering water levels in Tay Marsh does not provide significant additional flood protection for the Town of Perth.

Flooding Problems

A description of the flood limits and flood risks identified as a result of the backwater calculations are provided in the following paragraphs. Reference should be made to the flood plain maps; which show the computed water surface elevations, flood lines and fill lines; to assist in the interpretation of this section. Detailed information regarding the depth of flooding and flow velocities may be obtained by referring to the computer output from the backwater surface profiles.

A large flood plain exists downstream of Perth due to the low elevation of the land in relation to the river channel. This area is used primarily for agricultural purposes and if flooding occurs early in the spring and does not interfere with the timing of spring planting, this condition may be acceptable and flood damages would be relatively low. If other development or land use were to occur in this area the risk of flood damage would be relatively high.

Within the Town of Perth there are numerous residential and commercial buildings located inside the flood line. Beckwith Street and Drummond Street would be overtopped by a large flood.

It should be noted that none of the bridges in the study area, from Tay Marsh to Glen Tay, act as a control or cause excessive headloss which leads to upstream flooding.

A spill area is located north of the C.P.R. tracks. Flood waters from the Tay River could flow through the culvert under the railway tracks. If sufficient runoff is generated within the spill zone and adjacent land, the water level within this spill zone could be higher than the flood elevation in the Tay River. Alternatively if there is not a large amount of runoff generated within the spill zone the culvert under the C.P.R. tracks could limit the flow into the spill zone and thus result in a water level which is lower than the flood elevation then prevailing in the Tay River. The flow rate into the spill zone would be in the order of 1.5 - 2.0 m^3/s, (approximately one percent of the total flow), assuming the runoff generated within the spill zone is not large.

Haggarts Dam and Tay Road Dam form a hydraulic control to form. Thus flood levels upstream of these structures are not influenced by water levels downstream. Some residences are located in the flood plain upstream of Haggarts Dam and downstream of the Golf Course.

Upstream of the Golf Course to Glen Tay, the flood plain is relatively narrow. However there are several residences located on the fringes of the flood plain which could be subject to damage in the event of a major flood. Two spill zones have been identified along this reach of the river. The flow through these areas would discharge to Grants Creek. As a result, the design flow rates downstream of Grants Creek would not be changed by these spills. These spills could reduce the flow rate in the Tay River upstream of Grants Creek depending on the flood level in Grants Creek. Assuming the flood level in Grants Creek does not affect the water level in Tay River, approximately 1.0 m^3/s (less than one percent of the total flow) would enter the spill area in the vicinity of cross-section 8+358. The depth of flow entering the spill area is less than 0.5 metres. This reduced flow rate will not lower the flood level in Tay River significantly. An estimated 20 m^3/s, (approximately twenty percent of the total flow) would spill into Grants Creek in the vicinity of Glen Tay. The depth of flow entering the spill area is 2 metres. This spill would reduce the flood level in the order of 0.5 metres immediately downstream of Glen Tay. Further downstream the reduction would be much less.

The position of the flood lines would not change significantly with the above noted changes in water level. Thus it is not necessary to determine the flood levels in the spill zones and we recommend and have adopted that the water level computed assuming no spill be used for flood line definition.

Ice Jamming

It has been reported that flooding caused by ice jams has occurred. These jams have reportedly occurred upstream of Tay Marsh.

The presence of ice increases flood risks in a number of ways. A stable ice sheet on the water surface increases flow resistance and therefore reduces the hydraulic capacity of the channel. Increases in flow in a channel can lead to break up of the ice sheet. The chunks of ice can then form jams further downstream at constrictions in the channel, on mud banks or at locations where a stable ice sheet exists.

Two potential causes of ice jams can be identified in the Tay River upstream of Tay Marsh, namely:

1) Some islands exist between what appears to be the old river channel and the navigation channel, which could contribute to the formation of ice jams.

2) High flow rates could cause the break-up of the ice sheet on the Tay River while the ice cover over Tay Marsh remains stable.

Ice jamming has not been considered in the backwater calculations due to the unpredictable nature of ice jam formation.

The problems of ice jamming can be reduced by not lowering water level in Tay Marsh during the winter months. This will result in a stable ice cover being formed at a higher elevation. Thus there will be a larger flow area under the ice. This will reduce hydraulic friction and delay the break up of the ice cover.

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APPENDIX I

PHOTOGRAPHS

PHOTO 1 LOOKING UPSTREAM TO BEVERIDGE DAM

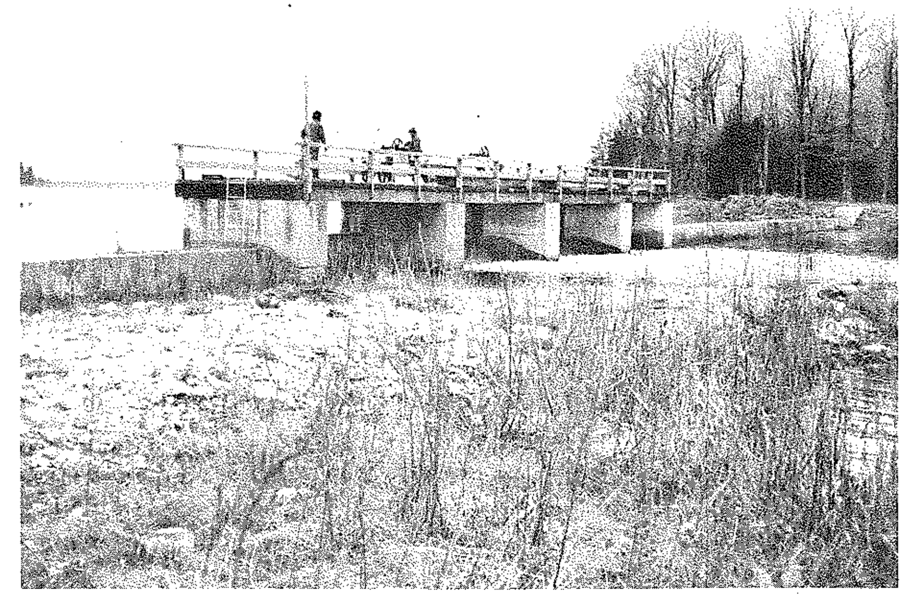


PHOTO 2 STOP LOG BAYS AT BEVERIDGE DAM

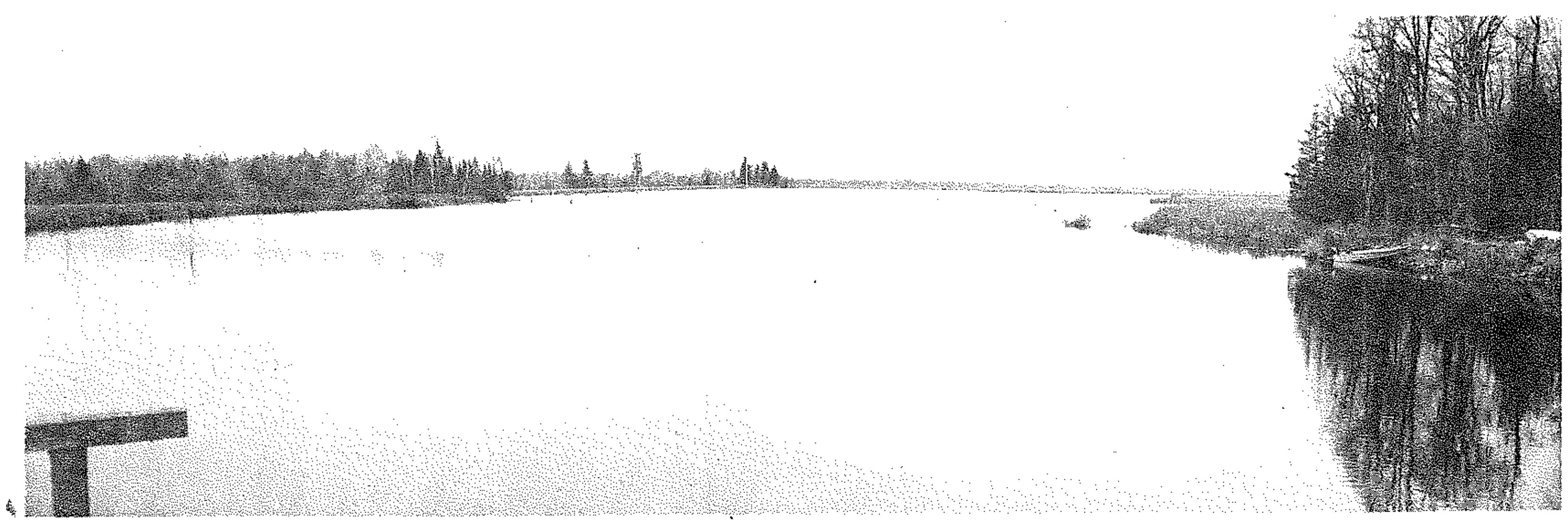


PHOTO 3 TAY MARSH AS SEEN LOOKING UPSTREAM FROM BEVERIDGE DAM

PHOTO 4 TYPICAL CHANNEL UPSTREAM OF TAY MARSH

PHOTO 5 LOOKING DOWNSTREAM FROM CRAIG STREET BRIDGE

PHOTO 6 LOOKING UPSTREAM TO CRAIG STREET BRIDGE

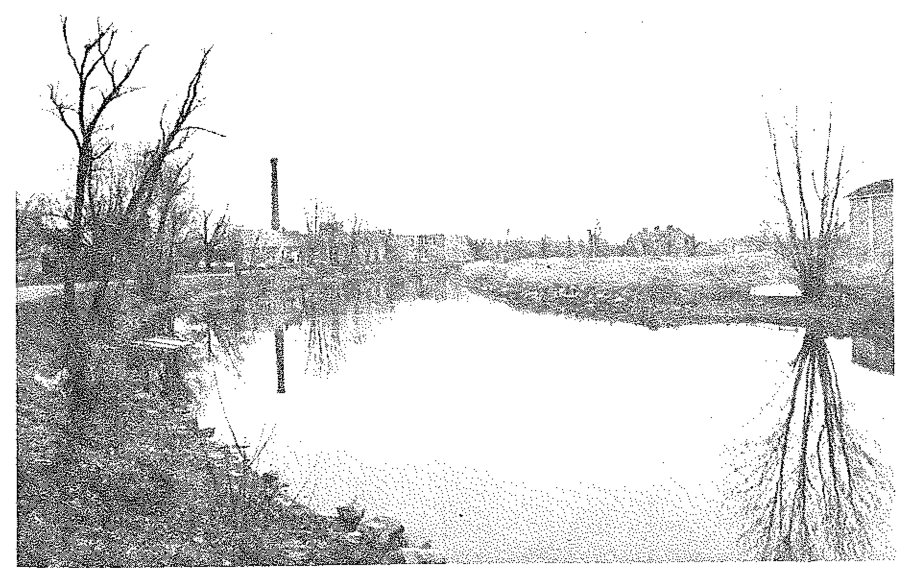


PHOTO 7 LOOKING DOWNSTREAM FROM BECKWITH BRIDGE

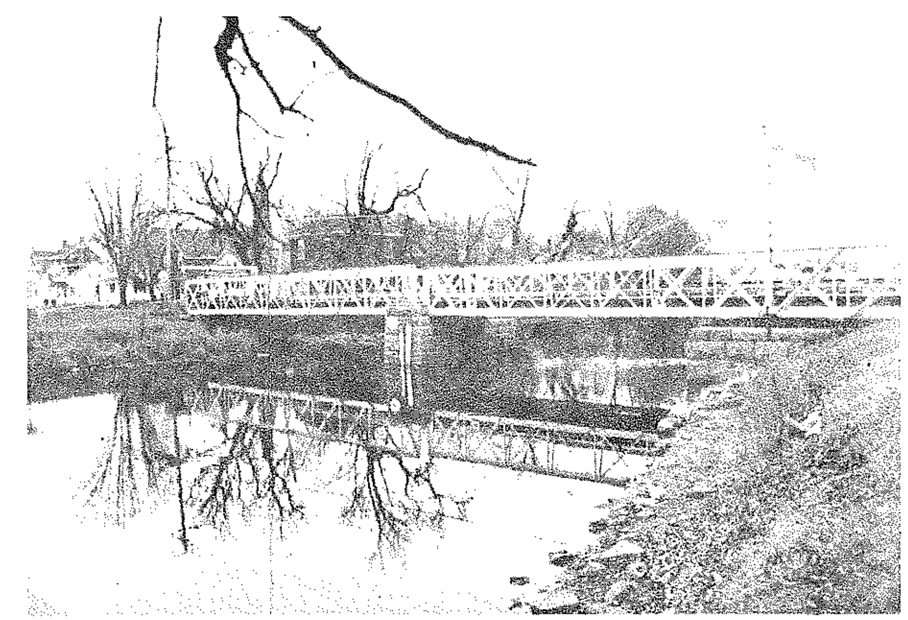
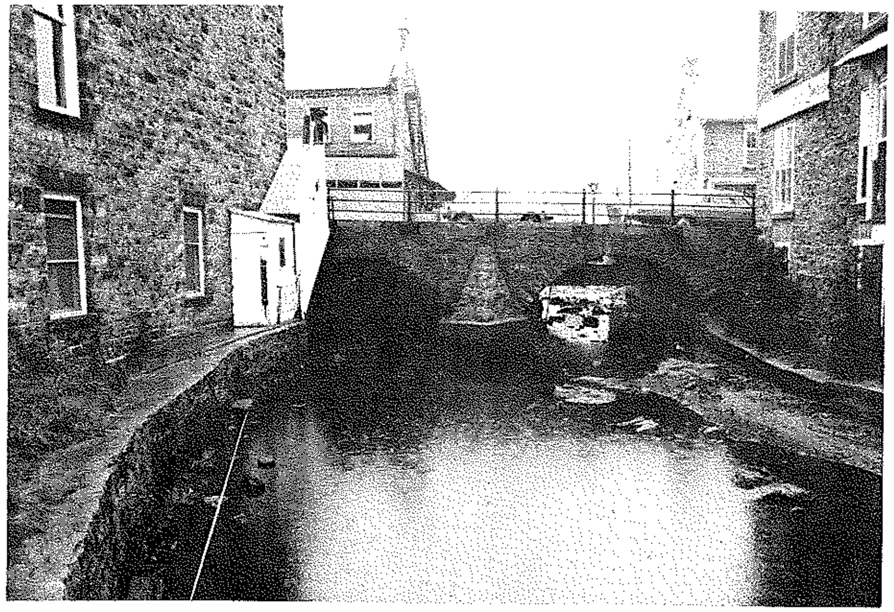


PHOTO 8 LOOKING UPSTREAM TO BECKWITH BRIDGE



OKING DOWNSTREAM TO GORE STREET BRIDGE ON NORTH CHANNEL
PERTH

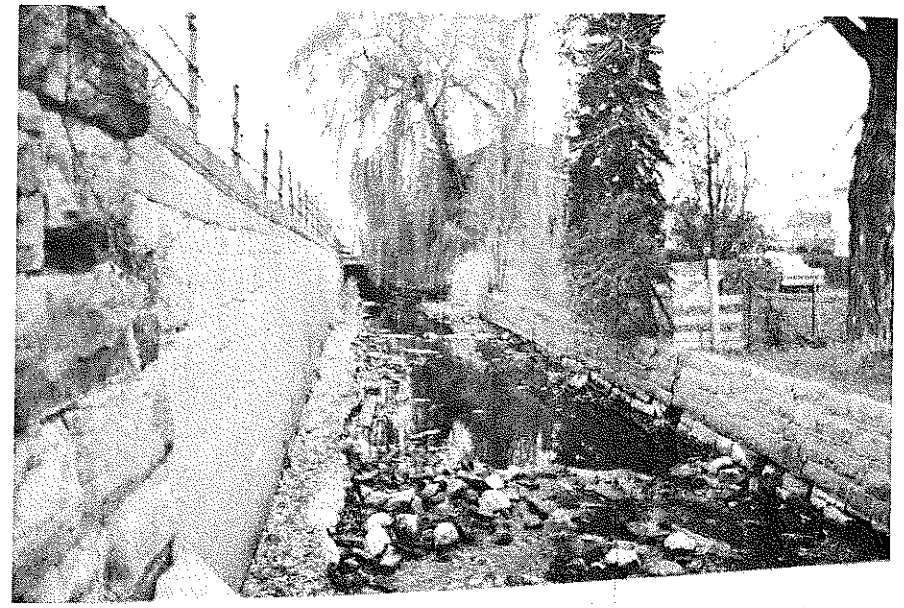
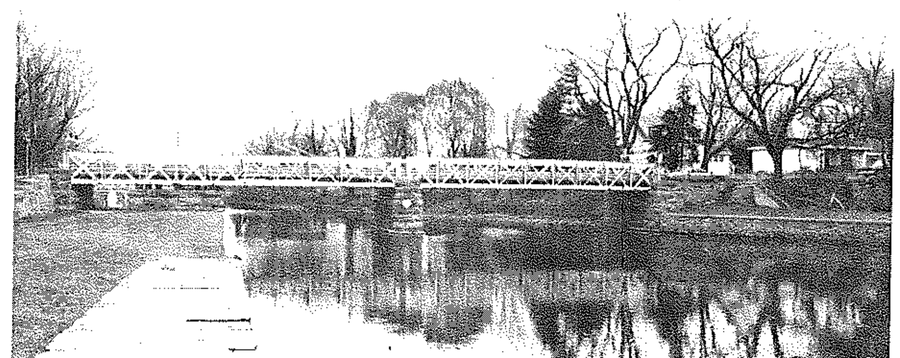


