PRELIMINARY ENGINEERING PROPOSALS AND DESIGNS FOR PREVENTION OF FLOODING AND PROVIDING WATER TABLE CONTROL FOR THE SHERRINGTON - STE. CLOTHILDE ORGANIC SOIL AREA

A PROJECT FOR COURSE 336-490D

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BY

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INTRODUCTION

In its natural state, peat and muck deposits have a too high water table for crop cultivation, and cannot be considered as an agricultural land. Drained and properly managed organic soils can produce very high yields of high quality vegetables. Excessive drainage and improper agronomic practices can change them into useless lands and cause eventual disappearance of this natural resource.

The Sherrington - Ste. Clothilde area has the largest single deposit of organic soil in the Montreal area totalling 16,504 acres, with 9,554 acres of arable land (9). The area is well served by good roads and is within 35 miles from the Montreal market. The warmest climate and the longest growing season in the Province makes the organic soils of Southwestern Quebec the most suitable lands for early vegetable production. Agricultural development of this area dates prior to 1933, with the most common garden crops such as potatoes, onions and carrots (12). By 1950 Norton Creek and Cranberry Creek had been channelized and new branch ditches were excavated. Three dams for controlling water table were constructed, one on Norton Creek near Ste. Clothilde and two on Cranberry Creek.

Soil subsidence that followed the lowering of the water table caused new drainage problems. Repeated floods that are extensively damaging to crops calls for further study and solutions for development and preserving of this organic deposit.

OBJECTIVES

The aims of this project were:

1. To study causes of flooding of the Sherrington - Ste. Clothilde organic soil area,
2. To propose a satisfactory flood prevention alternatives,
3. To carry out preliminary engineering calculations for the alternatives proposed based on the limited available data, and
4. To indicate the kinds of detailed engineering information which would still need to be obtained before final construction plans could be prepared.

PROCEDURE

The watershed and the organic soil area were inspected on the ground. Existing reports on the extent and nature of the soils were reviewed. From inspection of the topography, possible positions for channels and dams were selected. The expected peak flows were calculated using 25-years rainfall figures from the Montreal International Airport weather station. Channel capacities were calculated using the profile, channel cross sections, roughness estimates. New designs were calculated to convey estimated peak discharges and profiles were drawn.

RECOMMENDATIONS

1. Enlarge Norton Creek channel through the organic soil area.
2. Improve Cranberry Creek channel capacity.

3. Construct a dam for a flood control reservoir on the upper Norton Creek at the location shown on figure 11.
4. Excavate a new channel (Channel 2) as shown on figure 11.
5. Lower toe elevations of existing dams and construct two new dams, one on Norton Creek and one on Channel 2.

CHANGES IN ORGANIC SOILS UNDER RECLAMATION EFFECTS

The mucking process occuring in organic soils after drainage causes their evolution in two main directions:

1. Formation of peat muck on mucky soils, which later on become degraded and fade away;
2. Formation of black earths or similar soil kinds; the latter develop from organic soils with the content of clayey particles of 15% or more (18).

It is known that drainage and agricultural utilization of organic soils is followed by continuous subsidence of the surface and mineralization of the organic matter. Surface subsidence is the result of soil shrinkage by oxidation and compaction and direct soil loss by erosion and burning. Shrinkage is inevitable with drainage - lowering of the water table permits entry of air into pores. Oxidation of the organic soil by action of aerobic bacteria converts such matter to carbon dioxide which escapes into the atmosphere and water. The removal of water by drainage causes the weight of upper soil layers to compact lower layers. The operation of farming equipment in preparing seedbeds consolidates surface layers by pulverizing the soil and eliminating larger soil voids (5). The weight of the machines causes some compaction. Observation of many sites over many years in both North America and Europe indicates an average subsidence of about 1 inch per year. This rate varies with depth of organic material exposed above the water table, the total depth of organic layer, organic matter content and time after drainage. Organic soil will fade away till upper layers reach 90 - 95% of mineral matter and 1500 g/dcm^3 bulk density (17). The mineralization taking place in peat - muck soils causes a yearly loss of about 10t/ha of organic matter. This results in release of 5.5t/ha of coal on a yearly average. During oxidation a constant flow of considerable amounts of carbonic acid occurs which affect biochemical changes in soil (14).

The amounts of mineral substance accumulating in peat soil as a consequence of mineralization is not so high as to form a mineral layer over the peatland surface, protecting the soil against further mineralization like in the case of covering organic soil with clay or silt. Lowering the water table in organic soil always causes subsidence. Compaction takes place above and below the water table, but mineralization caused by increased chemical reactions, biological activity, and mechanical shrinkage occurs only above the water level. There are two types of shrinkage, reversible and irreversible. With irreversible shrinkage overdrained peat will not return to its initial volume after moistening. Controlled water - level experiments on organic soils in Northern Indiana over a 16.6-year period showed that the subsidence rate was directly related to depth of water table, and that subsidence was decreased with time. Average subsidence rates of 0.79 and 0.36 inches per year were found, respectively for 40 and 16-inch water table depths (8). Taking into account causes of the organic soil subsidence and the eventual disappearance of this valuable natural resource, reclamation work should be designed from the point of view of conservation. Drainage systems with controlled water level will greatly reduce subsidence rates. For the best effects water table levels should be kept at optimum for crop production during the growing season as close as possible to the plowing layer throughout dormant season.