PHOTO 13 LOOKING UPSTREAM FROM THE OUTLET OF NORTH CHANNEL IN PERTH



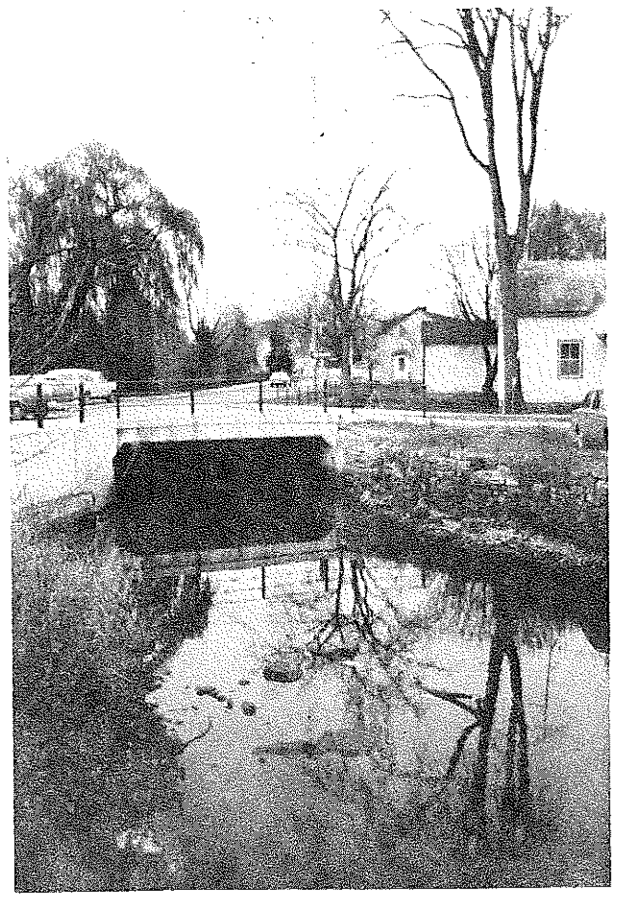


PHOTO 9 LOOKING DOWNSTREAM TO CONCRETE CULVERT AT DRUMMOND STREET ON NORTH CHANNEL IN PERTH

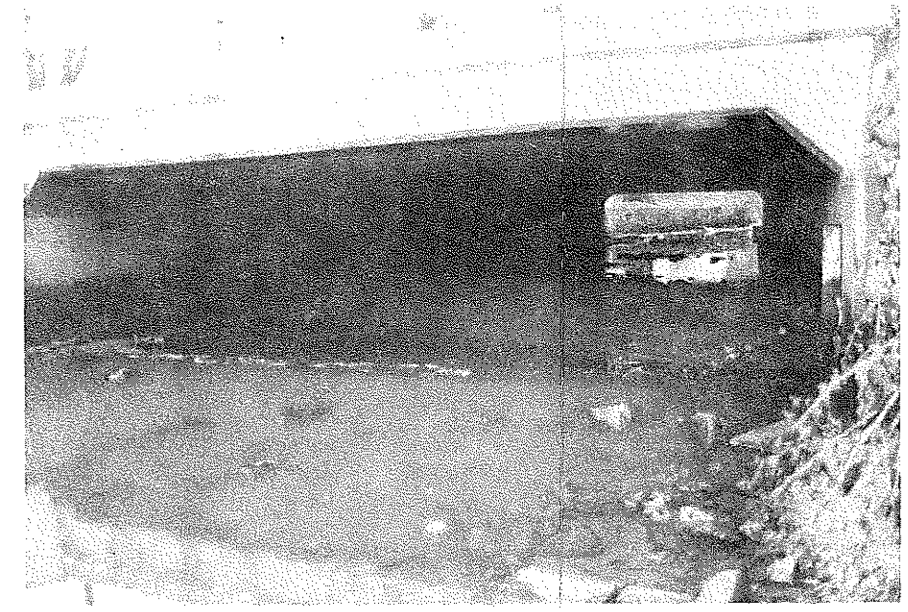


PHOTO 10 WEIR IN DRUMMOND STREET CULVERT

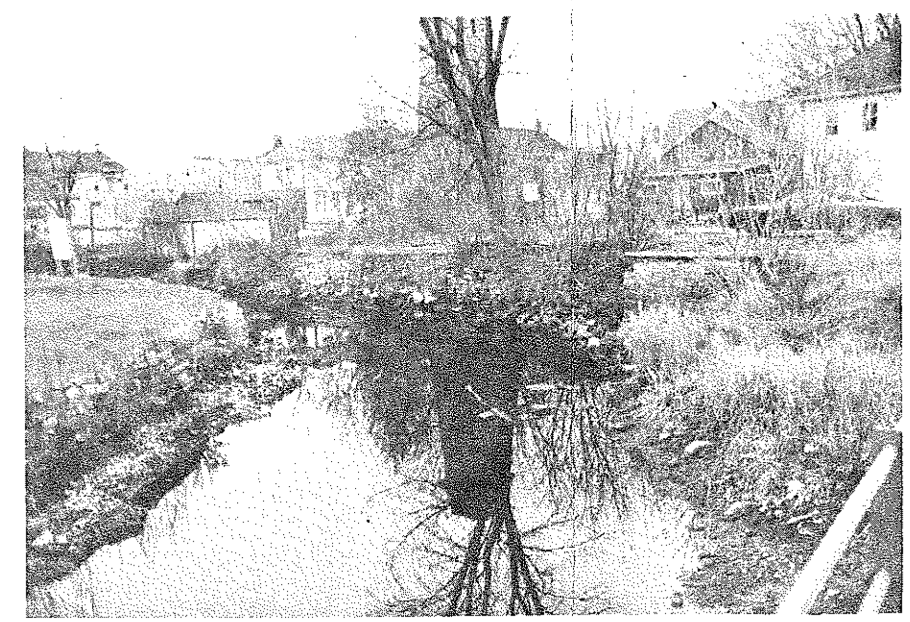


PHOTO 11 LOOKING UPSTREAM FROM DRUMMOND STREET CULVERT

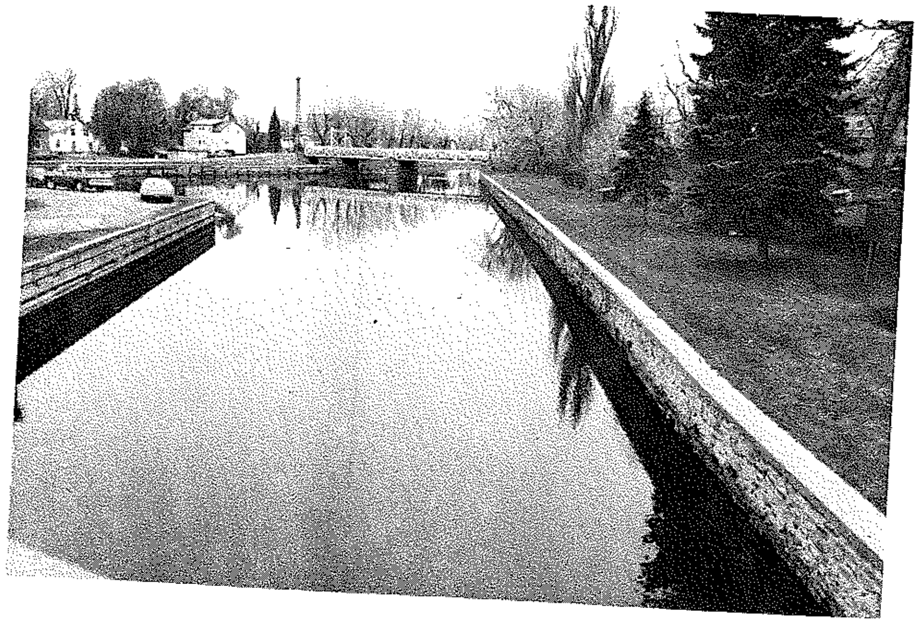
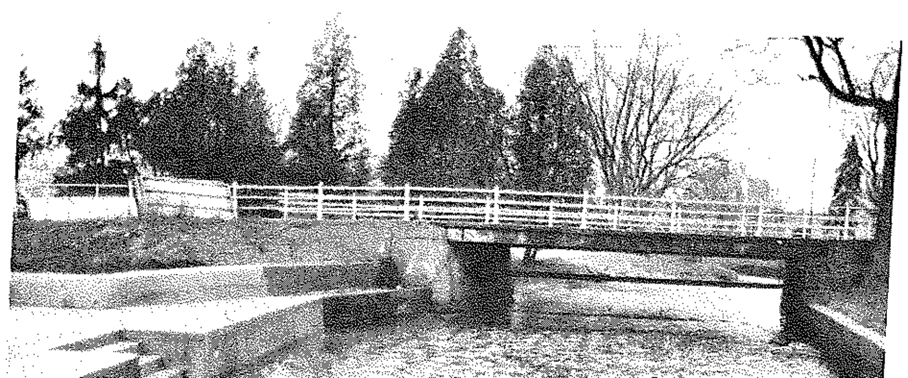


PHOTO 16 LOOKING DOWNSTREAM FROM GORE STREET BRIDGE TO THE PERTH BASIN AND DRUMMOND STREET BRIDGE

PHOTO 17 LOOKING UPSTREAM TO GORE STREET BRIDGE



LOOKING UPSTREAM TO FOOTBRIDGE ON CONNECTING CHANNEL

PHOTO 21 WEIR AT INLET TO CONNECTING CHANNEL

PHOTO 24 HAGGARTS DAM

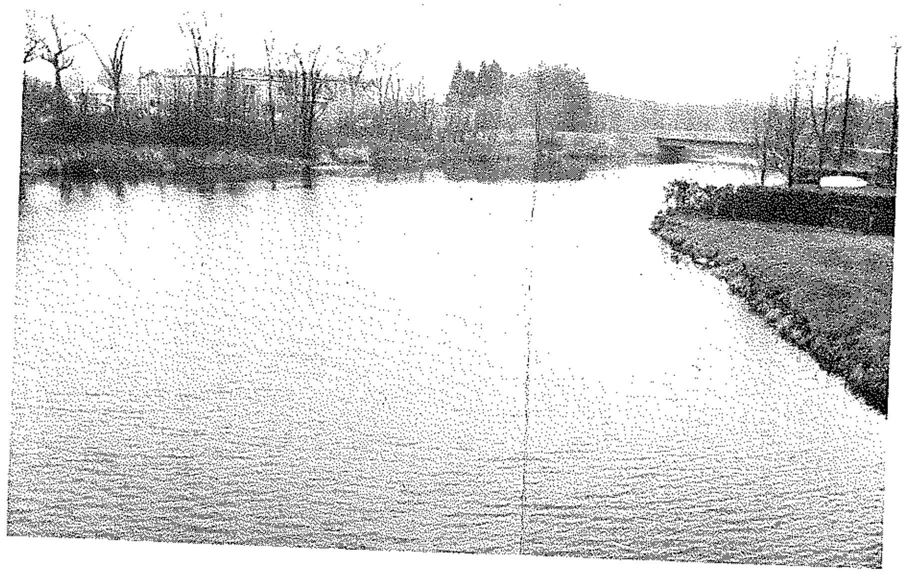


PHOTO 25 LOOKING UPSTREAM FROM TAY ROAD DAM

PHOTO 26 LOOKING DOWNSTREAM TO NORTH CHANNEL FROM TAY ROAD DAM

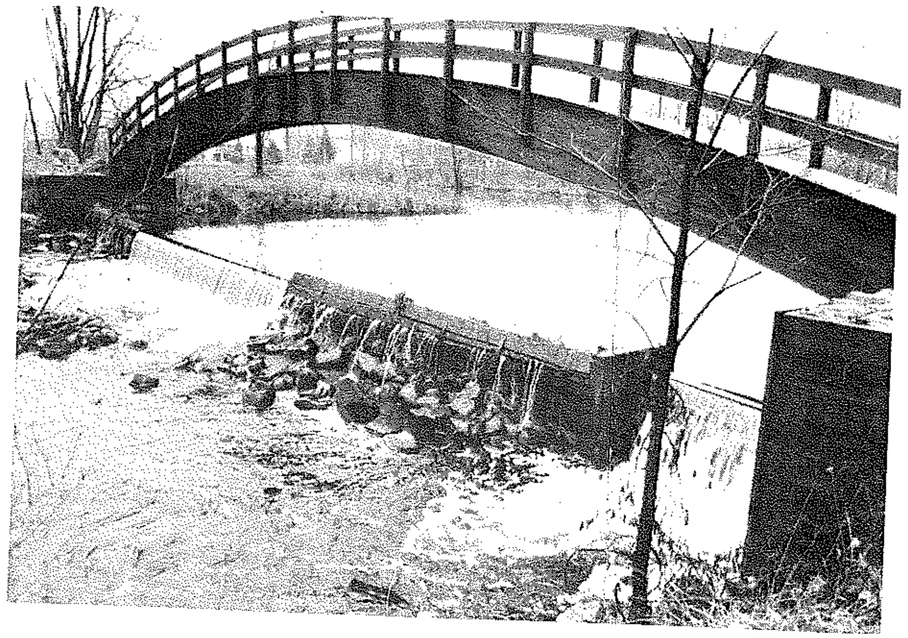


PHOTO 27 TAY ROAD DAM AND FOOTBRIDGE

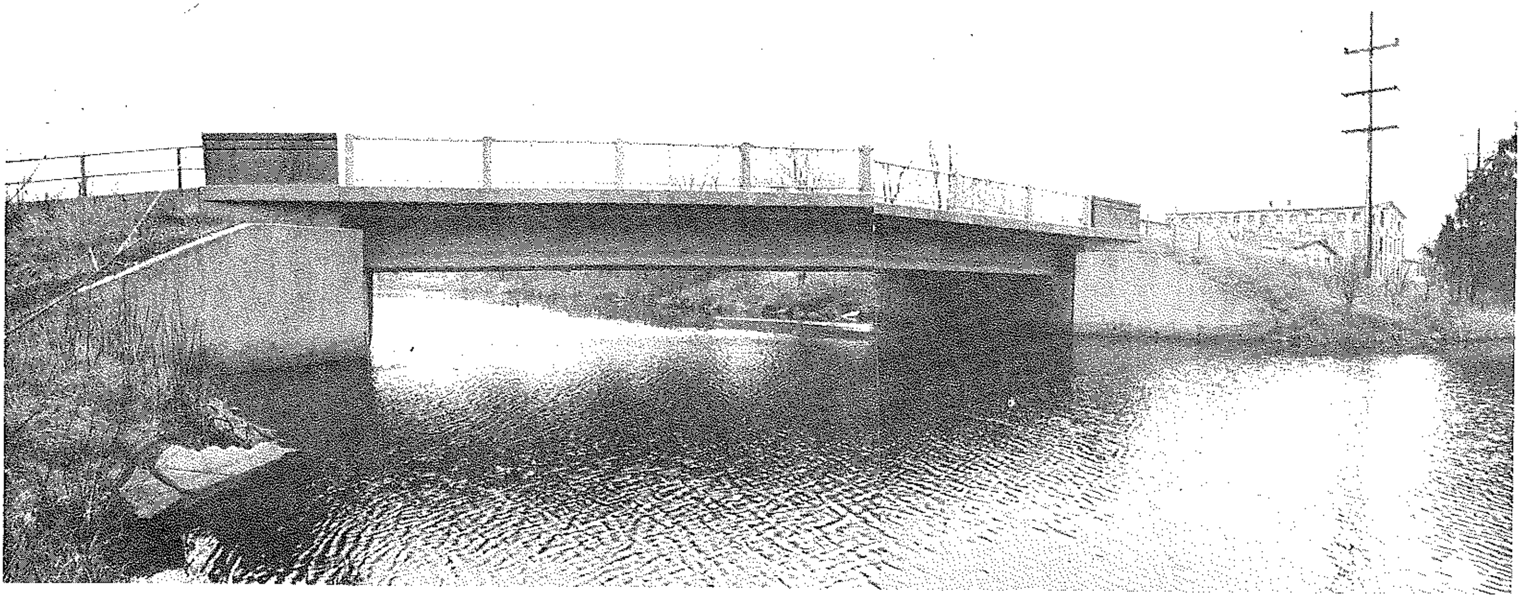


PHOTO 28 LOOKING DOWNSTREAM TO RODGERS ROAD BRIDGE

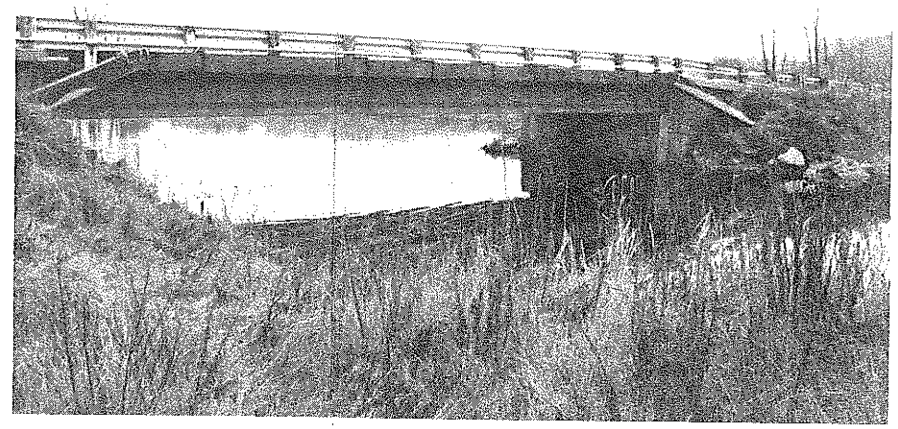


PHOTO 30 LOOKING DOWNSTREAM TO PETER STREET BRIDGE

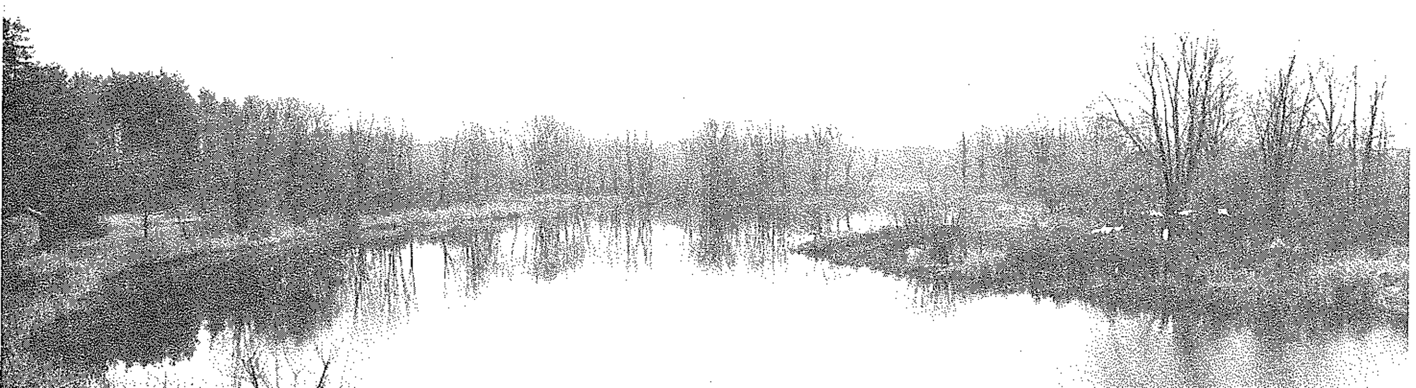


PHOTO 31 LOOKING DOWNSTREAM FROM PETER STREET BRIDGE TO OUTLET OF GRANTS CREEK

PHOTO 32 GOLF COURSE DAM

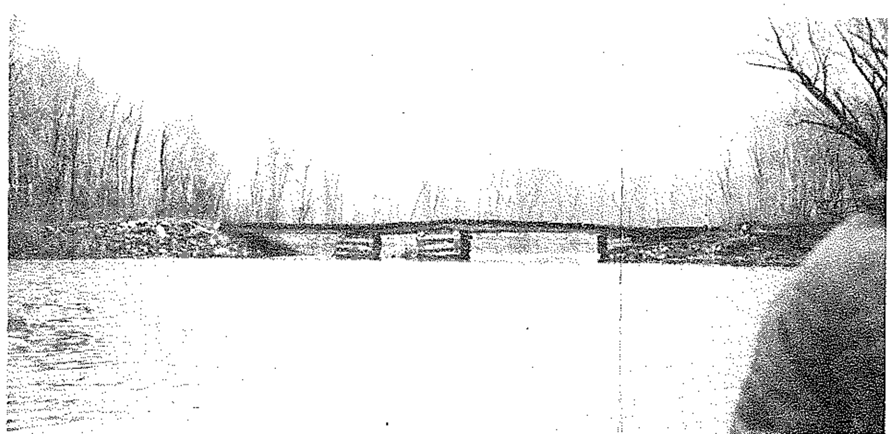


PHOTO 35 LOOKING DOWNSTREAM FROM BRIDGE #1

PHOTO 36 LOOKING UPSTREAM TO SECOND BRIDGE UPSTREAM FROM PERTH (BRIDGE #2)

PHOTO 37 LOOKING DOWNSTREAM FROM BRIDGE #2

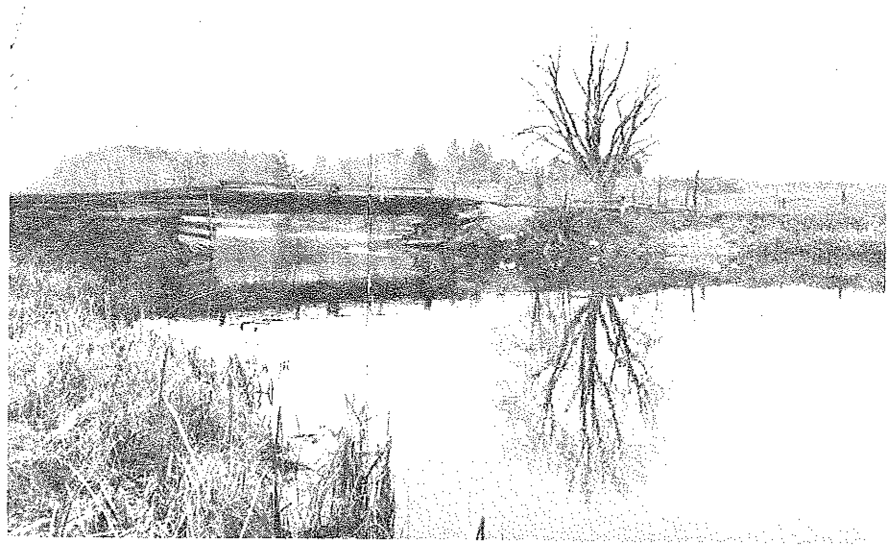


PHOTO 38 LOOKING UPSTREAM TO THIRD BRIDGE UPSTREAM FROM PERTH (BRIDGE #3)