SOIL MOISTURE CHARACTERISTICS IN RELATION TO AGRONOMIC REQUIREMENTS OF VEGETABLE PLANTS

Organic soils have a very high moisture - holding capacity. Well decomposed mucks hold up to one and one-half times their weight of water and semi humified peat more than double its weight. In greenhouse experiments, with well decomposed muck from the Ste. Clothilde Substation it was found that celery wilted when the moisture content of the soil was lower than 60%. On the other hand, the first wet-soil symptom appeared on the celery when the soil moisture was between 95 and 100% (3). Ostromecki (1960) states that for optimum plant growth, moisture in the root zone should not drop below 65 - 75% of field capacity nor exceed 85% of full water capacity. Some peats with their high moisture holding capacity may not release water to plant roots until the moisture content is over 100% (3). Unfortunately in some of the published papers it is not clear whether moisture contents are given as a percent by weight or by volume. The high moisture - holding capacity of organic soils prevents normal summer rains from penetrating deeply enough to supply moisture to the water table below plant roots. The rate of evaporation increases with the increase of the stage of decomposition and moisture of the organic soils. If evaporation from sandy surface is 100%, and clay 108%, it is 159% from the organic soil (11).

Although these soils hold large amounts of moisture, addition of water may be required for plant growth to fill the deficit caused by excessive evaporation. From the results of many experiments with controlled water table in organic soils, it can be seen that various plants respond differently to depth of water table. In general vegetable yields are reduced if the water table depth is less than 15 - 16 inches and over 40 inches. Controlled water - level experiments on organic soil in Northern Indiana over a 16.6-year period showed that onion, potato, peppermint, carrot and corn yields were greatly reduced by the 16 inch water table as compared with yields obtained on the 24, 32 and 40 inch water tables, which were essentially the same (8). Similar results were reported by Ellis and Morris (6) for 16, 27 and 38 inches water tables.

Frost effects on the fields with high water table is reduced, but a constantly moist soil surface provides optimum conditions for weed growth. High moisture also reduces nutrient availability to the plants; nitrogen and potash is easily leached to lower layers. Phosphorus cannot be secured by plants because of weak root system when the water table is high.

Recommended depth in cm of water table in organic soils for vegetable production (11).

Onion	70 - 100
Cauliflower	50 - 75
Cabbage	50 - 80
Tomatoes	50 - 80
Lettuce	40 - 70
Celery	45 - 75
Carrots	60 - 90
Potatoes	70 - 100

Moist organic soils have very low surface strength. For safe use of farm machinery water table should not be higher than 50 - 60 cm (20 - 24 inches).

CROP DAMAGE BY FLOODING

Generally plants can withstand inundation fairly well when they are in a dormant stage, but flooding during the off - growing season may affect subsequent crop yields, because of a deterioration in soil structure or by the effect of silt deposits left by flood waters. While plants are actively growing, the injury they suffer depends on their stage of growth at the time of flooding. The prevalent temperatures at the time of flooding markedly affects the degree of injury. The severe damage which occurs on hot days as a result of flooding is referred to as "scalding" (10). Some plants, like grasses, can withstand flooding during the growing season for a considerable length of time without suffering apparent ill - effects. The maximum summer inundation period during full growing season that will destroy crops is 36 hours for grasses and 5 hours for tender vegetables such as carrots, beans and onions (15). During the off - growing season the maximum allowable inundation, not deteriorating structure is:

Meadows	20	-	25	days
Pastures	10	-	15	days
Winter crops	10	-	15	days
Summer crops	5	-	7	days
Vegetables	3	-	5	days

Summer flooding of vegetables for a period shorter than 5 hours may not destroy the crop but upset in nutrient balance due to flooding will reduce yields and quality. Sediment can make vegetables such as cauliflower, lettuce, celery, etc. unacceptable on the market. Therefore, vegetable fields must be protected from summer flood waters.

CLIMATE

Southwestern Quebec has the warmest climate with the longest growing season in the Province. The general weather of this region is indicated by the following data from the Montreal International Airport for the 27 years, 1942 - 1968 (2).

Mean Annual Maximum Temperature	51.8° F
Mean Annual Minimum Temperature	35.7° F
Mean Annual Temperature	43.8° F
Maximum Observed Temperature	96.3° F Aug. 1944
Minimum Observed Temperature	-35.6° F Jan. 1957
Mean Annual Rainfall	28.28 in.
Mean Annual Snowfall	99.1 in.
Mean Annual Total Precipitation	38.19 in.
Greatest Annual Total Precipitation	47.65 in. (1954)
Least Annual Total Precipitation	30.30 in. (1964)
Greatest Monthly Precipitation	8.49 in. (June 1943)
Least Monthly Precipitation	0.02 in. (Aug. 1957)
Greatest Monthly Snow	52.4 in. (Feb. 1960)
Greatest 24 hr. Rainfall	2.85 in. 5 July 1958
Average number of days per month with .01 in. or more precipitation	13 days
Average number of days per month with .025 in. or more precipitation	4 days
Average growing season	Apr. 15 - Nov. 3
Frost Free Period	May 4 - Oct. 6 155 days
Growing degree days above 42° F	3463
Mean May to September Precipitation	18 in.
Mean Total Annual Potential Evapotranspiration	23 in.
Mean Annual Surplus of Precipitation over Potential Evapotranspiration	15 in.

SHERRINGTON - STE. CLOTHILDE AREA

Soils

This area is located in the counties of Chateauguay and Huntington near the village of Ste. Clothilde. This is the largest single area of organic soil south of Montreal with 16,504 acres of fibrosol (38.08%), mesisol (26.41%), and humisol (35.51%) deposit, of which 10,304 acres is 4 feet and more deep. The maximum depth of organic soil in this area is 24 feet. The depths of the organic deposits are shown on Fig. 1. The surface layer is from little to well decomposed. The predominant subsoils are sandy-clay and gray clay. Large areas of peat and muck are underlaid by gytja deposits, found from 4 to 10 feet below the surface and up to 12 feet thick.