PHOTO 39 LOOKING DOWNSTREAM FROM BRIDGE #3

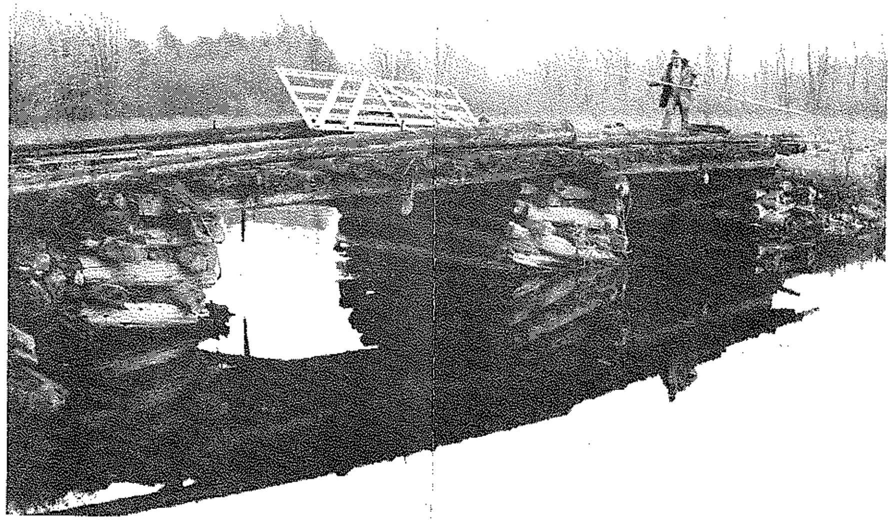
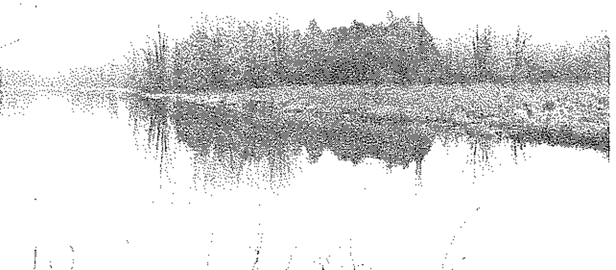
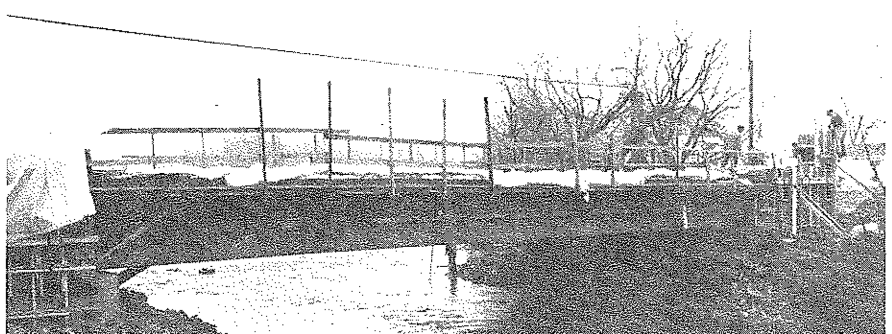
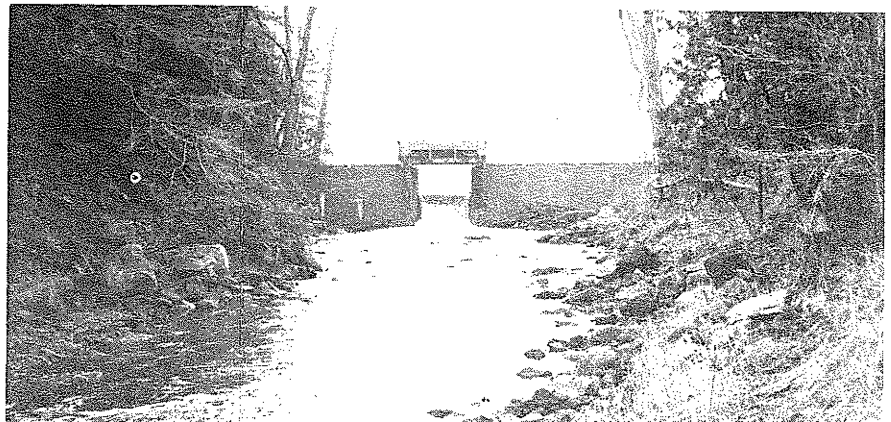


PHOTO 40 FOURTH BRIDGE UPSTREAM OF PERTH (BRIDGE #4)

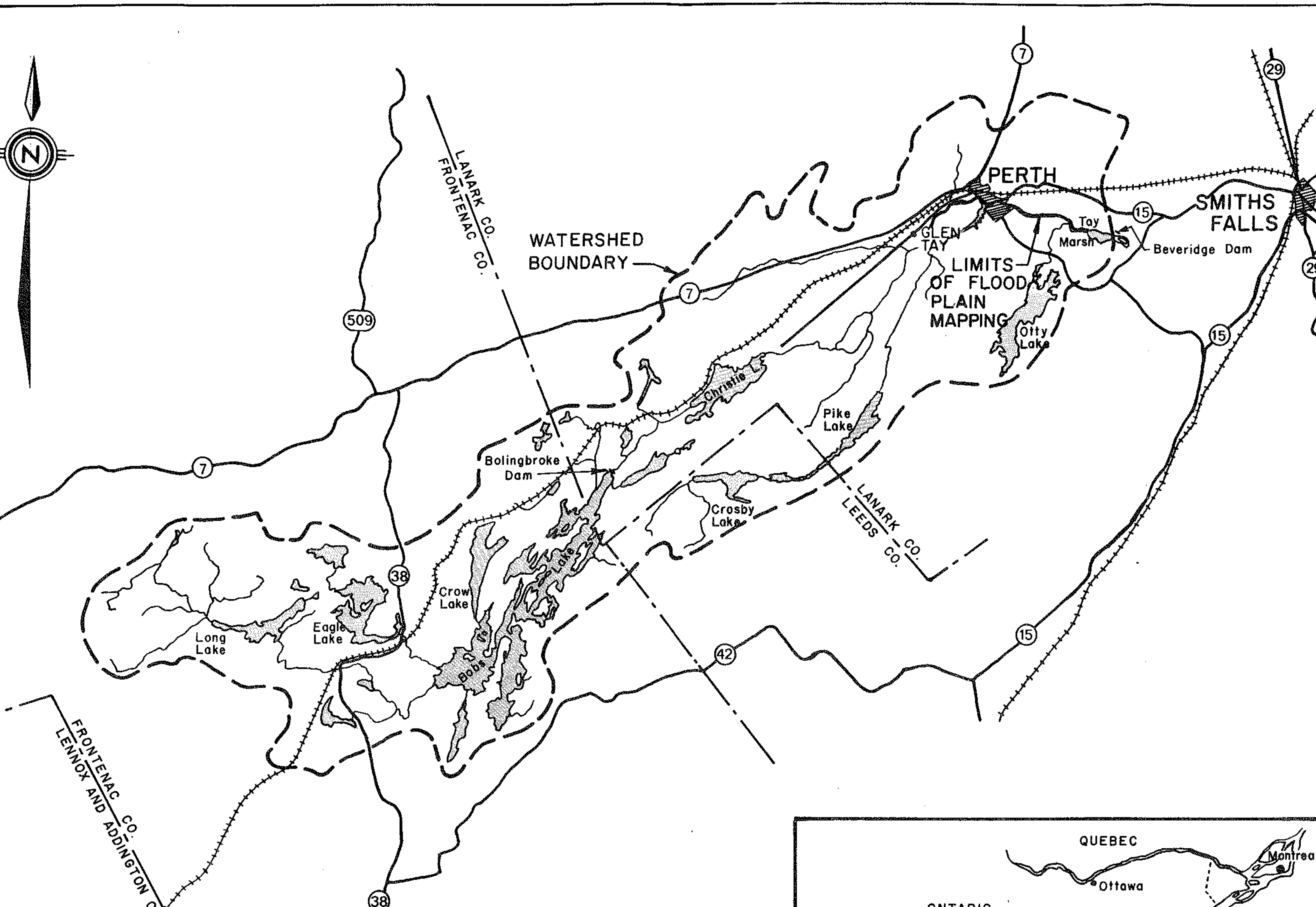






APPENDIX II

FIGURES



NOTES AND REFERENCES

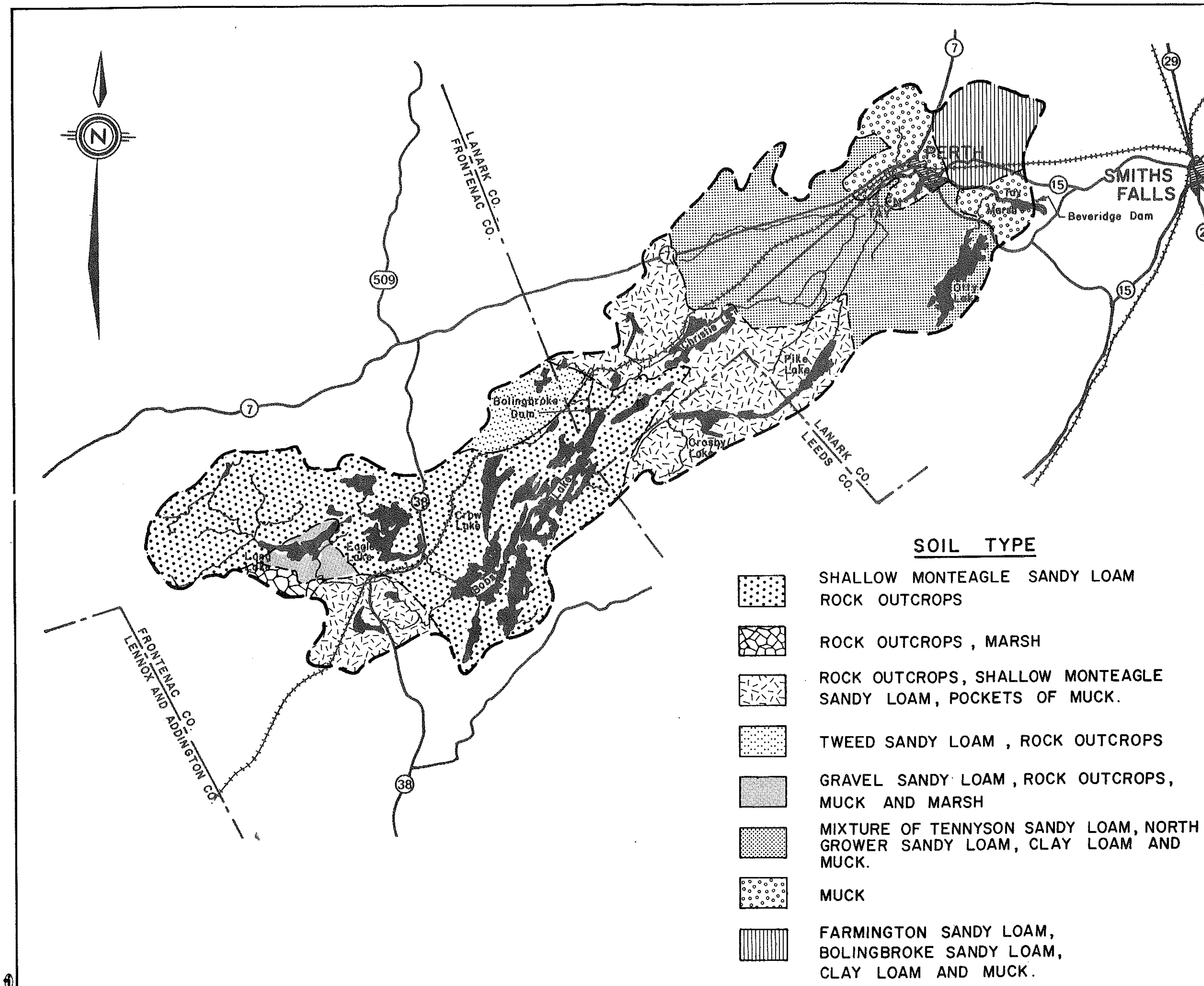
NO.	REVISION	DATE	BY

DWG. DATE	NOV. 1980	ORIENTATION	REG
DRAWN BY	P.G.		
CHECKED BY	P.D.C.		
DEPT. HEAD	F.M.B.	PROJ. MGR.	
ISSUE DATE			
ISSUED FOR			

PROJECT TITLE

TAY RIVER FLOOD PLAIN MAPPING

DRAWING TITLE



NOTES AND REFERENCES

NO.	REVISION	DATE	BY

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DRAWN BY P.G.
CHECKED BY P.D.C.
DEPT. HEAD F.M.B.
PROJ. MGR.
ORIENTATION
REG.
ISSUE DATE
ISSUED FOR

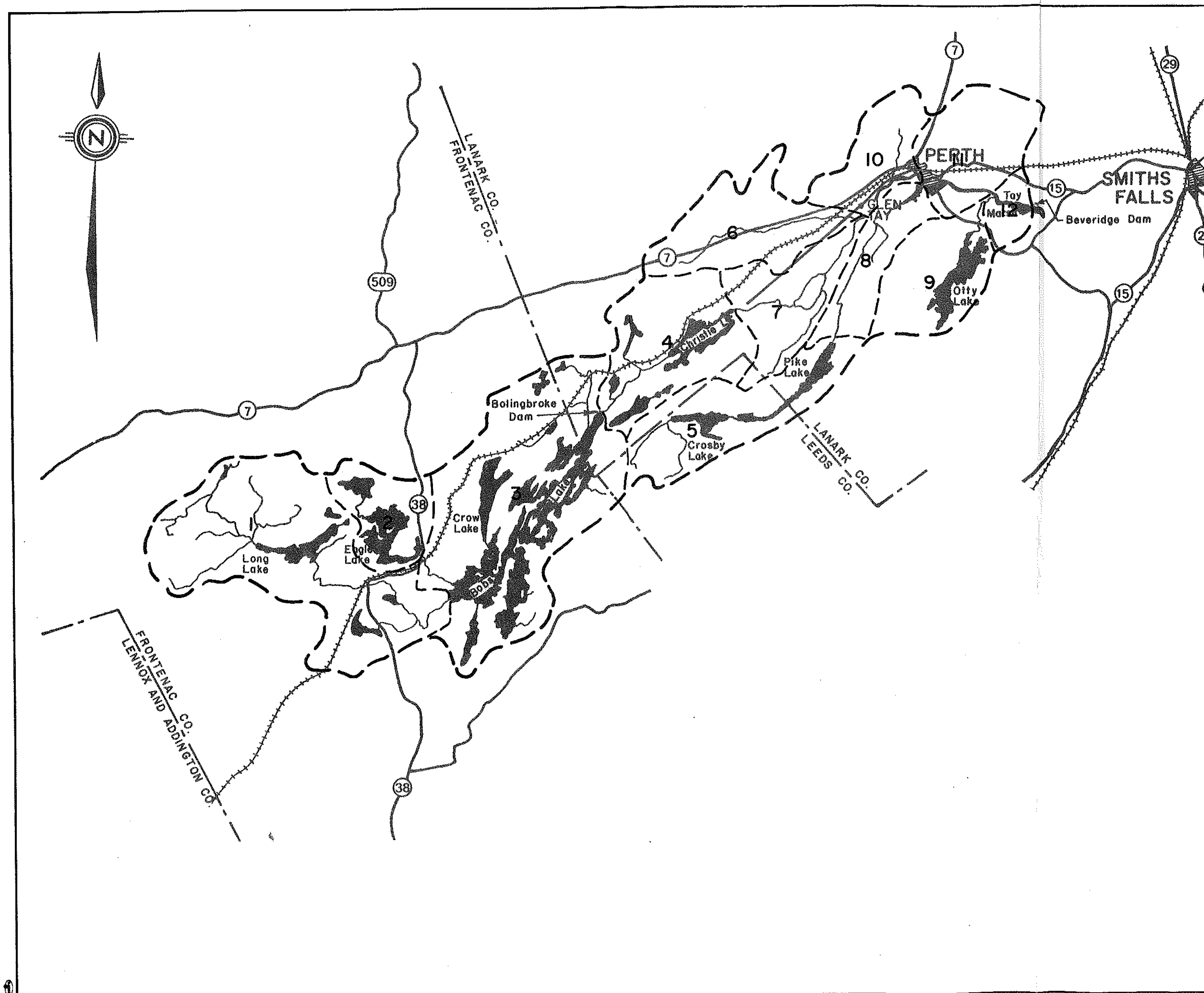
PROJECT TITLE TAY RIVER FLOOD PLAIN MAPPING

DRAWING TITLE TAY RIVER WATERSHED SOIL TYPES

FENCO
FENCO CONSULTANTS LTD.

SCALE IN KILOMETRES
5 0 5

DRAWING NUMBER FIGURE 2
REV.