Chemical Composition

Non-cultivated soils have very high organic matter content, 80 - 100% at 12 inches deep and over 90% at 36 inches deep. Non-cultivated lands are extremely acid with pH 2.5 - 4.0 at 12 inch depth and 4.0 - 5.0 at 36 inch depth. Cultivated soils as a result of lime applications are less acid with pH of 5.0 - 6.5. Cultivated lands are rich in availability of potash and phosphorus for plants. On the other hand there is a defficiency in K_2O and P_2O5, not exceeding 200 lbs/acre at 12 inch depth and less than 100 lbs/acre at 36 inch depth on virgin peats. The calcium content varies from 4000 lbs/acre to 15,000 lbs/acre at 36 and 12 inch depths respectively.

Actual Land Use

From the total of 16,504 acres of organic deposit, garden crops are grown on 5,147 acres, field crops on 3,165 acres, 1,242 acres are clear of trees but not cultivated and 6,950 acres is under woods.

Land use in the summer of 1971 is shown on Fig. 2 (9).

The main vegetables grown in the Sherrington - Ste. Clothilde area are:

	Acres	% of Total Area
Carrots	1,750	10.6
Potatoes	955	5.8
Onions	900	5.4
Lettuce	680	4.1
Celery	220	1.5

NORTON CREEK WATERSHED

Boundaries and Area

The watershed is bounded on the east by watershed of l'Acadie River; on the north-east by watershed of La Tortue and St. Pierre Rivers; on the west by watershed of the English River and on the north-west by the watersheds of Chateauguay River tributaries. Its length is about 17 miles. Its greatest width about 12 miles, and its narrowest width about one mile at the English River neck. The Norton Creek watershed has a total area of 110 square miles, and above Ste. Clothilde bridge about 93 square miles. Elevations of the watershed vary from about 136 feet above mean sea level at English River to about 340 feet above mean sea level at Beaver Meadows in New York State.

The Creek and Its Tributaries

The routes of Norton Creek and its tributaries with main drainage ditches are shown on Figure 3. The source of the main stream of Norton Creek is Beaver Meadows bog, above one mile south of Quebec - New York State border at an average elevation of about 325 feet above mean sea level.

The course of Norton Creek from its source to the organic deposit boundary (about 9 miles), is generally in Northerly direction. At Barington, Norton Creek changes its direction to north-west until it reaches Tributary "B". From Tributary "B" to its recipient - English River, the Norton Creek follows westerly direction. From the source to the organic soil boundary the average gradient is 0.0028 ft/ft.

At 4.3 miles distance from Cranberry Creek to Ste. Clothilde bridge the channel gradient is only 0.0001 ft/ft. On the remaining 8.5 miles from Ste. Clothilde to the English River the average slope is about 0.001 ft/ft. The largest tributary, Cranberry Creek, has an average gradient about 0.001 ft/ft and is about 7 miles long. It drains 24 square miles of land west of Norton Creek. The north-eastern part of the watershed is drained by tributaries "A" to "E" with average grades between 0.001 and 0.002 ft/ft. From the above description it can be seen that gradient of Norton Creek channel on the mineral soil section is much higher than through the lower organic soil area. The velocity of flow in the upper river is high and the lag time between rainfall and the resultant runoff is short. Flows in tributary channels through the organic soil area have a lower velocity and also a short distance to travel to reach the main stream. This kind of velocity distribution causes an accentuation of flood peaks.

HYDROLOGY

The results of the hydrological investigations provide the necessary information to permit the proposed flood prevention and drainage system to be designed to fulfill its intended functions. Since failure of a flood prevention system would result in damage to agricultural lands it is necessary to consider floods that could be expected within the watershed. Methods that would give complete protection from flooding do not exist. Channel capacities are designed to pass safely discharges of certain recurrence. The higher the level of protection, the more costly is the system. Therefore, the cost of construction has to be compromised with safety level. Usually in agricultural engineering practice, high value agricultural lands are protected from flood waters that occurs once in 25 to 50 years. In the case of organic soils which subside after drainage and with years of cultivation, the degree of flood protection decrease with time. Channels and control structures may need to be replaced every 30 or 50 years. Channels through these lands should be designed to convey the peak flow from a once in 50 years run-off. While it is of primary importance that the channel capacity will be sufficient to pass safely this peak flow, it is also important that the low summer flow will be maintained at suitable level for agricultural production.

DETERMINATION OF FLOOD FLOWS

Due to the fact that Norton Creek has not been gauged, it was necessary to use a theoretical approach to estimate the peak flow expected during a runoff event. Since it is good engineering practice not to rely on a single theoretical estimation, three methods are used for estimating the peak flow.

A) Rational Method

B) Unit Hydrograph (unitgraph), and

C) The values were compared with English River flow records.

The Rational Method is developed from the assumptions that:

(a) rainfall occurs at uniform intensity for a duration at least equal to the time of concentration of the watershed, and (b) rainfall occurs at a uniform intensity over the entire area of the watershed at the same time. Schwab (16) limits application of this method to watersheds of less than 5 square miles. Gray (7) recommends the rational method for watersheds up to 100 square miles.