NOTES AND REFERENCES

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DRAWN BY: P.G.
CHECKED BY: P.D.C.
DEPT. HEAD: F.M.B.
PROJ. MGR.:
ORIENTATION REG.:
ISSUE DATE:
ISSUED FOR:

PROJECT TITLE: TAY RIVER FLOOD PLAIN MAPPING

DRAWING TITLE: TAY RIVER WATERSHED SUBCATCHMENTS

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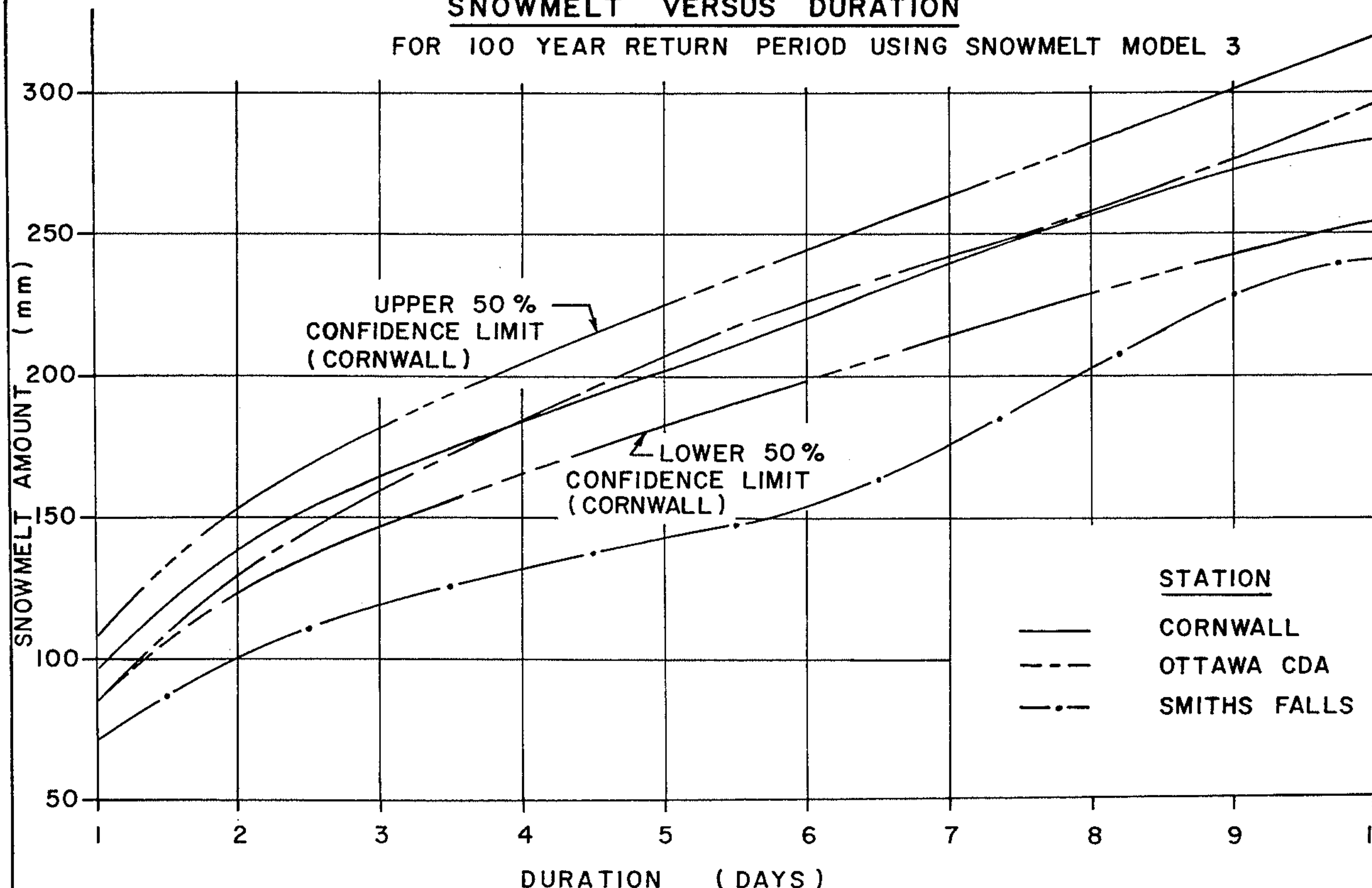
SCALE IN KILOMETRES
5 0 5

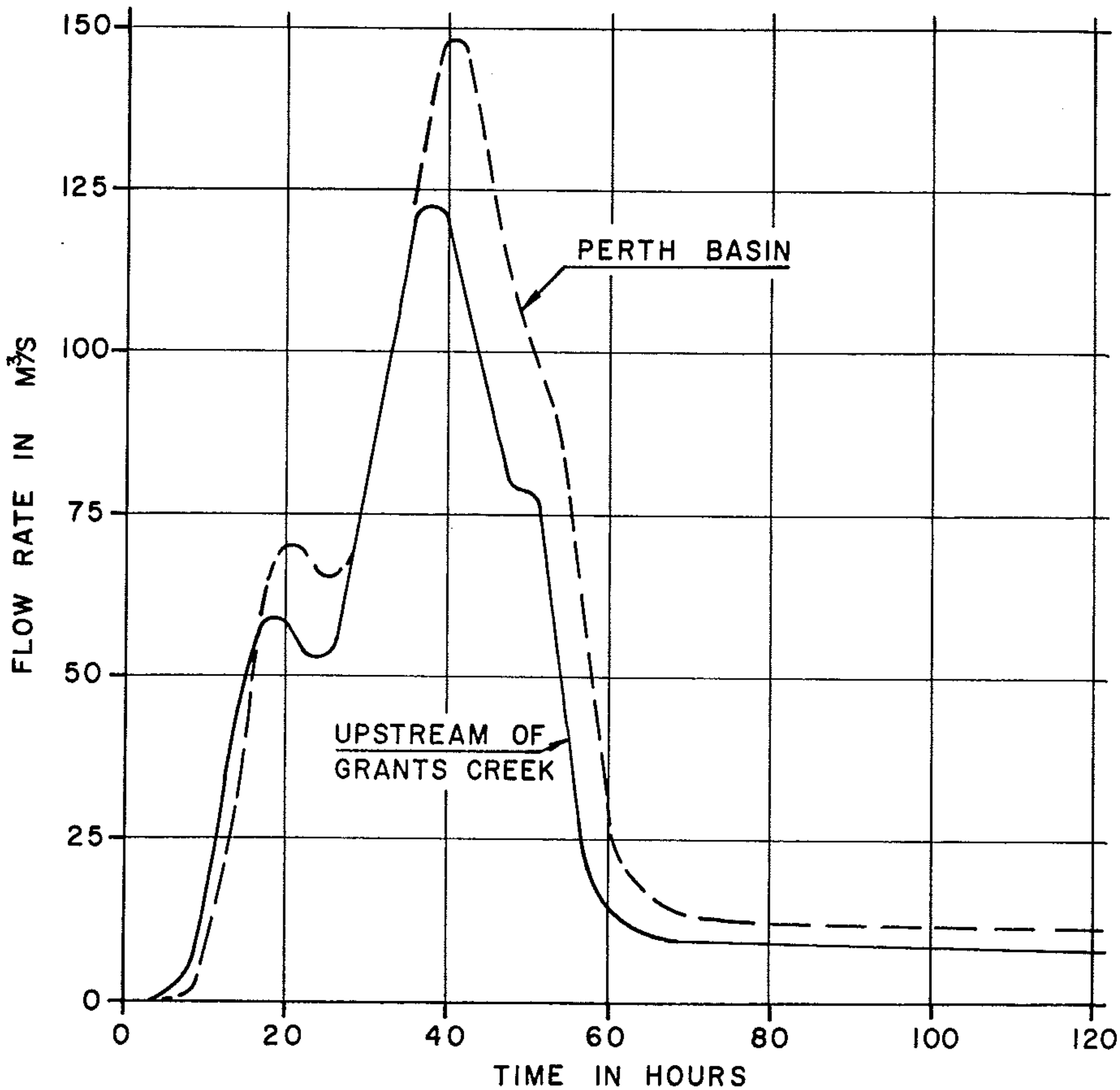
DRAWING NUMBER: FIGURE 3
REV.

FIGURE 5

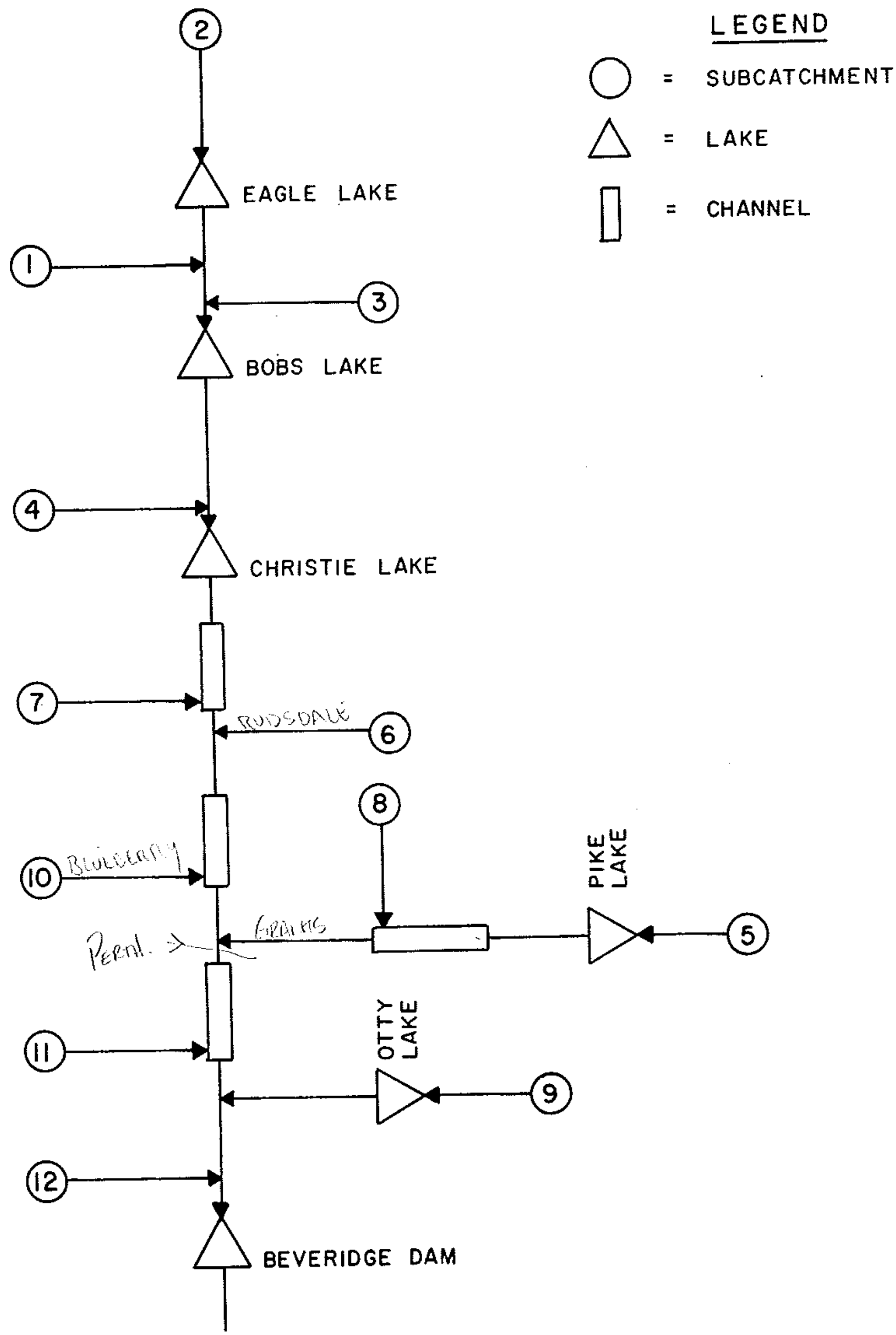
SNOWMELT VERSUS DURATION

FOR 100 YEAR RETURN PERIOD USING SNOWMELT MODEL 3





NO.	REVISION	BY	DATE	PROJECT TITLE		COMP.	DWG.	
				TAY RIVER FLOOD PLAIN MAPPING	MADE		P.G.	FENCO
					CH'D.		P.D.C.	
					APP.		F.M.B.	FENCO CONSULTANTS LTD.
				100 YEAR FLOOD HYDROGRAPHS	DATE			SCALE
					DWG.	FIGURE 6		REV.



NO.	REVISION	BY	DATE

PROJECT TITLE
TAY RIVER FLOOD PLAIN MAPPING

SCHEMATIC REPRESENTATION OF WATERSHED

	COMP.	DWG.
MADE		P.G.
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APP.		F.M.B.

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DATE | SCALE —
DWG. FIGURE 4 | REV.

APPENDIX III

TABLES

TABLE 1

SUMMARY OF FLOW RATES

METHOD OF CALCULATION	100 YEAR FLOW RATES IN M^3/S	
	UPSTREAM OF GRANTS CREEK	PERTH
Single Station Data Transfer		
- Mississippi River (02KF007)*	74	82
- Rideau River (02LA004)	165	183
- South Nation River (02LB007)	201	223
Regional Flood Frequency Analysis		
- CN Rail Method	117	127
- Method Described in "Magnitude and Frequency of Floods in Southern Ontario"	95	104
Watershed Classification		
- Class "A" Basin	80	89
- Class "B" Basin	189	209
Single Event Simulation Model		
- 2 day Snowmelt	124	150
- 1 day Rainfall	63	78

* Gauge Number

TABLE 2

SOIL-LAND USE AND ASSOCIATED CURVE NUMBER (AMC II)

LAND USE	SOIL TYPE			
	HYDROLOGIC GROUP A	HYDROLOGIC GROUP B	HYDROLOGIC GROUP BC	HYDROLOGIC GROUP C
PASTURE LAND	58	65	71	76
FORESTED LAND	50	58	65	71
RESIDENTIAL	N.A.	78	82	84
WATER SURFACES	100			

TABLE 3

SUMMARY OF WATERSHED CHARACTERISTICS

SUB-CATCHMENT	AREA (SQ.KM.)	AREA OF LAKES (SQ.KM.)	SUB-CATCHMENT SLOPE (%)	Tc (HR.)	PER CENT OF AREA IN EACH LAND USE CATEGORY				CN AMC II
					LAKE	FORESTED	PASTURE	RESIDENTIAL	
1	138.5	5.54	0.185	11.25	4	90	6	-	63
2	36.6	9.45	0.592	1.17	25	70	5	-	69
3	187.3	36.94	0.728	1.50	20	75	5	-	67
4	74.7	9.97	0.329	1.50	13	82	5	-	63
5	54.5	9.04	0.548	1.88	17	78	5	-	67
6	65.2	-	0.175	5.83	-	50	50	-	61
7	45.8	-	0.224	4.58	-	35	65	-	63
8	29.6	-	0.059	9.17	-	20	80	-	64
9	50.9	6.63	0.168	1.88	13	67	20	-	65
10	32.9	-	0.020	9.17	-	67	30	3	62
11	52.6	-	0.084	4.58	-	30	70	-	63
12	11.8	3.44	0.047	2.92	29	64	7	-	74

TABLE 4

RATING CURVE FOR EAGLE LAKE

OPERATING CONDITIONS 1, 3 AND 4

ELEVATION (metres)	DISCHARGE (m^3/s)	STORAGE (cubic metres x 10^6)
189.94	0.00	0.00
190.09	0.14	0.99
190.24	0.31	1.98
190.39	0.71	2.97
190.54	1.13	3.96
190.69	1.50	4.96
190.84	2.12	5.95
190.99	2.83	6.94
191.14	3.82	7.93
191.29	4.81	8.92
191.44	5.95	9.91
191.59	7.36	10.90
191.74	9.35	11.89
191.89	11.05	12.89
192.04	12.89	13.89

TABLE 5

RATING CURVE FOR BOB'S LAKE

(BOLINGBROOK DAM)

OPERATING CONDITION 4

ELEVATION (metres)	DISCHARGE (m^3/s)	STORAGE (cubic metres x 10^6)
160.15	0.00	0.0
160.46	1.13	5.8
160.76	3.12	14.4
161.07	4.81	23.1
161.31	5.67	31.8
161.68	6.23	40.4
161.98	6.80	49.1
162.29	7.37	57.8
162.59	7.93	66.5
162.90	8.50	75.2
163.20	16.29	83.9
163.51	28.91	92.6
163.81	44.21	101.3
164.12	62.34	110.0
164.42	83.88	118.7

(Based on Initial Water Level at the Bottom of the Conservation Zone and logs being installed as the lake fills so that outflow is controlled)

TABLE 6

RATING CURVE FOR CHRISTIE LAKE

OPERATING CONDITIONS 1, 2, 3 AND 4

ELEVATION (metres)	DISCHARGE (m^3/s)	STORAGE (cubic metres x 10^6)
154.27	0.00	0.00
154.42	1.13	0.99
154.57	2.55	1.98
154.72	4.25	2.97
154.87	5.66	3.96
155.02	7.93	4.95
155.17	10.20	5.95
155.32	12.46	6.94
155.47	19.82	7.93
155.62	28.32	8.92
155.77	39.65	9.91
155.88	51.00	10.76
155.95	62.34	11.04
156.04	73.68	11.62
156.10	85.02	11.97
156.22	96.35	12.64
156.25	102.02	12.82

TABLE 7

RATING CURVE FOR PIKE LAKE

OPERATING CONDITIONS 1, 2, 3 AND 4

ELEVATION (metres)	DISCHARGE (m^3/s)	STORAGE (cubic metres x 10^6)
144.82	0.00	0.00
145.12	0.57	0.00
145.43	1.70	2.01
145.73	3.40	4.02
146.04	5.66	6.03
146.34	7.93	8.04
146.65	9.91	10.05
146.95	12.74	12.07
147.26	14.87	14.08
147.56	16.99	16.09

TABLE 8

RATING CURVE FOR OTTY LAKE

OPERATING CONDITIONS 1, 2, 3 AND 4

ELEVATION (metres)	DISCHARGE (m^3/s)	STORAGE (cubic metres x 10^6)
131.40	0.00	0.00
131.70	2.51	2.02
132.01	7.08	4.04
132.32	13.03	6.06
132.62	20.05	8.08
132.93	28.04	10.10
133.23	36.82	12.12

TABLE 9

RATING CURVE FOR TAY MARSH (BEVERIDGE DAM)

OPERATING CONDITIONS 1, 3 AND 4

ELEVATION (metres)	DISCHARGE (m^3/s)	STORAGE (cubic metres x 10^6)
129.66	0.00	0.00
129.73	3.97	0.15
129.88	8.50	0.30
130.03	12.47	0.46
130.18	18.70	0.61
130.33	24.94	0.76
130.49	32.87	0.91
130.64	41.37	1.07
130.79	51.57	1.22
130.95	61.78	1.91
131.10	83.03	2.44
131.25	111.93	2.98
131.40	137.73	3.51
131.71	198.37	4.56

TABLE 10

100 YEAR RAINFALL AND SNOWMELT VOLUMES (mm)

EVENT	DURATION (HOURS) 6	12	24	48	72	96	120	240
RAINFALL	84.84	90.17	103.89	111.76	142.24	143.76	146.05	163.7
SNOWMELT	-	-	96.77	138.68	163.58	186.18	202.69	287.3

TABLE 11

CUMULATIVE RAINFALL HOURLY DISTRIBUTION

24 HOUR EVENT				
0.00	0.017	0.035	0.055	0.076
0.099	0.125	0.156	0.194	0.254
0.515	0.624	0.682	0.727	0.767
0.800	0.830	0.857	0.884	0.905
0.926	0.946	0.965	0.983	1.000

Obtained from U.S. Department of Agriculture, Technical Release 20. The same type of distribution was used for rainfall events with other durations.

TABLE 12

SNOWMELT CUMULATIVE HOURLY DISTRIBUTION

24 HOUR EVENT				
0.000	0.042	0.088	0.138	0.191
0.247	0.304	0.362	0.419	0.475
0.528	0.578	0.624	0.666	0.703
0.737	0.767	0.795	0.821	0.846
0.872	0.900	0.930	0.964	1.000

Obtained from Reference 6. The above sinusoidal distribution pattern was extended for snowmelts of longer duration.

TABLE 13
SUMMARY OF RESULTS
SINGLE EVENT SIMULATION MODEL

RUN NUMBER	EVENT DURATION (DAYS)	TYPE OF EVENT	AMC ASSUMED	OPERATING POLICY ASSUMED	FLOW RATE M^3/S			GENERAL COMMENTS
					PERTH	UPSTREAM OF TAY MARSH	DOWNSTREAM OF TAY MARSH	
1	10	Snowmelt	100	1	150	188	176	- Stored input Hydrograph in HYMO. - Tc based on Kirpich Formula, gross slope and multiplier of 2. - Snowmelt Model 3 results used.
2	10	Snowmelt	100	2	181	220	207	- Stored input Hydrograph in HYMO. - Tc based on Kirpich Formula, gross slope and multiplier of 2. - Snowmelt Model 3 results used.
3	10	Snowmelt	100	1	146	182	177	- Compute input Hydrograph in HYMO. - Tc based on Kirpich Formula, gross slope and multiplier of 2. - Snowmelt Model 3 results used.
4	1	Rain Storm	II	1	78	100	70	- Compute input Hydrograph in HYMO. - Tc based on Kirpich Formula, gross slope and multiplier of 2.
5	1	Rain Storm	II	2	78	100	74	- Compute input Hydrograph in HYMO. - Tc based on Kirpich Formula, gross slope and multiplier of 2.
6	5	Snowmelt	100	1	146	191	183	- Compute input Hydrograph in HYMO. - Tc based on Kirpich Formula, gross slope and multiplier of 2. - Snowmelt Model 3 results used.
7	5	Snowmelt	100	2	190	234	226	- Compute input Hydrograph in HYMO. - Tc based on Kirpich Formula, gross slope and multiplier of 2. - Snowmelt Model 3 results used.
8	2	Rain Storm	II	2	59	79	64	- Compute input Hydrograph in HYMO. - Tc based on Kirpich Formula, gross slope and multiplier of 2.
9	5	Snowmelt	100	3	138	183	176	- Compute input Hydrograph in HYMO. - Tc based on Kirpich Formula, gross slope and multiplier of 2. - Snowmelt Model 3 results used.

TABLE 13 (Continued)
SUMMARY OF RESULTS
SINGLE EVENT SIMULATION MODEL

RUN NUMBER	EVENT DURATION (DAYS)	TYPE OF EVENT	AMC ASSUMED	OPERATING POLICY ASSUMED	FLOW RATE M^3/S			GENERAL COMMENTS
					PERTH	UPSTREAM OF TAY MARSH	DOWNSTREAM OF TAY MARSH	
10	1	Rain Storm	II	1	117	147	112	- Compute input Hydrograph in HYMO. - Tc based on Kirpich Formula, gross slope and multiplier of 2. - Constant value of CN=70 used.
11	0.5	Rain Storm	II	1	65	78	55	- Compute input Hydrograph in HYMO. - Tc based on Kirpich Formula, gross slope and multiplier of 2.
12	10	Snowmelt	100	4	115	-	-	- Compute input Hydrograph in HYMO. - Tc based on Kirpich Formula, gross slope and multiplier of 2. - Snowmelt Model 3 results used.
13	5	Snowmelt	100	4	142	-	-	- Compute input Hydrograph in HYMO. - Tc based on Kirpich Formula, gross slope and multiplier of 2. - Snowmelt Model 3 results used.
14	3	Snowmelt	100	4	164	217	205	- Compute input Hydrograph in HYMO. - Tc based on Kirpich Formula, gross slope and multiplier of 2. - Snowmelt Model 3 results used.
15	1	Snowmelt	100	4	225	299	260	- Compute input Hydrograph in HYMO. - Tc based on Kirpich Formula, gross slope and multiplier of 2. - Snowmelt Model 3 results used.
15A	1	Snowmelt	100	4	225	299	260	- Same as Run #15 except with adjusted Tc for Subcatchemnt 1.
16	2	Snowmelt	100	4	185	248	233	- Compute input Hydrograph in HYMO. - Tc based on Kirpich Formula, gross slope and multiplier of 2. - Snowmelt Model 3 results used.
17	1	Snowmelt	100	2	225	299	268	- Compute input Hydrograph in HYMO. - Tc based on Kirpich Formula, gross slope and multiplier of 2. - Snowmelt Model 3 results used.

TABLE 13 (Continued)
SUMMARY OF RESULTS
SINGLE EVENT SIMULATION MODEL

RUN NUMBER	EVENT DURATION (DAYS)	TYPE OF EVENT	AMC ASSUMED	OPERATING POLICY ASSUMED	FLOW RATE M^3/S			GENERAL COMMENTS
					PERTH	UPSTREAM OF TAY MARSH	DOWNSTREAM OF TAY MARSH	
18	1	Rain/ Snowmelt	100	4	132	174	152	- Compute input Hydrograph in HYMO. - Tc based on Kirpich Formula, gross slope and multiplier of 2. - Snowmelt Model 2 results used.
19	1	Snowmelt	III	4	124	164	138	- Compute input Hydrograph in HYMO. - Tc based on Kirpich Formula, gross slope and multiplier of 2. - Snowmelt Model 3 results used.
20	1	Snowmelt	100	-	-	-	-	- Subcatchment 1 divided into 2 sub-areas to test sensitivity of subcatchment size.
21	1	Snowmelt	100	4	201	214	199	- Compute input Hydrograph in HYMO. - Tc based on Kirpich Formula, gross slope and multiplier of 2. - Snowmelt Model 3 results used. - Channel routing revised.
22	1	Snowmelt	III	4	129	163	135	- Compute input Hydrograph in HYMO. - Tc based on Kirpich Formula, weighted slope. - Snowmelt Model 3 results used. - Channel routing revised.
23	2	Snowmelt	III	4	150	186	173	- Compute input Hydrograph in HYMO. - Tc based on Kirpich Formula, weighted slope. - Snowmelt Model 3 results used. - Channel routing revised.
24	2	Snowmelt	III	2	150	187	175	- Compute input Hydrograph in HYMO. - Tc based on Kirpich Formula, weighted slope. - Snowmelt Model 3 results used. - Channel routing revised.
25	3	Snowmelt	III	4	134	169	159	- Compute input Hydrograph in HYMO. - Tc based on Kirpich Formula, weighted slope. - Snowmelt Model 3 results used. - Channel routing revised.

APPENDIX IV

EXTREME VALUE ANALYSIS OF SNOWMELT ESTIMATES

EXTREME VALUE ANALYSIS OF SNOWMELT ESTIMATES

Daily snowmelt estimates for Cornwall, Ottawa and Smith Falls were analyzed using Gumbel extreme value statistics. The period of record was 24, 89 and 13 years for Cornwall, Ottawa and Smiths Falls respectively. The results presented in Tables I through XV provide extreme values for durations from 1 to 10 days and for return periods up to 100 years. The snowmelt estimates were based on degree-day equations. Five different snowmelt equations were used giving five different sets of snowmelt values.

Data

The input data used in this analyses and in the calculation of the snowmelt estimates were daily maximum and minimum temperatures, daily rainfall total and daily snow depth measurements by ruler. A snow density of 0.1 was assumed to convert snow depth into its water equivalent. Such snow measurements may not be spatially representative. The snowmelt estimates should therefore be considered with the same precaution in mind.

Snowmelt Calculation

Daily snowmelt estimates were calculated using degree-day type equations. Five different equations were used and a description of each is given below.

1) Model 1

$$SM1 = 0.0397\ (T_a - 27.6) \qquad \text{(inches/day)}$$

T_a = mean daily air temperature °F

Ref: Pysklywec, D.W., K.S. Kavar, and D.I. Bray (1968): Snowmelt at an Index Plot, _Water Resour. Res._, 4(5), 937-946.

2) Model 2

$$SM2 = (0.074 + 0.007\ R)\ (T_a - 32) + 0.05 \qquad \text{(inches/day)}$$

R = daily rainfall in inches

T_a = mean daily air temperature °F

Ref: United States Army Corps of Engineers (1956): Snow Hydrology, North Pacific Division, Portland, Oregon.

3) Model 3

$$SM3 = 3.0\ (T_a + TCA(((T_X - T_N)/8) + T_N)) \qquad \text{(mm/day)}$$

T_a = mean daily air temperature °C

T_X = maximum daily temperature °C

T_N = minimum daily temperature °C

TCA = $(T_N/4.4)$ but must be $0 \leq TCA \leq 1.5$

Ref: Quick, M.C. and A. Pipes (1975): The UBC Watershed Model, Proceedings of Symposium in Bratislava, Application of Mathematical Models in Hydrology and Water Resources System, IAHS Pub. No. 115.

4) Model 4

$$SM4 = 0.02\ (T_X - 32) \qquad \text{(inches/day)}$$

T_X = maximum daily air temperature °F

Ref: Bruce, J.P. and R.H. Clark (1966): Introduction to Hydrometeorology, p. 257, Pergamon Press, Toronto.

5) Model 5

$$SM5 = 0.08\ (T_a - 32) \qquad \text{(inches/day)}$$

T_a = mean daily air temperature °F

Method of Analysis

Maximum annual values for rainfall and for each of the five snowmelt estimate data sets were determined for 1 to 10 day periods. These annual maximum value series were then analyzed using Gumbel extreme value (GEV) statistics to derive extreme value estimates for return periods up to 100 years. The monthly maximum values for each duration period have been tabulated together with the starting date of each duration period over which the maximum value occurred. The annual maximum value series for each duration period have also been tabulated in ascending order together with the corresponding return period and frequency to facilitate plotting on Gumbel graph paper.

No attempt was made to estimate missing data. Months with missing data were not analyzed for maximum values but an annual maximum was still determined from the rest of the months in the year with good data.

TABLE I
LONG DURATION EXTREME VALUE STATISTICS FOR SNOWMELT
MODEL 1

CORNWALL, ONTARIO (1955 to 1978)

Return Period (years)	Duration in Days 1	2	3	4	5	6	7	8	9	10
2	16.8 0.8	28.5 1.3	37.5 1.7	44.8 2.3	50.8 2.7	55.2 3.1	58.7 3.5	61.7 4.0	64.2 4.4	66.7 4.8
5	23.1 1.4	38.9 2.3	51.7 3.2	63.6 4.2	73.2 5.0	80.5 5.7	87.5 6.5	94.6 7.4	100.3 8.1	106.2 8.9
10	27.2 1.9	45.8 3.2	61.2 4.4	76.0 5.8	88.0 7.0	97.3 7.9	106.6 9.0	116.4 10.3	124.2 11.2	132.3 12.3
25	32.5 2.7	54.5 4.4	73.1 6.1	91.7 8.0	106.7 9.5	118.5 10.8	130.7 12.3	144.0 14.0	154.5 15.4	165.3 16.8
50	36.3 3.2	60.9 5.3	81.9 7.3	103.3 9.6	120.6 11.5	134.2 13.0	148.6 14.8	164.5 16.9	176.9 18.5	189.8 20.2
100	40.2 3.8	67.3 6.2	90.7 8.6	114.9 11.3	134.4 13.4	149.8 15.2	166.4 17.3	184.8 19.8	199.1 21.7	214.1 23.7
No. of Years	24.	24.	24.	24.	24.	24.	24.	24.	24.	24.

Values are given in mm with the 50% confidence limit.

TABLE II

LONG DURATION EXTREME VALUE STATISTICS FOR SNOWMELT

MODEL 1

OTTAWA, ONTARIO (1889 to 1978)

Return Period (years)	Duration in Days 1	2	3	4	5	6	7	8	9	10
2	27.69 0.55	41.69 0.69	51.93 0.86	61.68 1.15	70.41 1.32	78.46 1.48	86.07 1.70	93.11 1.88	99.50 2.06	106.05 2.28
5	35.59 0.96	51.58 1.20	64.34 1.51	77.86 1.96	89.33 2.30	99.77 2.59	110.56 2.97	120.20 3.29	129.11 3.59	138.83 3.98
10	40.82 1.31	58.14 1.64	72.55 2.06	88.57 2.68	101.87 3.13	113.88 3.53	126.77 4.06	138.13 4.49	148.71 4.90	160.53 5.43
25	47.43 1.78	66.42 2.23	82.94 2.79	102.11 3.64	117.70 4.26	131.71 4.79	147.25 5.50	160.79 6.09	173.48 6.66	187.95 7.37
50	52.33 2.13	72.56 2.67	90.64 3.35	112.15 4.36	129.45 5.11	144.94 5.75	162.45 6.60	177.60 7.31	191.85 7.99	208.29 8.84
100	57.20 2.49	78.66 3.12	98.28 3.91	122.11 5.09	141.11 5.96	158.07 6.71	177.53 7.71	194.29 8.53	210.09 9.32	228.48 10.32
No. of Years	89.	89.	89.	89.	89.	89.	89.	89.	89.	89.

Values are given in mm with the 50% confidence limit.

TABLE III
LONG DURATION EXTREME VALUE STATISTICS FOR SNOWMELT
MODEL 1

SMITHS FALLS, ONTARIO (1964 to 1978)

Return Period (years)	Duration in Days 1	2	3	4	5	6	7	8	9	10
2	26.15 0.93	35.35 0.93	44.20 1.37	51.31 1.81	57.87 2.29	63.49 2.60	68.84 2.89	73.09 3.32	76.67 3.74	78.80 4.04
5	32.23 1.80	41.43 1.80	53.15 2.64	63.15 3.50	72.88 4.43	80.52 5.03	87.80 5.60	94.87 6.43	101.18 7.24	105.30 7.83
10	36.26 2.52	45.46 2.52	59.07 3.71	70.99 4.91	82.82 6.22	91.79 7.06	100.35 7.86	109.30 9.03	117.40 10.16	122.84 10.99
25	41.35 3.48	50.56 3.48	66.56 5.12	80.89 6.77	95.37 8.58	106.03 9.74	116.21 10.84	127.52 12.46	137.90 14.01	145.01 15.15
50	45.13 4.20	54.34 4.20	72.11 6.18	88.23 8.17	104.68 10.36	116.59 11.76	127.97 13.09	141.03 15.04	153.11 16.92	161.46 18.30
100	48.88 4.92	58.09 4.93	77.62 7.24	95.53 9.58	113.93 12.15	127.08 13.78	139.65 15.34	154.45 17.63	168.20 19.83	177.78 21.44
No. of Years	13.	13.	13.	13.	13.	13.	13.	13.	13.	13.

Values are given in mm with the 50% confidence limit.

TABLE IV
LONG DURATION EXTREME VALUE STATISTICS FOR SNOWMELT
MODEL 2

CORNWALL, ONTARIO (1955 to 1978)

Return Period (years)	Duration in Days 1	2	3	4	5	6	7	8	9	10
2	24.2 1.1	40.0 2.0	50.0 2.7	59.0 3.4	64.8 3.8	70.0 4.2	74.4 4.7	77.5 5.3	79.9 5.9	81.8 6.3
5	32.9 2.0	56.7 3.7	72.5 5.0	86.8 6.2	95.9 7.0	104.3 7.7	113.2 8.7	121.0 9.8	128.0 10.8	133.2 11.5
10	38.7 2.7	67.7 5.2	87.3 7.0	105.2 8.7	116.4 9.7	127.0 10.7	139.0 12.1	149.8 13.5	159.8 15.0	167.3 18.0
25	46.0 3.7	81.7 7.1	106.1 9.6	128.5 11.9	142.4 13.2	155.6 14.6	171.4 16.5	186.2 18.5	200.1 20.5	210.3 21.9
50	51.4 4.3	92.1 8.6	120.1 11.5	145.8 14.3	161.6 15.9	176.9 17.6	195.5 19.9	213.2 22.3	229.9 24.7	242.3 26.4
100	56.7 5.2	102.4 10.0	133.9 13.5	162.9 16.7	180.7 18.6	198.0 20.6	219.5 23.3	240.0 26.1	259.6 28.9	274.0 30.9
No. of Years	24.	24.	24.	24.	24.	24.	24.	24.	24.	24.

Values are given in mm with the 50% confidence limit.

TABLE V

LONG DURATION EXTREME VALUE STATISTICS FOR SNOWMELT

MODEL 2

OTTAWA, ONTARIO (1889 to 1978)

Return Period (years)	Duration in Days									
	1	2	3	4	5	6	7	8	9	10
2	32.32 0.57	52.18 0.89	66.77 1.25	78.45 1.49	88.87 1.73	98.22 1.95	106.36 2.16	113.81 2.39	120.98 2.61	127.54 2.90
5	40.51 0.99	65.01 1.56	84.68 2.17	99.94 2.61	113.76 3.02	126.24 3.40	137.43 3.77	148.11 4.16	158.55 4.56	169.17 5.05
10	45.93 1.36	73.50 2.13	96.54 2.97	114.16 3.56	130.25 4.12	144.80 4.64	158.01 5.15	170.81 5.68	183.42 6.22	196.74 6.90
25	52.78 1.84	84.24 2.88	111.53 4.03	132.14 4.83	151.08 5.60	168.24 6.30	184.00 6.99	199.50 7.71	214.85 8.45	231.57 9.36
50	57.87 2.21	92.20 3.46	122.64 4.83	145.47 5.80	166.53 6.72	185.63 7.56	203.29 8.38	220.78 9.25	238.16 10.13	257.41 11.23
100	62.91 2.58	100.11 4.04	133.68 5.64	158.71 6.76	181.87 7.84	202.90 8.82	222.43 9.78	241.90 10.79	261.31 11.83	283.06 13.11
No. of Years	89.	89.	89.	89.	89.	89.	89.	89.	89.	89.

Values are given in mm with the 50% confidence limit.

TABLE VI
LONG DURATION EXTREME VALUE STATISTICS FOR SNOWMELT
MODEL 2

SMITHS FALLS, ONTARIO (1964 to 1978)

Return Period (years)	Duration in Days 1	2	3	4	5	6	7	8	9	10
2	28.71 1.42	43.62 1.57	52.50 2.07	59.92 2.49	66.80 2.80	74.05 3.25	79.11 3.94	84.87 4.64	87.66 5.16	89.80 5.42
5	37.99 2.74	53.88 3.03	66.03 4.00	76.22 4.82	85.15 5.42	95.35 6.29	104.95 7.63	115.26 8.97	121.45 9.98	125.32 10.49
10	44.13 3.84	60.67 4.25	74.99 5.61	87.01 6.76	97.29 7.60	109.46 8.83	122.05 10.71	135.37 12.60	143.82 14.01	148.84 14.73
25	51.88 5.30	69.25 5.87	86.31 7.74	100.65 9.32	112.63 10.49	127.28 12.18	143.67 14.78	160.79 17.37	172.09 19.32	178.56 20.32
50	57.64 6.40	75.62 7.08	94.71 9.34	110.77 11.26	124.01 12.67	140.49 14.71	159.71 17.84	179.64 20.98	193.06 23.33	200.61 24.53
100	63.35 7.50	81.94 8.30	103.05 10.95	120.81 13.19	135.31 14.84	153.62 17.24	175.62 20.91	198.36 24.59	213.87 27.35	222.49 28.75
No. of Years	13.	13.	13.	13.	13.	13.	13.	13.	13.	13.

Values are given in mm with the 50% confidence limit.

TABLE VII
LONG DURATION EXTREME VALUE STATISTICS FOR SNOWMELT
MODEL 3

CORNWALL, ONTARIO (1955 to 1978)

Return Period (years)	Duration in Days 1	2	3	4	5	6	7	8	9	10
2	29.1 2.2	45.8 3.0	-	-	-	75.4 4.7	79.3 5.2	82.9 5.7	85.7 6.1	87.9 6.5
5	47.2 4.1	70.8 5.6	83.9 6.5	95.9 7.4	106.0 8.0	114.7 8.7	121.8 9.5	129.3 10.4	135.8 11.2	141.3 12.1
10	59.2 5.6	87.3 7.7	103.2 9.1	117.7 10.3	128.7 11.1	140.8 12.1	149.9 13.2	160.0 14.4	169.0 15.6	176.6 16.6
25	74.3 7.7	108.1 10.6	127.6 13.4	145.3 14.0	158.6 15.2	172.5 16.8	185.4 18.1	198.9 19.8	210.9 21.3	221.3 22.8
50	85.5 9.3	123.5 12.8	145.7 15.0	165.8 16.8	180.8 18.3	186.7 20.0	211.8 21.8	227.7 23.8	241.9 25.7	254.4 27.4
100	96.7 10.8	138.8 14.9	163.7 17.5	186.1 19.8	202.8 21.5	220.6 23.3	238.0 25.5	256.3 27.8	272.8 30.1	287.3 32.0
No. of Years	24.	24.	24.	24.	24.	24.	24.	24.	24.	24.

Values are given in mm with the 50% confidence limit.

TABLE VIII
LONG DURATION EXTREME VALUE STATISTICS FOR SNOWMELT
MODEL 3

OTTAWA, ONTARIO (1889 to 1978)

Return Period (years)	Duration in Days 1	2	3	4	5	6	7	8	9	10
2	36.27 0.87	58.15 1.34	72.43 1.67	84.68 1.89	94.93 2.10	104.75 2.28	113.26 2.38	120.50 2.57	127.50 2.78	134.21 2.99
5	48.74 1.51	77.46 2.34	96.40 2.91	111.91 3.30	125.07 3.66	137.51 3.97	147.53 4.16	157.43 4.48	167.49 4.85	177.26 5.22
10	56.99 2.07	90.24 3.20	112.26 3.97	129.94 4.51	145.02 4.99	159.21 5.43	170.22 5.68	181.88 6.12	193.97 6.62	205.76 7.13
25	67.42 2.80	106.39 4.34	132.32 5.39	152.72 6.12	170.23 6.78	186.61 7.37	198.89 7.70	212.77 8.30	227.42 8.99	241.77 9.68
50	75.16 3.36	118.37 5.21	147.19 6.47	169.62 7.35	188.94 8.13	206.95 8.84	220.16 9.24	235.69 9.96	252.24 10.79	268.49 11.61
100	82.84 3.93	130.26 6.08	161.95 7.54	186.40 8.57	207.51 9.49	227.13 10.31	241.27 10.79	258.44 11.62	276.87 12.59	295.01 13.55
No. of Years	89.	89.	89.	89.	89.	89.	89.	89.	89.	89.