The Triangular Unitgraph method is applicable to almost any size and type of watershed since the principle of the unitgraph is the basis for determining the peak flows at a particular location, provided that the watersheds and runoff parameters selected are applicable to this method. Peak flow potential of natural channels varies greatly between different locations due to differences in geology, topography and moisture sources. The following discussion outlines the basis upon which the design flow estimates used for the preliminary design of the proposals were derived.

Rainfall

The amount of the rainfall must be first defined in order to determine the resulting runoff. The rainfall intensity-duration curves for Montreal (Dorval) based on 25 years of records have been used in this study. Rainfalls of 50 years recurrence interval were estimated by extending available data on Gumbel porbability paper.

Runoff

In order to estimate the amount of runoff that will result from a given amount of precipitation on a specific area, considerable judgement must be exercised. The more valid the information available, the more accurate will be the estimate.

Watershed characteristics used in runoff calculations:

Area of watershed	A =	59520 acres
	A_m =	93 square miles

Maximum length of travel of water	L =	90600 feet
	L_m =	17.2 miles
Difference in ground elevation between upstream end of watercourse and the point of interest	H =	166 feet
Average slope	S =	0.00183 ft/ft

Runoff Calculations:

A. Rational Method

$Qp = CiA$

where Qp = rate of runoff (cfs),

C = runoff coefficient,

i = rainfall intensity (in/hr) of a storm whose duration is equal to the time of concentration of the basin, and

A = area of the watershed (acres).

Time of concentration, t_c

$$t_c = 0.0078 L^{0.77} S^{-0.385}$$

where t_c = time of concentration (minutes)

$$t_c = 0.0078 \times 90600^{0.77} \times 0.00183^{-0.385} = 580 \text{ minutes}$$

Rainfall intensity from Fig. 5

$i = 0.36$

Estimated runoff coefficient

$C = 0.30$

Once - in - 50 years peak flow

$Qp = 0.30 \times 0.36 \times 59520 = \underline{6428 \text{ cfs}}$

B. Unit Hydrograph - Soil Conservation Service Method

For this watershed peak flow could be expected from a rainstorm of 6-hours duration.

Calculation of runoff volume:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S}$$

where Q = direct surface runoff in inches,

P = storm rainfall in inches,

S = maximum potential difference between rainfall and runoff in inches, starting at the time of the storm's beginning.

Soil Complex Curve Number

$$N = \frac{1000}{10 + S}$$

For runoff estimation antecedent Condition II was assumed, which can be described as the average case for annual floods, that is, an average of the conditions which have preceded the occurrence of the maximum annual flood on numerous watersheds. This case can be adopted when considering runoff generated by summer rain storms.

Estimated Soil Complex number for Norton Creek watershed conditions

$$N = 78.5$$

Rainfall for a 6-hour storm (from Fig. 6) is 3.36 inches

$$S = \frac{1000}{78.5} - 10 = 2.74$$

$$Q = \frac{(3.36 - 0.2 \times 2.74)^2}{3.36 + (0.8 \times 2.74)} = 1.42 \text{ inches}$$

Peak Flow Calculation:

In order to obtain the flood runoff from a storm, the direct runoff Q in inches must be related to the watershed conditions. The physical characteristics of the watershed, such as the area, length of the watercourse, and variation in ground elevation are used to determine the unitgraph upon which the flood flow estimates are to be computed. The relationships that can be developed by representing the unitgraph as a triangle are shown on Figure 7. The lag time was determined from Sangal's curve (Figure 8).

The watershed constant "K" is determined from the equation

$$K = \frac{72.6L_m}{(H/L_m)^{\frac{1}{2}}} = \frac{72.6 \times 17.2}{(166/17.2)^{\frac{1}{2}}} = 402$$

Entering Figure 8 with the known value of "K" the lag time is determined to be 10 hours.

For a rainfall period "D" established at 6 hours

Time to peak $Tp = D/2 + L$

$$Tp = \frac{6}{2} + 10 = 13 \text{ hours}$$

Base length of Unitgraph

$$Te = 2.67Tp = 2.67 \times 13 = 34.7 \text{ hours}$$

and the Peak Flow is given by equation

$$Qp = \frac{484\ AmQ}{Tp}$$

$$Qp = \frac{484 \times 93 \times 1.42}{13} = \underline{4916 \text{ cfs}}$$

C. Various empirical formulae have been derived over the years which give maximum flood flows at a site. One frequently used formula relates the peak discharge to basin area. The peak discharge of record for stream in a region is expressed as a function of area of runoff (4).

$$q_p = KA^{-0.5}$$

where q_p = the peak discharge per unit area in cfs/sq. mi.

k = constant for the region, which can be determined for discharge Qp.

The maximum observed discharge on the English River for the six years of records (1967 - 1972) occured on April 14, 1971 and was 6650 cfs.

At basin area 275 sq.mi.

$k = 401$

and q_p at Ste. Clothilde (93 sq. mi.)

$q_p = 41.58$ cfs/sq.mi.

$Q_p = 41.58 \times 93 = \underline{3867 \text{ cfs}}$

This peak flow was generated from rainfall - snowmelt event, and it is difficult to estimate its return period. For comparison reasons only, this peak flow is equal to a once - in - 7 years peak using Rational Method. It is possible that results from both methods are correct, since the Rational Method gives maximum possible runoff, and assumptions made for Unit Hydrograph calculations (Condition II) are related to summer storms. Taking into account the need of adding mineral matter to organic soils to reduce rate of subsidence, short duration flooding in the early spring before the growing season would be permissible.

A few hours inundation cannot deteriorate the soil structure. Sediments rich in nutrients will improve fertility and increase mineral content of the soil. In this report flood control designs are based on peak flow obtained from Unit Hydrograph Method calculations.