Values are given in mm with the 50% confidence limit.

TABLE IX
LONG DURATION EXTREME VALUE STATISTICS FOR SNOWMELT
MODEL 3

SMITHS FALLS, ONTARIO (1964 to 1978)

Return Period (years)	Duration in Days 1	2	3	4	5	6	7	8	9	10
2	31.37 1.62	46.48 2.15	57.51 2.53	65.31 2.70	74.75 2.77	78.89 2.94	84.28 3.70	90.09 4.62	94.62 5.45	96.96 5.90
5	41.98 3.14	60.55 4.16	74.09 4.90	83.03 5.23	92.88 5.36	98.18 5.70	108.56 7.17	120.37 8.95	130.35 10.55	135.63 11.42
10	49.01 4.40	69.87 5.84	85.07 6.88	94.76 7.35	104.89 7.52	110.95 8.00	124.62 10.06	140.42 12.56	154.01 14.81	161.23 16.03
25	57.89 6.07	81.64 8.05	98.94 9.48	109.59 10.13	120.05 10.37	127.09 11.03	144.93 13.88	165.75 17.32	183.90 20.43	193.57 22.11
50	64.48 7.33	90.38 9.72	109.23 11.45	120.58 12.24	131.30 12.52	139.06 13.32	159.99 16.76	184.55 20.91	206.07 24.68	217.56 26.70
100	71.02 8.59	99.05 11.39	119.45 13.42	131.50 14.34	142.47 14.67	150.95 15.61	174.94 19.64	203.20 24.51	228.09 28.92	241.38 31.29
No. of Years	13.	13.	13.	13.	13.	13.	13.	13.	13.	13.

Values are given in mm with the 50% confidence limit.

TABLE X
LONG DURATION EXTREME VALUE STATISTICS FOR SNOWMELT
MODEL 4

CORNWALL, ONTARIO (1955 to 1978)

Return Period (years)	Duration in Days 1	2	3	4	5	6	7	8	9	10
2	12.7 0.6	22.2 1.0	28.3 1.5	34.9 1.8	38.4 2.1	44.2 2.5	48.6 2.9	52.5 3.3	56.2 3.6	58.8 3.8
5	17.6 1.1	30.5 1.9	41.2 2.7	49.6 3.3	56.8 3.9	64.9 4.6	72.5 5.4	79.7 6.1	85.4 6.6	94.5 7.1
10	23.8 1.5	36.1 2.6	49.1 3.7	59.4 4.6	68.3 5.4	78.6 6.4	88.3 7.4	97.7 8.5	104.7 9.1	111.4 9.8
25	24.8 2.1	43.1 3.6	50.1 5.1	71.8 6.3	82.8 7.4	95.9 8.8	108.3 10.2	120.5 11.6	129.2 12.4	137.8 13.5
50	27.8 2.5	48.2 4.3	66.5 6.1	80.9 7.6	93.6 8.9	108.7 10.6	123.2 12.3	137.4 14.0	147.3 15.0	157.4 16.2
100	33.8 2.9	53.4 5.0	73.9 7.2	90.0 8.9	104.4 10.4	121.4 12.4	137.9 14.3	154.2 16.3	165.3 17.5	176.8 19.0
No. of Years	24.	24.	24.	24.	24.	24.	24.	24.	24.	24.

Values are given in mm with the 50% confidence limit.

TABLE XI
LONG DURATION EXTREME VALUE STATISTICS FOR SNOWMELT
MODEL 4

OTTAWA, ONTARIO (1889 to 1978)

Return Period (years)	Duration in Days 1	2	3	4	5	6	7	8	9	10
2	25.70 0.55	36.50 0.61	44.79 0.69	53.43 0.87	61.82 1.07	69.94 1.28	76.87 1.44	82.77 1.58	88.82 1.76	94.70 1.93
5	33.64 0.96	45.31 1.07	54.77 1.21	65.91 1.51	77.18 1.86	88.27 2.22	97.52 2.51	105.54 2.76	114.05 3.06	122.38 3.36
10	38.89 1.31	51.15 1.46	61.38 1.65	74.18 2.07	87.35 2.54	100.41 3.04	111.19 3.42	120.61 3.77	130.76 4.18	140.70 4.58
25	45.53 1.78	58.52 1.98	69.73 2.24	84.63 2.81	100.19 3.45	115.74 4.12	128.47 4.64	139.65 5.12	151.87 5.67	163.85 6.22
50	50.45 2.14	63.99 2.38	75.93 2.69	92.38 3.37	109.73 4.14	127.12 4.94	141.29 5.57	153.78 6.14	167.53 6.81	181.03 7.46
100	55.34 2.50	69.41 2.77	82.08 3.14	100.07 3.93	119.19 4.83	138.41 5.77	154.01 6.50	167.80 7.17	183.07 7.94	198.07 8.71
No. of Years	89.	89.	89.	89.	89.	89.	89.	89.	89.	89.

Values are given in mm with the 50% confidence limit.

TABLE XII
LONG DURATION EXTREME VALUE STATISTICS FOR SNOWMELT
MODEL 4

SMITHS FALLS, ONTARIO (1964 to 1978)

Return Period (years)	Duration in Days 1	2	3	4	5	6	7	8	9	10
2	27.61. 1.02	34.32 1.26	39.13 1.39	46.15 1.63	51.40 1.97	58.11 2.43	62.79 2.82	67.78 2.98	71.71 3.31	75.28 3.58
5	34.28 1.97	42.57 2.43	48.26 2.70	56.80 3.15	64.33 3.82	74.01 4.70	81.28 5.46	87.33 5.78	93.39 6.40	98.74 6.93
10	38.70 2.77	48.02 3.42	54.31 3.79	63.85 4.42	72.90 5.36	84.54 6.59	93.53 7.67	100.28 8.11	107.75 8.99	114.27 9.73
25	44.28 3.81	54.92 4.71	61.95 5.22	72.76 6.09	83.72 7.40	97.84 9.09	108.99 10.57	116.63 11.18	125.88 12.40	133.90 13.42
50	48.42 4.61	60.04 5.69	67.61 6.31	79.37 7.35	91.75 8.93	107.70 10.98	120.47 12.77	128.77 13.50	139.34 14.97	148.46 16.20
100	52.53 5.40	65.11 6.67	73.24 7.39	85.93 8.62	99.72 10.47	117.49 12.86	131.86 14.96	140.81 15.82	152.69 17.54	162.92 18.99
No. of Years	13.	13.	13.	13.	13.	13.	13.	13.	13.	13.

Values are given in mm with the 50% confidence limit.

TABLE XIII
LONG DURATION EXTREME VALUE STATISTICS FOR SNOWMELT
MODEL 5

CORNWALL, ONTARIO (1955 to 1978)

Return Period (years)	Duration in Days 1	2	3	4	5	6	7	8	9	10
2	24.6 1.1	41.2 2.1	51.0 2.8	59.9 3.5	66.1 3.9	72.8 4.4	77.1 5.0	80.8 5.5	83.4 6.1	88.8 6.4
5	33.9 2.1	58.2 3.8	74.1 5.3	88.2 6.4	98.2 7.2	109.3 8.2	118.1 9.2	120.3 10.2	133.1 11.2	138.2 11.8
10	40.0 2.9	69.5 5.3	89.3 7.2	107.3 8.8	119.4 10.0	133.5 11.3	145.2 12.7	156.5 14.2	166.0 15.5	173.1 16.4
25	47.7 3.9	83.8 7.3	108.6 9.8	130.8 12.1	146.3 13.7	164.0 15.5	179.5 17.5	194.5 19.4	207.7 21.2	217.1 22.4
50	53.4 4.7	94.3 8.7	122.9 11.8	148.4 14.8	166.2 16.5	188.6 18.7	204.9 21.0	222.8 23.4	238.5 25.5	249.8 27.0
100	59.1 5.5	104.8 10.2	137.1 13.8	165.9 17.0	185.9 19.3	209.1 21.9	230.1 24.6	250.8 27.3	269.2 29.9	282.3 31.6
No. of Years	24.	24.	24.	24.	24.	24.	24.	24.	24.	24.

Values are given in mm with the 50% confidence limit.

TABLE XV
LONG DURATION EXTREME VALUE STATISTICS FOR SNOWMELT
MODEL 5

SMITHS FALLS, ONTARIO (1964 to 1978)

Return Period (years)	Duration in Days 1	2	3	4	5	6	7	8	9	10
2	29.65 1.51	45.71 1.75	54.58 2.15	62.90 2.56	71.15 2.64	76.40 3.15	81.94 3.77	86.96 4.49	90.11 4.98	92.47 5.63
5	39.54 2.92	57.19 3.39	68.64 4.15	79.67 4.95	88.44 5.11	97.04 6.10	106.65 7.30	116.39 8.69	122.75 9.64	129.35 10.89
10	46.09 4.10	64.79 4.76	77.96 5.83	90.77 6.95	99.89 7.17	110.70 8.56	123.00 10.24	135.87 12.20	144.36 13.53	153.76 15.29
25	54.37 5.66	74.40 6.57	89.72 8.04	104.80 9.59	114.35 9.89	127.96 11.80	143.67 14.13	160.48 16.83	171.66 18.67	184.61 21.09
50	60.51 6.83	81.52 7.93	98.45 9.71	115.21 11.58	125.08 11.94	140.77 14.25	159.01 17.06	178.74 20.32	191.92 22.54	207.50 25.47
100	66.60 8.00	88.59 9.29	107.11 11.38	125.54 13.57	135.73 13.99	153.48 16.70	174.23 20.00	196.87 23.81	212.03 26.41	230.21 29.94
No. of Years	13.	13.	13.	13.	13.	13.	13.	13.	13.	13.

Values are given in mm with the 50% confidence limit.

APPENDIX V

ANALYSIS OF OUTLET FROM CHRISTIE LAKE

Planning
Engineering
Project Management

FENCO

1 Yonge Street
Toronto, Canada M5E 1E7
416 - 361 - 4722
Cable 'FENCOENG'
Telex 06 - 23765

December 24, 1980

Rideau Valley Conservation Authority
Box 599
Manotick, Ontario
K0A 2N0

ATTENTION: Mr. O. Stirajs, R.P.F.
Resources Manager

Dear Sir,

ANALYSIS OF OUTLET FROM CHRISTIE LAKE

Summary

The Rideau Valley Conservation Authority requested that FENCO CONSULTANTS LTD. investigate the Tay River downstream of Christie Lake. The purpose of the study was to identify any obstructions in the channel which might be causing high water levels in the Christie Lake. It has been reported that damage to cottages adjacent to Christie Lake have been caused by high lake levels.

The proposed work program was outlined in our letter to the Authority of March 4, 1980. The Scope of Work included data collection, field reconnaissance and surveys, data analysis, solution identification and report preparation. This work has been completed and the results are documented in this letter, and the attached computer calculation sheets.

The results of the study indicate that water levels at the outlet of Christie Lake is controlled by the hydraulic capacity of the natural channel. Our analysis indicates that bridges over the Tay River are not causing the flooding problems.

Major channelization of the Tay River would be required to reduce flood levels in Christie Lake. The amount of excavation required would be a function of the design flood and the maximum tolerable water level for that design flow rate.

Preliminary calculations indicate that a 100 year flood could be of the order of 30 m^3/S (1000 cfs) or more. A study carried out for Parks Canada by Acres Consulting Services Limited ("Study of the Operation of the Rideau-Cataraqui System", March 1977) indicates that winter flows in excess of 5 m^3/S (175 cfs) may damage docks.

The maximum allowable water level cannot be defined without a detailed survey of the cottages around the lake. It is conceivable that the width of the Tay River would have to be doubled to provide any significant reduction in flood levels. It has been estimated that it would cost approximately $1,700,000 per kilometer, excluding the cost of replacing bridges, to modify the river in this manner.

It is recommended that flood proofing of structures on Christie Lake be investigated. A survey should be carried out to define possible damage as a function of lake level. Also the cost of flood proofing to various levels would need to be estimated. A survey of this nature may reveal that modification of a few structures which are built low with respect to the lake may eliminate major problems caused by high water levels. It may be possible to enlist the help of affected cottage owners to carry out a preliminary survey of this nature. The survey would include:

1) a map showing the locations of structures subject to damage
2) the names and addresses of affected owners
3) a description of the type of each structure
4) the damage that occurred
5) the cost of repairs
6) a photograph of the structure before or after it was damaged
7) other observations and comments made by individual owners.

To our knowledge there have been no reports of debris or ice jamming at the bridges. However this may be occurring. It is suggested that local residents could monitor these bridges and report any jams. Photographs of any jams and associated flooding would be beneficial in performing any further studies that may be required.

Water levels in Christie Lake are governed by the flow rate out of the lake. This flow rate is dependent to a large extent on the flow into Christie Lake from Bolingbrook Dam. There is some concern that Bolingbrook Dam operated by Parks Canada for the Rideau Canal is not being used to its best advantage to provide flood protection to Christie Lake. We have reviewed the operating policy outlined in the report "Study of the Operation of the Rideau-Cataraqui System". In principle, this policy appears to be the most acceptable aproach to providing flood protection to Christie Lake, Bob's Lake and other areas within the Tay River watershed.

The successful practical implementation of this policy depends on a large number of factors such as forecasts of runoff, determination of acceptable flow release rates in different seasons and quick response in changing the settings of the controls on the structure.

We are not able to assess the effectiveness of the actual operations of Bolingbrook Dam. There is no readily available data upon which an assessment can be made and it was beyond the scope of this study to perform a comprehensive analysis of how well the actual operations met the objectives of the proposed operating policy.

Field Reconnaissance and Surveys

The field work carried out for this project was very similar to the type of work carried out for a floodplain mapping project. That is:

1) The river channel was inspected and soundings were taken along the river for a distance of approximately 4.8 km (3 miles) downstream of Christie Lake.

2) Bridge dimensions were obtained for the structures noted on Figure 1 and other bridges downstream of the main study area.

3) Due to the fact that detailed topographic mapping was not available, a detailed level survey was carried out to obtain the elevations of the bridges and representative cross-sections along the river. The approximate locations of these cross-sections are indicated on Figure 1.

4) Photographs of the bridges and typical reaches of the river were obtained. Copies of these photographs are attached.

No obstructions, log jams or beaver dams were noted during the field work. A rapid, indicated on Figure 1, was the only visible evidence of a possible control section.

Data Analysis

The analysis of the data was made using computer program HEC-2 which computes water surface elevations as a function of flow rates, downstream water level, river geometry and channel roughness.

Additional manual calculations were performed to determine the effect of ice cover on the hydraulic capacity of the channel and bridges. Head losses through several bridges were calculated assuming (i) a stable ice cover and (ii) no ice cover. The conveyance capacity of a typical cross section was computed with a stable ice cover and without an ice cover.

The field surveys were used to establish a series of cross-sections which define the geometry of the river and the bridges. The number of sections used in computer model was greater than the number surveyed in the field for the following reasons:

1) Economics limits the number of sections that can be surveyed in the field.

2) The geometry of the stream is fairly uniform and thus, a large number of sections is not required to model the stream.

3) However, to prevent numerical errors in calculations a large number of sections should be used in the computer program.

The additional sections used were obtained by interpolation of the field data.

A number of profiles were computed in each run. That is, the flow rates varied from 1.3 m^3/S (50 cfs) to 42.5 m^3/S (1500 cfs) and a water surface profile was computed for each flow rate.

The differences between the three sets of computer runs are described below:

Run 1 - The downstream starting elevation was assumed to be uniform flow depth.

Run 2 - The downstream starting elevation was assumed to be critical depth over the existing rapids.

Run 3 - The downstream starting elevation was assumed to be critical depth at the rapids assuming that the obstruction which forms the rapids had been removed.

Analysis of the results leads to the following conclusions:

1) The modelled water surface elevation agrees favourably with the water surface profile measured during the field survey. The water levels predicted at Christie Lake agree favourably with the relationship of flow rates and water level defined in the report "Study of the Operation of the Rideau - Cataraqui System" when flows are less than 14.2 m^3/sec (500 cfs). A comparison of the results is shown in Figure 2. Thus we have concluded that the backwater model is providing an accurate description of the physical conditions.

2) Examination of the computer output indicates that none of the bridges act as a hydraulic control which would cause high water levels in Christie Lake. There is no evidence that there is excessive headloss at any particular structure which would cause high water levels in Christie Lake.

3) The presence of a stable ice cover does not cause a substantial increase in head loss through the bridges. Increases in head loss through a bridge due to the presence of ice were of the order of 2 centimeters.

4) It was concluded that the water levels in Christie Lake are governed by the natural hydraulic capacity of the Tay River channel.

5) An ice cover will reduce the hydraulic capacity of the natural channel. Our calculations indicate that under low flow conditions, the hydraulic conveyance capacity of the channel could be reduced by some 55%.

6) Removal of the rock which causes the rapids indicated on Figure 1 would not result in lower water levels at Christie Lake when flow rates are high. However, water levels may be lowered in the Tay River under low flow conditions. This may not be desireable.

7) The only means of reducing water levels caused by high flow rates is to increase the cross-section area of the Tay River. The channel would have to be widened along a length of at least 4.8 to 6.4 km (3 to 4 miles) downstream from Christie Lake. This is not considered to be a practical solution as it would cost approximately $12,500,000. It is not possible to increase hydraulic capacity by increasing the slope of the channel.

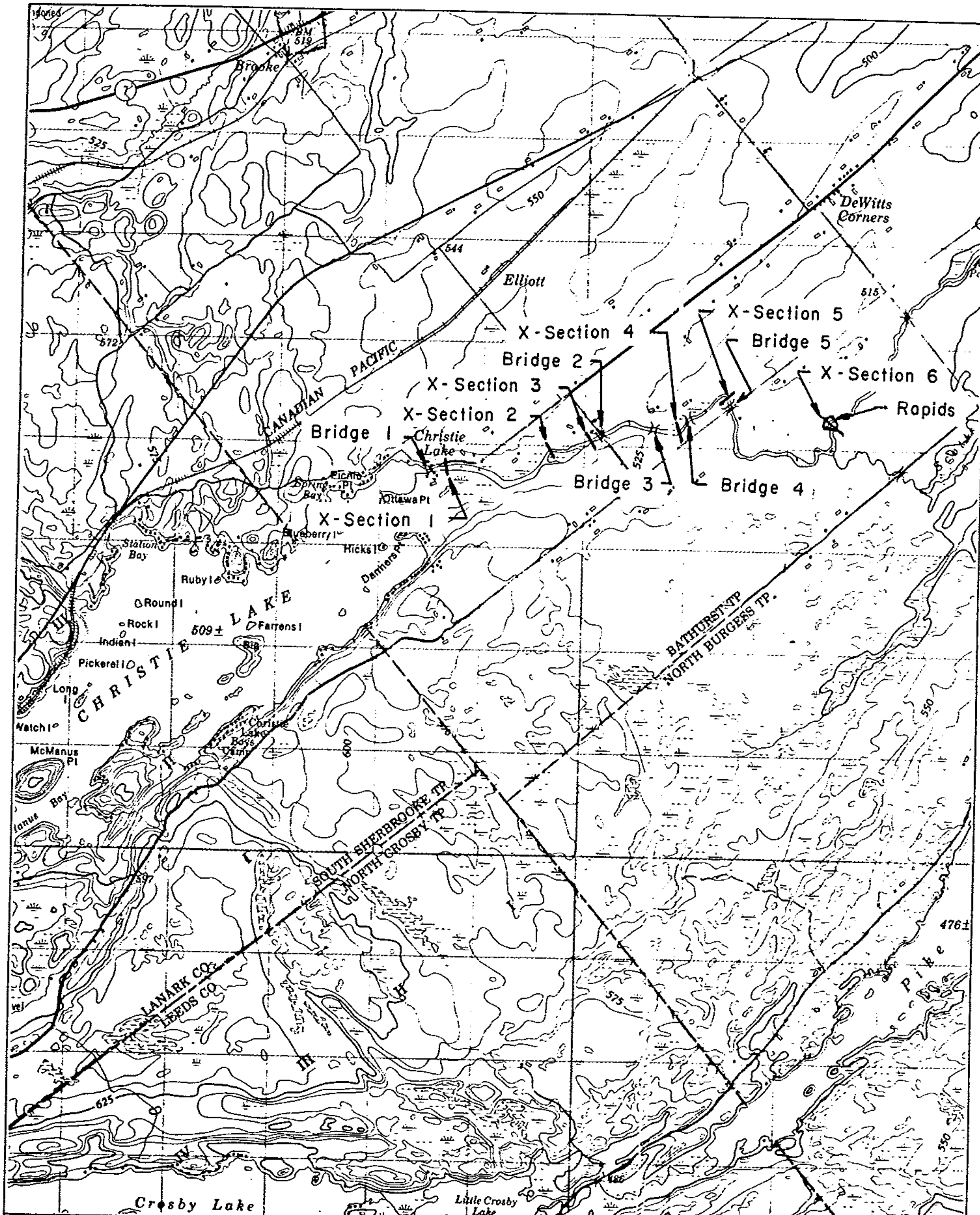
We trust that the above information will assist you with the consideration of problems at Christie Lake. If you have any questions, please do not hesitate to contact us.

Yours very truly,
FENCO CONSULTANTS LTD.

F. M. Biesenthal

F.M. Biesenthal, P.Eng.

FMB/nr
8516
Encl.



NO.	REVISION	BY	DATE

PROJECT TITLE

CHRISTIE LAKE OUTLET ANALYSIS

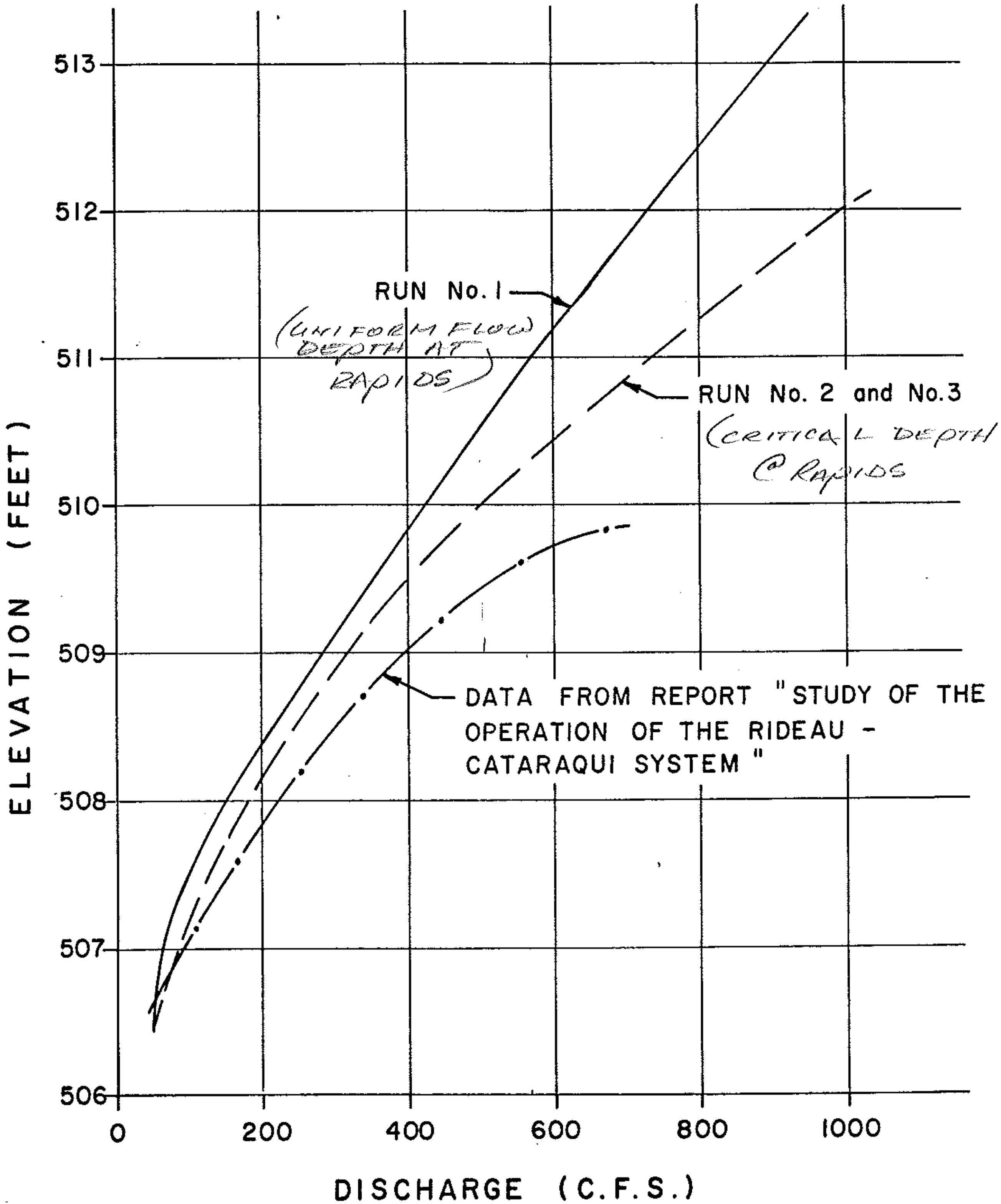
KEY PLAN

	COMP.	DWG.
MADE		P.G.
CH'D.		P.D.C.
APP.		F.M.B.

FENCO

FENCO CONSULTANTS LTD.

DATE		SCALE	
DWG.	FIGURE 1		REV.



NO.	REVISION	BY	DATE

PROJECT TITLE

CHRISTIE LAKE
OUTLET ANALYSIS

RATING CURVE

	COMP.	DWG.
MADE		P.G.
CH'D.		P.D.C.
APP.		F.M.B.

FENCO
FENCO CONSULTANTS LTD.

DATE

SCALE

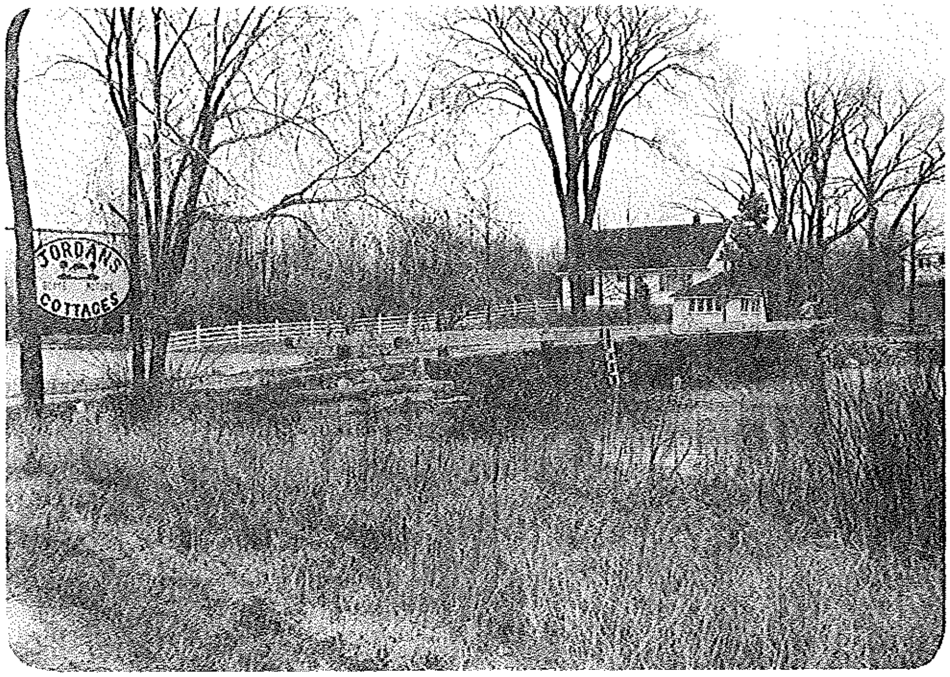
DWG. FIGURE 2

REV.

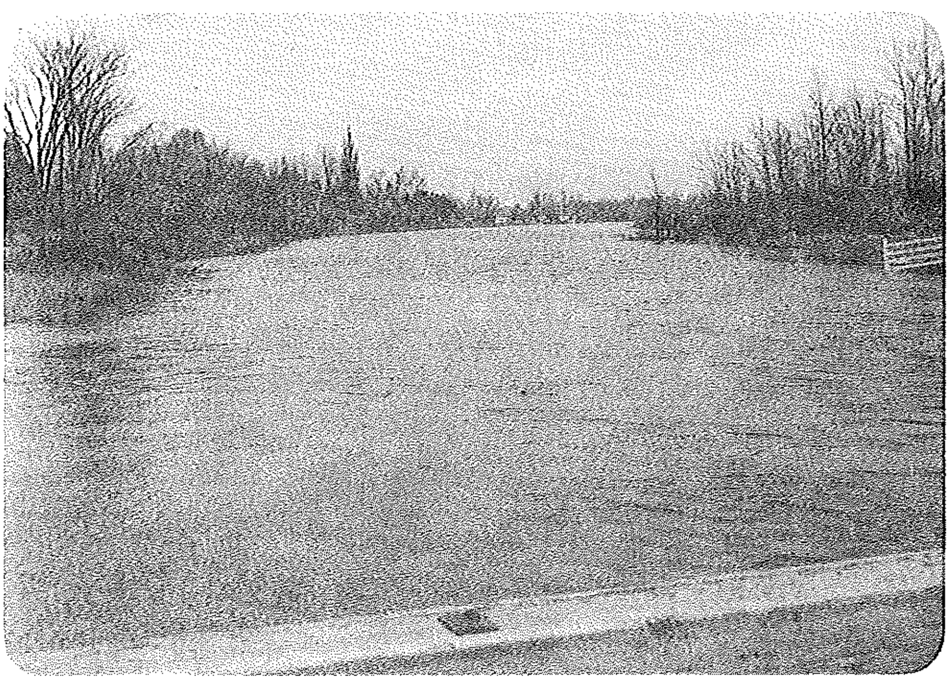
ANALYSIS OF OUTLET FROM

CHRISTIE LAKE

Project I-8516-8



Looking Downstream Toward Bridge Number 1

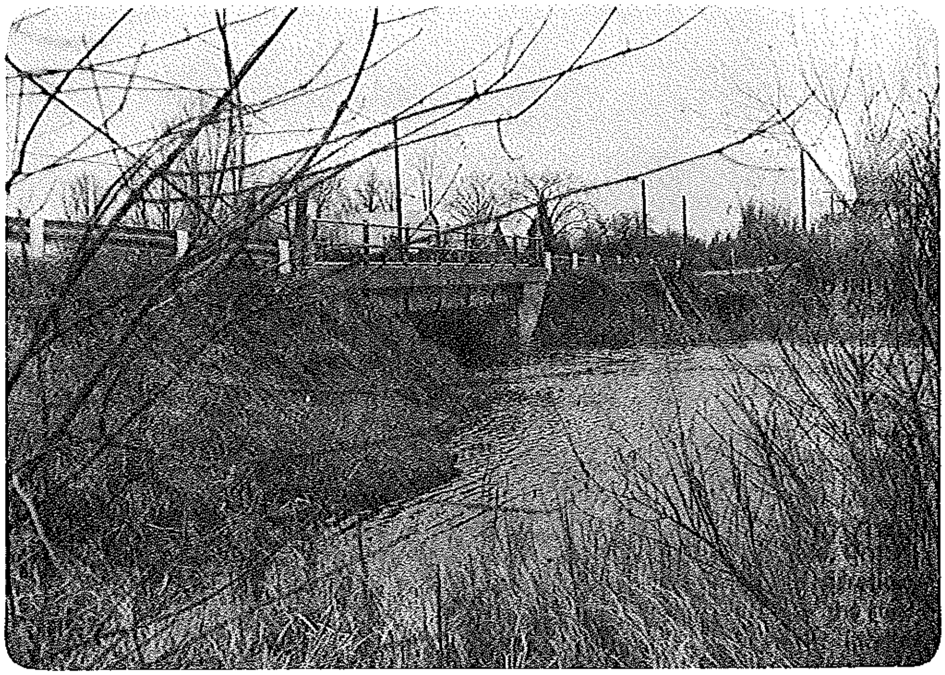


Looking Downstream From Bridge Number 1

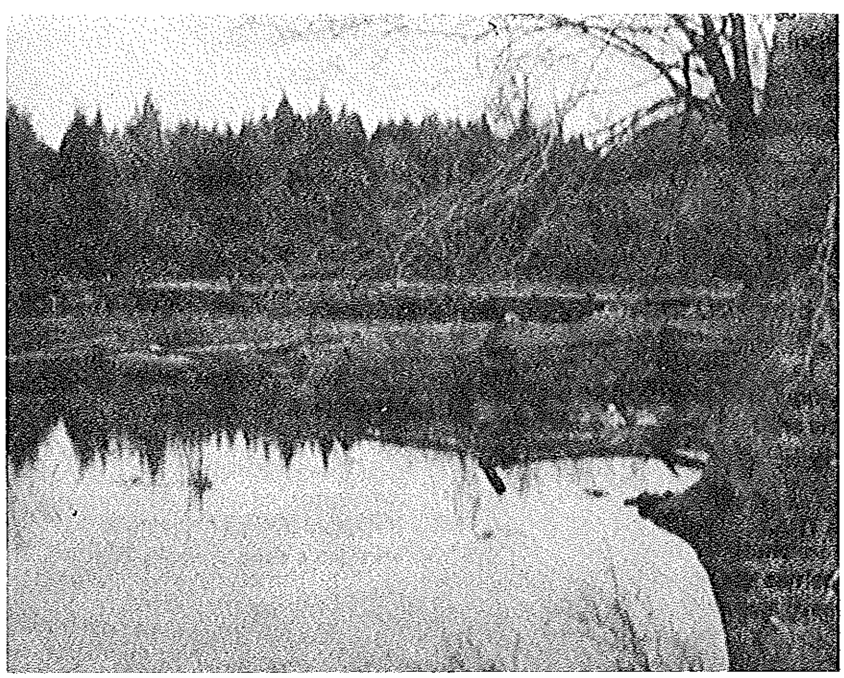
ANALYSIS OF OUTLET FROM

CHRISTIE LAKE

Project I-8516-8



Looking Downstream Toward Bridge Number 2



Looking Upstream Toward Bridge Number 3

ANALYSIS OF OUTLET FROM

CHRISTIE LAKE

Project I-8516-8

Looking Upstream Toward Bridge Number 4

Looking Upstream Toward Bridge Number 5

APPENDIX VI

FLOODPLAIN MAPS

SHEET ____

RIDEAU VALLEY CONSERVATION AUTHORITY

RIDEAU VALLEY CONSERVATION AUTHORITY

TAY RIVER

FLOOD PLAIN MAPPING

GLEN TAY TO THE TAY MARSH

ONTARIO REGULATION No. ____
SCHEDULE No. ____

Scale 1:2 000

Metres

Feet

CONTOUR INTERVAL 1 METRE
(0.5 METRE INTERPOLATIONS)

LEGEND

Contour, Index	
" Intermediate	
" Supplementary	
" Approximate	
" Depression	
Spot Elevation, Water Level	
Regional Storm Flood Level	
Regional Storm Flood Line	
Fill And Construction Limits	
Cross Section	
Cross Section Number	14000

GENERAL INFORMATION

ORTHOPHOTO MAP COMPILED AND DRAWN BY NORTHWAY–GESTALT CORPORATION FROM 1:8000 AERIAL PHOTOGRAPHY TAKEN JANUARY 15 1986.

THE MAPPING HAS BEEN PREPARED ACCORDING TO THE CAAS SPECIFICATIONS FOR 1:2000 TOPOGRAPHIC MAPPING.

NORTH AMERICAN DATUM 1927
UNIVERSAL TRANSVERSE MERCATOR (6°) PROJECTION
ZONE 18 CENTRAL MERIDIAN 75°W
GRID INTERVAL 100 METRES

APPROVED BY:

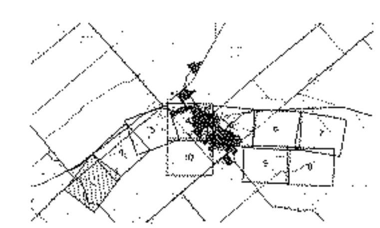
NORTHWAY–GESTALT CORP.
N.G.C. JOB NO. C-0627-2

FENCO CONSULTANTS LTD.
DATE: APRIL 1991

FENCO

FENCO CONSULTANTS LTD.

PROJECT: 0516 APRIL 1991



KEY PLAN 1:100,000

DRAWING No 1 OF 10

SHEET ____

RIDEAU VALLEY CONSERVATION AUTHORITY

RIDEAU VALLEY CONSERVATION AUTHORITY

TAY RIVER

FLOOD PLAIN MAPPING

GLEN TAY TO THE TAY MARSH

ONTARIO REGULATION No. ________
SCHEDULE No. ________

Scale 1:2 000

CONTOUR INTERVAL 1 METRE
(0.5 METRE INTERPOLATIONS)

LEGEND

Contour, Index	
" Intermediate	
" Supplementary	
" Approximate	
" Depression	
Spot Elevation, Water Level	
Regional Storm Flood Level	
Regional Storm Flood Line	
Fill And Construction Limits	
Cross Section	
Cross Section Number	1+000

GENERAL INFORMATION

ORTHOPHOTO MAP COMPILED AND DRAWN BY NORTHWAY-GESTALT CORPORATION FROM 1:8000 AERIAL PHOTOGRAPHY TAKEN JANUARY 15 1980.

THE MAPPING HAS BEEN PREPARED ACCORDING TO THE CAAS SPECIFICATIONS FOR 1:2000 TOPOGRAPHIC MAPPING.

NORTH AMERICAN DATUM 1927
UNIVERSAL TRANSVERSE MERCATOR (UTM) PROJECTION
ZONE 18 CENTRAL MERIDIAN 75°W
GRID INTERVAL 100 METRES.

APPROVED BY:

REGISTERED PROFESSIONAL ENGINEER J. D. THOMPSON PROVINCE OF ONTARIO

NORTHWAY-GESTALT CORP.
N.G.C. JOB NO. C-8827-2

FENCO CONSULTANTS LTD.
DATE APRIL 1981

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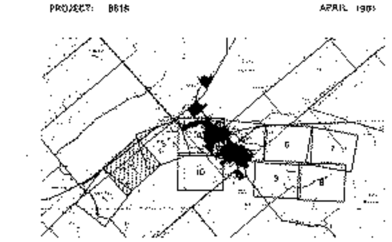
FENCO CONSULTANTS LTD.