DETERMINATION OF DESIGN FLOW

Small drainage ditches are usually designed only for peak flow discharge. Natural streams of larger drainage basins must be able to convey peak flow and also maintain required velocity in the channel throughout the year. A water level corresponding to summer flow should be high enough to prevent excessive drainage.

Many methods are used to determine the flow for which the summer flow channel is designed. A few of these will be mentioned. If the flow records are available the agricultural stream can be designed to convey:

1) average from many years flow of highest frequency of occurrence during vegetation season;
2) average yearly or average seasonal flow;
3) spring flow - which occurs after the spring peak runoff. Water level corresponding to this flow should allow free outflow from drainage channels that land preparation for spring planting is not delayed.

Spring flow can be identified as the one that occurs 8 days after the last rainfall - snowmelt peak runoff.

To determine design flow for the spring flow channel method 3 was adopted.

An assessment was made of the vegetation period flows in the English River. The area tributary to Howick Road - Bridge gauge is 275 sq. mi. and includes Norton Creek watershed. The years of records utilized were from 1968 to 1972 (1). An average "8th" day flow for this period is 311 cfs or 1.13 cfs per square mile. On the assumption that the average flow rate in the river is directly proportional to the tributary area, the design spring flow rate in Norton Creek at Ste. Clothilde is 105 cfs.

The last assumption is based on the fact that this flow is generated by subsurface runoff; and the surface runoff watershed coefficient does not apply in this case.

The average summer flow can be obtained by using the "rule of thumb" which assumes flow rates of 1/10 cfs per sq. mi. of tributary area. On this basis, the average summer flow rate in the Norton Creek at Ste. Clothilde is about 9 cfs.

POSSIBLE FLOOD CONTROL MEASURES

In general two classes of measures eliminating flooding of the area can be used.

1. Flood prevention
    a) reducing runoff by land treatment
    b) flow retardation in reservoirs to reduce the peak flow rates
    c) diverting water from part of watershed to another river system
    d) excavating a new channel to by-pass the upstream water around the protected area.
2. Flood control within the area
    a) channel improvement increasing discharge capacity
    b) dikes along the channel which confine the river flow to a definite width for the protection of surrounding land from overflow.

The practicalities of these measures are analyzed below for the Norton Creek Watershed.

1.a. The most effective watershed treatment that reduces runoff is increase of wooded area. Since the area is developed for agricultural use this measure cannot be considered.

1.b. There are two sites where dams can be constructed. At section 28 and at section 32 + 6. In the first location the drainage area above the dam is 25 square miles and the reservoir will eliminate about 0.8 square mile of organic soil. The second location is on mineral soil. The drainage area is 16 square miles and can be increased to 19 square miles by diverting some of the water from the Cranberry Creek basin. Water stored in the reservoir at the latter location because of higher elevation can be used for irrigation.

1.c. Topographically it is not feasible to divert water from a significantly large area to another watershed.

1.d. A by-pass channel can be constructed as located on Figure 10 to divert water from about 28 square miles of land on the east side of Norton Creek and empty it into Norton Creek near Ste. Clothilde village.

2.a. At present the river bed slope from Cranberry Creek to Ste. Clothilde is only 0.0001 ft/ft. Because of a low water velocity in the channel, large amount of sediments are deposited at various parts of the river watercourse. Also, the cross section area in this reach is too small to pass flood water. Thus, this reach of channel needs to be enlarged.

2.b. Dikes are commonly used as a flood control measure. The concentrated shape of Norton Creek watershed indicates that the upper part and sides contribute approximately equally to the peak runoff. If the river is embanked with dikes, water will accumulate behind the dikes and will need to be pumped up to the river. Because of the flat topography and the number of tributaries, many pump stations would be needed.

Dikes are constructed of fill material borrowed adjacent to and parallel with the dike. Organic soils with very low stability are the least suitable soils as an embankment material and should be used for temporary dikes only (5). Ste. Clothilde peats and mucks contain at the average over 90% of organic matter, therefore, should not be used as a dike construction material.

SUGGESTED FLOOD CONTROL MEASURES

After preliminary calculations of discharge capacities and peak flow in Norton Creek it has been found that no single measure from the list above can be of satisfactorily solution. Two alternate situations, with a combination of two measures were adopted for detailled consideration. These alternatives are listed and described as.

Alternative I

Deepening and enlarging Norton Creek channel from station 12 + 000 to station 33 + 000, see figure 10. Improving Cranberry Creek channel. Excavating a new channel (Channel 1) from the CNR track above

Barington Station along the route north-west to Tributary "C", crossing Tributary "B" below Gasparine, joining Tributary "A" at the edge of the organic deposit and discharging into Norton Creek at Station 15 + 500. Channel 1 drains about 28 square miles.

Alternative 2

Enlarging Norton Creek channel from station 12 + 000 to station 32 + 600. Improving Cranberry Creek channel capacity. Constructing a dam for flood control reservoir at station 32 + 600. Excavating a new channel (Channel 2) as in Alternative 1 but extended to the dam. Channel 2 drains 32 square miles and also can serve as an irrigation channel. Topographic locations of channels and reservoir are shown on Figures 10 and 11.

NORTON CREEK CHANNEL DESIGN

In channel design, primary consideration was given to minimizing subsidence of the soil. Since surface subsidence follows every drainage work and lowering of the water level in the stream, it would be ideal to maintain the channel bed and water level at their present elevation. The middle section of the Norton Creek flows through the deepest deposit of organic soil with the highest rate of subsidence. The lower section "Ste. Clothilde neck" flows through stoney ridge with a stable bed. Constant lowering of the soil profile in the middle section causes a decrease in stream grade and reduces channel discharge capacity. Low velocities favour deposition of sediments, which gives another problem in maintaining uniform channel cross-section.

To increase water velocity, it is necessary to lower the channel bed elevation. Lowering the stream bottom one to two feet at

Ste. Clothilde bridge increases the grade of the middle section from 0.0001 to 0.00026 ft/ft.

Since dikes are not to be constructed, peak runoff must flow in an excavated channel. It is possible to excavate a channel of trapezoidal cross section large enough for peak discharge, but this gives a channel with a too low velocity for low summer flow and sedimentation and meandering will result.

To stay in the permissible velocity range, a composite cross section of the Norton Creek channel is proposed. Typical cross sections and stream profiles with proposed bed elevations are shown on Fig. 12. (Alternative 1) and Fig. 13 (Alternative 2). Also levels of peak, spring and summer flow waters are shown on the profiles.

Channel discharge capacities at typical sections are given in Tables 2 and 4.

The channel bed through the main part of the organic soil, from the confluence with Tributary "B" to Tributary "E", in general, will not be deepened. To improve drainage conditions in the southwestern part of the deposit, a cut about 2 feet deep in the rocky bottom near the crossing with CNR is needed. From station 25 + 000 to the end of the organic deposit the channel bed must be deepened 1 to 2 feet to provide free outflow from drainage ditches in this region. In a few places between station 19 + 000 and Cranberry Creek there are local surface hollows where water from flood peaks can overflow the banks. Soil excavated from the channel can be used to raise the banks of the river in these places. Fill from the excavation should be graded such that there will not be water accumulation along the banks during runoff.

FLOOD CONTROL RESERVOIR

The location chosen for a reservoir dam is at station 32 + 600. This narrow valley with a little "island" gives good opportunity of constructing an earth dam with a minimum amount of work. A dam about 20 feet in maximum height will raise water to an elevation 200 feet above mean sea level and create a reservoir with a capacity of approximately 2,300 acre feet. The area under reservoir would be 370 acres. The drainage area above the reservoir site is about 16 square miles. The diverting ditch in the southern Cranberry Creek sub-basin increases this area to 19 square miles. Estimated once - in - 50 years runoff from a 3-hour rainfall for this area is 1.36 inches or 1,378 acre feet. This amount of runoff can be safely stored in this reservoir during the storm period and released after the recession of the peak flow on the lower part of the river. Norton Creek channel capacity from the dam to station 28 + 000 is 570 cfs and proportionally greater down stream. Discharge from the reservoir (after the peak flow passes) at the rate of 400 cfs can be safely received by the designed channel. Since the reservoir capacity exceeds runoff volume, it can serve two purposes, flood retention and irrigation. 1000 acre feet could be used for irrigation and reserve of about 1300 acre feet kept at all times for flood control.

WATER TABLE CONTROL

Controlled water table levels would slow down subsidence and reduce adverse effects of a fluctuating water table on crop yields.

In the Ste. Clothilde area organic soil subsided to such an extent that the three existing dams on Norton Creek and Cranberry Creek can no longer be used for water table control.

Dams constructed on main streams control large areas of land and it is difficult to maintain the water table at the required level throughout reach between dams. There is always the possibility of overdrainage in one part and waterlogging in another at the same time.

For the best effect, the water table control should be integrated with detailed drainage systems. Dams of flashboard or automatic gate control should be installed in the laterals and some collector ditches. Installing dams in laterals rather than in main channels has the advantage of controlling the water table in different fields, according to the plant and local topographic requirements.

Considering the short life of drainage systems on organic soils, due to surface subsidence, the small dams should be constructed of timber rather than concrete. Small timber - water gates can be replaced or reconstructed at low cost after the soil subsides.

On the fields with subsurface drainage, water table elevations can be controlled by installing controlled outlet boxes on collector lines. Such outlets can be placed in manholes and junction boxes.

Often during the dry season evapotranspiration exceeds rainfall, therefore the water table drops below the controlled level and irrigation would be required.

Since three dams already exist, they can be used for some water storage for overhead irrigation. One new dam could be constructed on Norton Creek at the section 25 + 100 as shown on Fig. 11 (Alternative 2). Another dam on the Channel 2 at section 6 + 300 below the confluence with Tributary "C", gives the opportunity of gravitational irrigation of the area between Channel 2 and Norton Creek from Tributary "D" to Tributary "C".

In order that the existing dams can function properly, the toe elevations should be lowered in accordance with the designed channel bed.

FURTHER ENGINEERING WORK WHICH WOULD BE NEEDED BEFORE CONSTRUCTION COULD BE UNDERTAKEN

The plan of the area used in this report was redrawn from the Topographic Map, year 1953, scale 1:50,000 and contour interval 25 feet.

Runoff calculations were based on theorectical methods with watershed coefficients estimated from general map situation and are only approximate.

Considering this inadequate topographic material and approximate hydrological calculations, this report should be used only as a guide for further engineering investigations.

Engineering designs for this size of a project should not be based on theoretical approach calculations.

Before construction project designs are undertaken, the following work and investigations are required:

1. Establish stream gauges

   a) on Norton Creek near Ste. Clothilde village

b) near site of proposed dam

c) on Cranberry Creek

Steamflow data from about 5 years should be obtained. Using the Unit Hydrograph method and longer term weather data, suitable design hydrographs could be developed.