PROJECT: 8818 APRIL 1981



KEY PLAN 1:100,000

DRAWING No 2 OF 10

SHEET ____

RIDEAU VALLEY CONSERVATION AUTHORITY

RIDEAU VALLEY CONSERVATION AUTHORITY

TAY RIVER

FLOOD PLAIN MAPPING

GLEN TAY TO THE TAY MARSH

ONTARIO REGULATION No.____
SCHEDULE No.____

Scale 1:2 000

CONTOUR INTERVAL 1 METRE
(0.5 METRE INTERPOLATIONS)

LEGEND

Contour, Index	135
" Intermediate	134
" Supplementary	
" Approximate	
" Depression	
Spot Elevation, Water Level	
Regional Storm Flood Level	
Regional Storm Flood Line	
Fill And Construction Limits	
Cross Section	
Cross Section Number	1+000

GENERAL INFORMATION

ORTHOPHOTO MAP COMPILED AND DRAWN BY NORTHWAY-GESTALT CORPORATION FROM 1:8000 AERIAL PHOTOGRAPHY TAKEN JANUARY 15 1980.

THIS MAPPING HAS BEEN PREPARED ACCORDING TO THE CAAS SPECIFICATIONS FOR 1:2000 TOPOGRAPHIC MAPPING.

NORTH AMERICAN DATUM 1927
UNIVERSAL TRANSVERSE MERCATOR (6°) PROJECTION
ZONE 18. CENTRAL MERIDIAN 75°W
GRID INTERVAL 100 METRES.

APPROVED BY:

J. D. THOMPSON

NORTHWAY-GESTALT CORP.
N.G.C. JOB NO. C-8027-2

FENCO CONSULTANTS LTD.
DATE APRIL 1981

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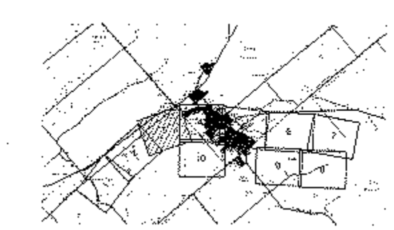
PROJECT: 8516 APRIL 1981



KEY PLAN 1:100,000

DRAWING No 3 OF 10

SHEET ____

RIDEAU VALLEY CONSERVATION AUTHORITY

RIDEAU VALLEY CONSERVATION AUTHORITY

TAY RIVER

FLOOD PLAIN MAPPING

GLEN TAY TO THE TAY MARSH

ONTARIO REGULATION No. __________
SCHEDULE No. __________

Scale 1:2 000

CONTOUR INTERVAL 1 METRE
(0.5 METRE INTERPOLATIONS)

LEGEND

Contour, Index	135
Intermediate	134
Supplementary	
Approximate	
Depression	
Spot Elevation, Water Level	
Regional Storm Flood Level	
Regional Storm Flood Line	
Fill And Construction Limits	
Cross Section	
Cross Section Number	1+000

GENERAL INFORMATION

ORTHOPHOTO MAP COMPILED AND DRAWN BY NORTHWAY-GESTALT CORPORATION FROM 1:8000 AERIAL PHOTOGRAPHY TAKEN JANUARY 16 1980.

THE MAPPING HAS BEEN PREPARED ACCORDING TO THE CAAS SPECIFICATIONS FOR 1:2000 TOPOGRAPHIC MAPPING.

NORTH AMERICAN DATUM 1927
UNIVERSAL TRANSVERSE MERCATOR (6°) PROJECTION
ZONE 18. CENTRAL MERIDIAN 75°W
GRID INTERVAL 100 METRES.

APPROVED BY:

J. D. THOMPSON — REGISTERED PROFESSIONAL ENGINEER — PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL SURVEYOR — PROVINCE OF ONTARIO

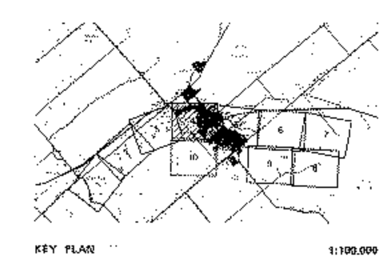
NORTHWAY-GESTALT CORP.
N.G.L. JOB NO. C-8627-2

FENCO CONSULTANTS LTD.
DATE APRIL 1981

FENCO

FENCO CONSULTANTS LTD.

PROJECT: 0516 APRIL 1981



KEY PLAN 1:100,000

DRAWING No 4 OF 10

SHEET ____

RIDEAU VALLEY CONSERVATION AUTHORITY

RIDEAU VALLEY CONSERVATION AUTHORITY

TAY RIVER

FLOOD PLAIN MAPPING

GLEN TAY TO THE TAY MARSH

ONTARIO REGULATION No. ____
SCHEDULE No. ____

Scale 1:2 000

CONTOUR INTERVAL 1 METRE
(0.5 METRE INTERPOLATIONS)

LEGEND

- Contour, Index
- Intermediate
- Supplementary
- Approximate
- Depression
- Spot Elevation, Water Level
- Regional Storm Flood Level
- Regional Storm Flood Line
- Fill And Construction Limits
- Cross Section
- Cross Section Number

GENERAL INFORMATION

ORTHOPHOTO MAP COMPILED AND DRAWN BY NORTHWAY-GESTALT CORPORATION FROM 1:8000 AERIAL PHOTOGRAPHY TAKEN JANUARY 15 1980.

THE MAPPING HAS BEEN PREPARED ACCORDING TO THE CAAS SPECIFICATIONS FOR 1:2000 TOPOGRAPHIC MAPPING.

NORTH AMERICAN DATUM 1927
UNIVERSAL TRANSVERSE MERCATOR (6°) PROJECTION
ZONE 18. CENTRAL MERIDIAN 75°W
GRID INTERVAL 100 METRES.

APPROVED BY:

J. D. THOMPSON

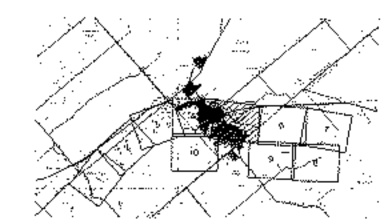
NORTHWAY-GESTALT CORP.
N.G.C. JOB NO. C-8627-2

FENCO CONSULTANTS LTD.
DATE APRIL 1981

FENCO

FENCO CONSULTANTS LTD.

PROJECT: 6516 APRIL 1981



KEY PLAN 1:100,000

DRAWING No 5 OF 10

SHEET ____

RIDEAU VALLEY CONSERVATION AUTHORITY

RIDEAU VALLEY CONSERVATION AUTHORITY

TAY RIVER

FLOOD PLAIN MAPPING

GLEN TAY TO THE TAY MARSH

ONTARIO REGULATION No. ____
SCHEDULE No. ____

Scale 1:2 000

CONTOUR INTERVAL 1 METRE
(0.5 METRE INTERPOLATIONS)

LEGEND

Contour, Index	
" Intermediate	
" Supplementary	
" Approximate	
" Depression	
Spot Elevation, Water Level	
Regional Storm Flood Level	
Regional Storm Flood Line	
Fill And Construction Limits	
Cross Section	
Cross Section Number	1+000

GENERAL INFORMATION

ORTHOPHOTO MAP COMPILED AND DRAWN BY NORTHWAY-GESTALT CORPORATION FROM 1:8000 AERIAL PHOTOGRAPHY TAKEN JANUARY 15 1980.

THE MAPPING HAS BEEN PREPARED ACCORDING TO THE CAAS SPECIFICATIONS FOR 1:2000 TOPOGRAPHIC MAPPING.

NORTH AMERICAN DATUM 1927
UNIVERSAL TRANSVERSE MERCATOR (6°) PROJECTION
ZONE 18 CENTRAL MERIDIAN 75°W
GRID INTERVAL 100 METRES.

APPROVED BY:

REGISTERED PROFESSIONAL ENGINEER J. D. THOMPSON PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER P. D. CHEESIE PROVINCE OF ONTARIO

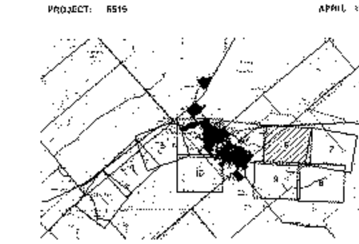
NORTHWAY-GESTALT CORP.
N.G.C. JOB NO. C-8827-2

FENCO CONSULTANTS LTD.
DATE APRIL 1981

FENCO

FENCO CONSULTANTS LTD.

PROJECT: 5515 APRIL 1981



KEY PLAN 1:100,000

DRAWING No 6 OF 10

SHEET ____

RIDEAU VALLEY CONSERVATION AUTHORITY

RIDEAU VALLEY CONSERVATION AUTHORITY

TAY RIVER

FLOOD PLAIN MAPPING

GLEN TAY TO THE TAY MARSH

ONTARIO REGULATION No. ....

SCHEDULE No. ....

Scale 1:2 000

CONTOUR INTERVAL 1 METRE
(0.5 METRE INTERPOLATIONS)

LEGEND

Contour, Index	
" Intermediate	
" Supplementary	
" Approximate	
" Depression	
Spot Elevation, Water Level	
Regional Storm Flood Level	
Regional Storm Flood Line	
Fill And Construction Limits	
Cross Section	
Cross Section Number	14000

GENERAL INFORMATION

ORTHOPHOTO MAP COMPILED AND DRAWN BY NORTHWAY-GESTALT CORPORATION FROM 1:8000 AERIAL PHOTOGRAPHY TAKEN JANUARY 15 1980.

THE MAPPING HAS BEEN PREPARED ACCORDING TO THE CAAS SPECIFICATIONS FOR 1:2000 TOPOGRAPHIC MAPPING.

NORTH AMERICAN DATUM 1927
UNIVERSAL TRANSVERSE MERCATOR (6°) PROJECTION
ZONE 18. CENTRAL MERIDIAN 75°W
GRID INTERVAL 100 METRES.

APPROVED BY:

J. D. THOMPSON

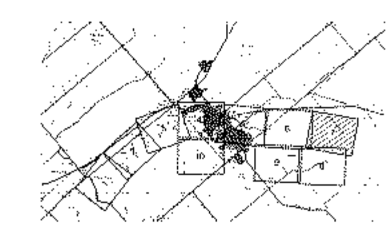
NORTHWAY-GESTALT CORP.
N.G.C. JOB NO. C-8627-2

FENCO CONSULTANTS LTD.
DATE APRIL 1981

FENCO

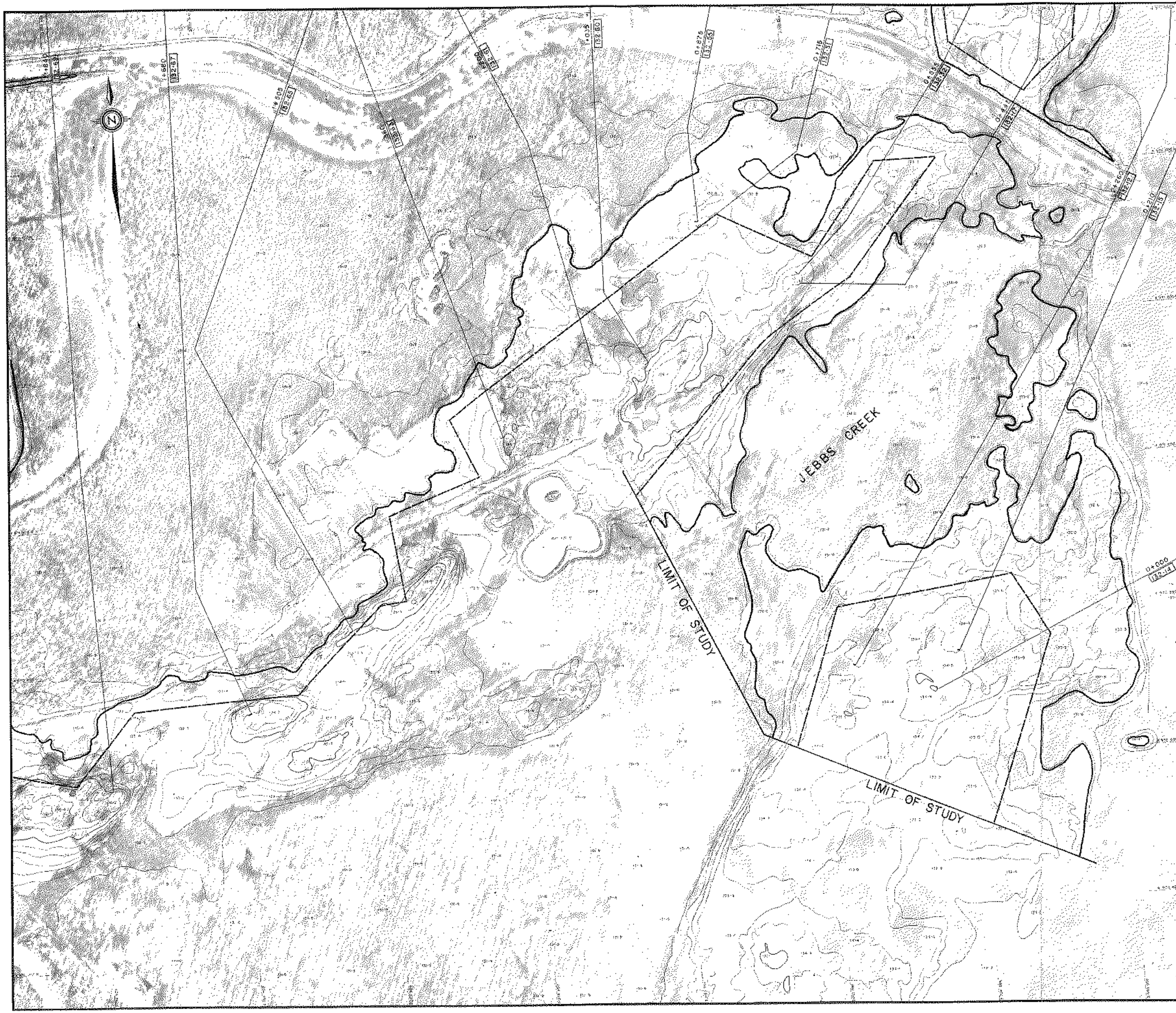
FENCO CONSULTANTS LTD.

PROJECT: 8510 APRIL 1981



KEY PLAN 1:100,000

DRAWING No 7 OF 10



SHEET ____

RIDEAU VALLEY CONSERVATION AUTHORITY

RIDEAU VALLEY CONSERVATION AUTHORITY

TAY RIVER

FLOOD PLAIN MAPPING

GLEN TAY TO THE TAY MARSH

ONTARIO REGULATION No. ____
SCHEDULE No. ____

Scale 1:2 000

CONTOUR INTERVAL 1 METRE
(0.5 METRE INTERPOLATIONS)

LEGEND

Contour, Index	
Intermediate	
Supplementary	
Approximate	
Depression	
Spot Elevation, Water Level	
Regional Storm Flood Level	59·4
Regional Storm Flood Line	
Fill And Construction Limits	
Cross Section	
Cross Section Number	1+000

GENERAL INFORMATION

ORTHOPHOTO MAP COMPILED AND DRAWN BY NORTHWAY-GESTALT CORPORATION FROM 1:8000 AERIAL PHOTOGRAPHY TAKEN JANUARY 15 1980.

THE MAPPING HAS BEEN PREPARED ACCORDING TO THE CAAS SPECIFICATIONS FOR 1:2000 TOPOGRAPHIC MAPPING.

NORTH AMERICAN DATUM 1927
UNIVERSAL TRANSVERSE MERCATOR (6°) PROJECTION
ZONE 18 CENTRAL MERIDIAN 75°W
GRID INTERVAL 100 METRES.

APPROVED BY:

J. D. THOMPSON

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N.G.C. JOB NO. D-2027-2

FENCO CONSULTANTS LTD.
DATE APRIL 1981

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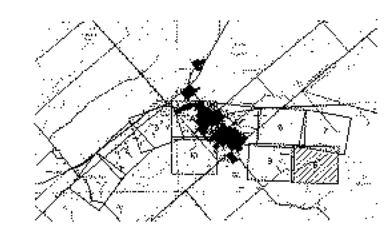
PROJECT: 8510 APRIL 1981



KEY PLAN 1:100,000

DRAWING No 8 OF 10

SHEET ____

RIDEAU VALLEY CONSERVATION AUTHORITY

RIDEAU VALLEY CONSERVATION AUTHORITY

TAY RIVER

FLOOD PLAIN MAPPING

GLEN TAY TO THE TAY MARSH

ONTARIO REGULATION No. ____
SCHEDULE No. ____

Scale 1:2 000

CONTOUR INTERVAL 1 METRE
(0.5 METRE INTERPOLATIONS)

LEGEND

Contours, Index
Intermediate
Supplementary
Approximate
Depression
Spot Elevation, Water Level
Regional Storm Flood Level
Regional Storm Flood Line
Fill And Construction Limits
Cross Section
Cross Section Number — 1+000

GENERAL INFORMATION

ORTHOPHOTO MAP COMPILED AND DRAWN BY NORTHWAY-GESTALT CORPORATION FROM 1:8000 AERIAL PHOTOGRAPHY TAKEN JANUARY 15 1980.

THE MAPPING HAS BEEN PREPARED ACCORDING TO THE OMAS SPECIFICATIONS FOR 1:2000 TOPOGRAPHIC MAPPING.

NORTH AMERICAN DATUM 1927
UNIVERSAL TRANSVERSE MERCATOR (6°) PROJECTION
ZONE 18. CENTRAL MERIDIAN 75°W
GRID INTERVAL 100 METRES.

APPROVED BY:

J. D. THOMPSON — REGISTERED PROFESSIONAL ENGINEER — PROVINCE OF ONTARIO

P. R. C. KSSIE — REGISTERED PROFESSIONAL ENGINEER — PROVINCE OF ONTARIO

NORTHWAY-GESTALT CORP.
N.G.C. JOB NO. C-8627-2

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KEY PLAN — 1:100,000

DRAWING No 9 OF 10

SHEET____

RIDEAU VALLEY CONSERVATION AUTHORITY

RIDEAU VALLEY CONSERVATION AUTHORITY

TAY RIVER

FLOOD PLAIN MAPPING

GLEN TAY TO THE TAY MARSH

ONTARIO REGULATION No.____________
SCHEDULE No.____________

Scale 1:2 000

CONTOUR INTERVAL 1 METRE
(0.5 METER INTERPOLATIONS)

LEGEND

Contour, Index	
" Intermediate	
" Supplementary	
" Approximate	
" Depression	
Spot Elevation, Water Level	
Regional Storm Flood Level	
Regional Storm Flood Line	
Fill And Construction Limit	
Cross Section	
Cross Section Number	1+000

GENERAL INFORMATION

ORTHOPHOTO MAP COMPILED AND DRAWN BY NORTHWAY-GESTALT CORPORATION FROM 1:8000 AERIAL PHOTOGRAPHY TAKEN JANUARY 15 1980.

THE MAPPING HAS BEEN PREPARED ACCORDING TO THE CAAS SPECIFICATIONS FOR 1:2000 TOPOGRAPHIC MAPPING.

NORTH AMERICAN DATUM 1927
UNIVERSAL TRANSVERSE MERCATOR (6°) PROJECTION
ZONE 18. CENTRAL MERIDIAN 75°W
GRID INTERVAL 100 METRES.

APPROVED BY:

J. D. THOMPSON — REGISTERED PROFESSIONAL ENGINEER — PROVINCE OF ONTARIO

P. D. C. — REGISTERED PROFESSIONAL ENGINEER — PROVINCE OF ONTARIO

NORTHWAY-GESTALT CORP.
N.G.C. JOB NO. C-8027-2

FENCO CONSULTANTS LTD.
DATE APRIL 1981

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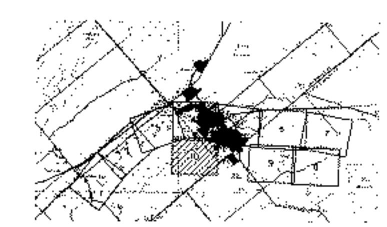
FENCO CONSULTANTS LTD.

PROJECT: 8616 APRIL 1981



KEY PLAN 1:100,000

DRAWING No 10 OF 10