2. Make up-to-date detailed topographic maps of the area. Old maps cannot be used because of soil subsidence. Maps should be made with sufficient detail to allow the design of drainage systems for each farm.
3. Make profiles and cross-sections of Norton Creek and its tributaries.
4. Analyze slope stability of the channel of typical soils and cross-sections for correct channel side slopes design.
5. Measure soil saturated hydraulic conductivity (vertical and horizontal) for further drainage and irrigation designs.
6. Measure soil conductivity along the route of channel 2 for calculating seepage losses. If losses were too high and there were not enough available water from the reservoir during dry season, Channel 2 should not be constructed from the reservoir to station 13 + 000.
7. Investigate the alternative of a pipeline and pump to replace Channel 2.
8. Make a detailed profile along the proposed route and any

suitable alternate routes for Channel 2.

9. Estimate the costs for alternatives 1 and 2.
10. Set up some permanent bench marks from which to check the subsidence of some selected organic area from time to time in the future.
11. Set up some water level recorders to make a continuous recording of the water table levels in some organic soil areas.
12. Make a foundation investigation at the proposed reservoir site so that a suitable dam can be designed.

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ALTERNATIVE I

Table 1

Drainage areas above selected points along the Norton Creek and estimated peak flows of once - in - 50 year frequency

Description of Area	Area		Peak Flow cfs
	Square Miles	Acres	
Total watershed above Ste. Clothilde Bridge	93	59520	4916*
Above the confluence of Norton Creek with Tributary "A"	64	40960	4078
At the confluence with Cranberry Creek	55	35200	3780
Above the confluence with Tributary "E"	28	17920	2697
Above the road at section 33 - 000	16	10240	2039

* Runoff peak flow calculated from 6 hour rainfall hydrograph

Peak flows at sections other than indicated were calculated using area relation $Q_p = KA^{0.5}$ where K is the watershed coefficient and A is the drainage area.

Table 2

Discharge capacities of designed Norton Creek channel
at the cross-sections indicated

Typical Cross Section	Reach Station to Station Thousands of yds.	Area Drained Above Section sq. mi.	Required Discharge cfs	Designed			
				Flow Area sq.ft.	Bed Slope ft/ft	Velocity* ft/sec	Discharge cfs
15 + 000	11.2 - 15.0	93	4916	950	0.0007	5.26	5000
15 + 500	15.0 - 22.6	64	4078	1537	0.00026	3.39 2.92	4634
22 + 600	22.6 - 25.0	28	2697	1168	0.00026	3.00 2.53	3042
25 + 000	25.0 - 28.0	26	2595	834	0.00044	3.44 2.94	2600
28 + 000	28.0 - 33.0	20	2280	679	0.00067	4.14 3.36	2500

* Velocities in the channel were calculated using Manning's equation with a roughness coefficient n = 0.030 for all reaches. Double values indicate velocity at center and side sections of composite cross section.

ALTERNATIVE 2

Table 3

Drainage areas above selected points along the Norton Creek and estimated peak flows of once - in - 50 year frequency

Description of Area	Area*		Peak Flow** cfs
	Square Miles	Acres	
Total watershed above Ste. Clothilde Bridge	74	47360	3008
Above the confluence with Tributary "A"	41	26240	2238
At the confluence with Cranberry Creek	32	20480	1978
Above the confluence with Tributary "E"	6	3840	857
Above the road at section 28 - 000	2.2	1408	519

* Areas do not include 19 square miles above the dam.

** Flows with zero outflow during runoff event from the area above the dam.

ALTERNATIVE 2

Table 4

Discharge capacities of designed Norton Creek channel
at the cross-sections indicated

Typical Cross Section	Reach Station to Station Thousands of yds.	Area Drained Above Section sq. mi.	Required Discharge cfs	Designed			
				Flow Area sq.ft.	Bed Slope ft/ft	Velocity* ft/sec	Discharge cfs
15 + 000	12.0 - 15.5	74	3008	770	0.00060	5.12 3.79	3348
15 + 500	12.5 - 22.6	41	2238	820	0.00026	3.50 2.60	2448
22 + 600	22.6 - 25.0	8	989	524	0.00026	2.92 2.14	1278
25 + 000	25.0 - 28.0	4.5	741	372.5	0.00033	2.95 1.97	881
28 + 000	28.0 - 32.6	2.2	519	156	0.00076	3.66	570

* Velocities in the channel were calculated using Manning's equation with a roughness coefficient $n = 0.030$ for all reaches. Double values indicate velocity at center and side sections of composite cross section.

EXAMPLES OF CALCULATIONS

Alternative 2 - Flood Control Dam on Norton Creek Section 32 + 600

Norton Creek Dam Site

Area drained	Am	=	19 square miles
Maximum length of travel of water	Lm	=	7.05 miles
Difference in ground elevation	H	=	142 feet
Depth of 3-hours rainfall, from Fig. 6	P	=	3.15 inches
Soil Complex Number	N	=	80

Runoff:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S}$$

$$S = \frac{1000}{N} - 10 = \frac{1000}{80} - 10 = 2.5$$

and $$Q = \frac{(3.15 - 0.2 \times 2.5)^2}{3.15 + (0.8 \times 2.5)} = 1.36 \text{ inches}$$

or $$Q = \frac{19 \times 1.36 \times 640}{12} = \underline{1378 \text{ acre feet}}$$

Norton Creek Ste. Clothilde Bridge site (Dam gates closed)

Area drained	Am	=	74 square miles
Maximum length of travel of water	Lm	=	10.1 miles
Difference in ground elevation	H	=	16 feet
Depth of 6-hours rainfall	P	=	3.36 inches
Soil Complex Number	N	=	76

Runoff:

$$S = \frac{1000}{76} - 10 = 3.16$$

$$Q = \frac{(3.36 - 0.2 \times 3.16)^2}{3.36 + 0.8 \times 3.16} = 1.26 \text{ inches}$$

Peak Flow:

$$Qp = \frac{484 \times Am \times Q}{Tp}$$

$$K = \frac{72.6Lm}{(H/Lm)^{\frac{1}{2}}} = \frac{72.6 \times 10.1}{(16/10.1)^{\frac{1}{2}}} = 583$$

Lag time from Fig. 8, L = 12 hours

Time to peak:

$$Tp = \frac{D}{2} + L = \frac{6}{2} + 12 = 15 \text{ hours}$$

and $$Qp = \frac{484 \times 74 \times 1.26}{15} = \underline{3008 \text{ cfs}}$$

Channel 2

Area drained	Am	=	32 sqaure miles
Maximum length of travel of water	Lm	=	12.5 miles
Difference in ground elevation	H	=	28 feet
Depth of 6-hours rainfall	P	=	3.36 inches
Soil Complex Number	N	=	76

Runoff:

Q = 1.26 inches (same as at Ste. Clothilde)

Peak Flow:

$$K = \frac{72.6 \times 12.5}{(28/12.5)^{\frac{1}{2}}} = 907$$

Lag time from Fig. 8, L = 15 hours

Time to peak:

$$Tp = \frac{6}{2} + 15 = 18 \text{ hours}$$

and $$Qp = \frac{484 \times 32 \times 1.26}{18} = \underline{1084 \text{ cfs}}$$

Cranberry Creek

Area drained	A_m =	21 square miles
Maximum length of travel of water	L_m =	7 miles
Difference in ground elevation	H =	30 feet
Depth of 6-hours rainfall	P =	3.36 inches
Soil Complex Number	N =	76

Runoff:

$Q = 1.26$ inches (same as at Ste. Clothilde)

Peak Flow:

$$K = \frac{72.6 \times 7}{(30/7)^{\frac{1}{2}}} = 245$$

Lag time from Fig. 8, L = 7.6 hours

Time to peak:

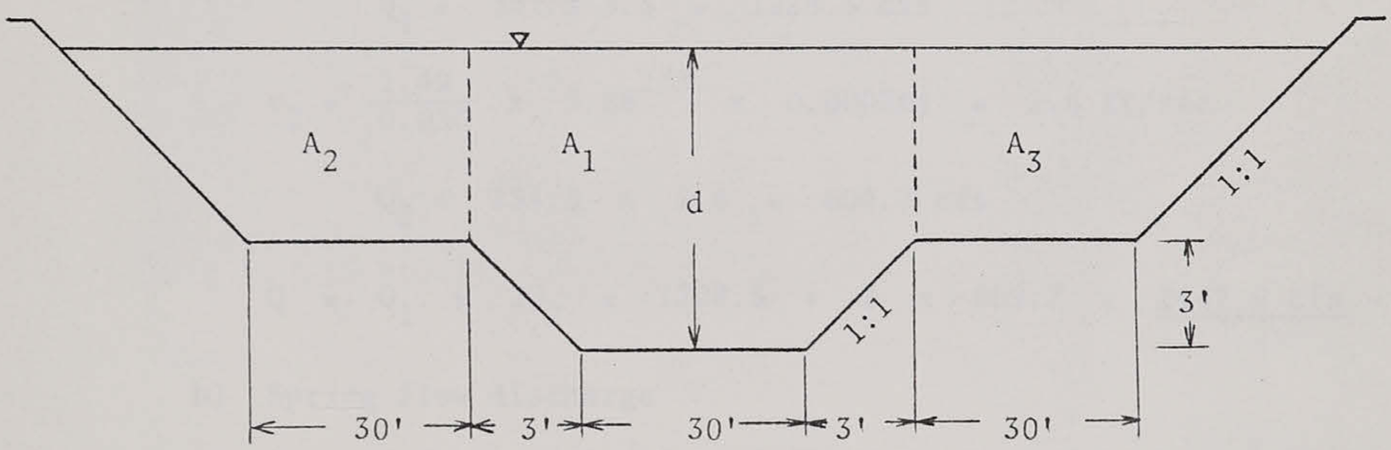
$$Tp = \frac{6}{2} + 7.6 = 10.6 \text{ hours}$$

and $$Qp = \frac{484 \times 21 \times 1.26}{10.6} = \underline{1208 \text{ cfs}}$$

Channel discharge capacity

Norton Creek - cross section above 15 + 500

a) Peak flow	Qp	=	2238 cfs
b) Spring flow	Qspr	=	68 cfs
c) Summer flow	Qs	=	6 cfs
Channel slope	S	=	0.00026 ft/ft
Roughness coefficient	n	=	0.030



Discharge $Q = A \times v$

where: Q = discharge cfs

A = cross section area ft^2

v = velocity ft/sec

Velocity using Manning's formula,

$$v = \frac{1.49}{n} R^{2/3} S^{\frac{1}{2}}$$

where: n = roughness coefficient

R = hydraulic radius (ft)

S = channel slope (ft/ft)

a) Peak flow discharge

<u>d - 10 ft</u>

A_1 = 351 ft^2 R_1 = 0.12 ft

A_2 = 234.5 ft^2 R_2 = 5.88 ft

A_2 = A_3

$$v_1 = \frac{1.49}{0.030} \times 9.12^{2/3} \times 0.00026^{\frac{1}{2}} = 3.5 \text{ ft/sec}$$

Q_1 = 351 x 3.5 = 1228.5 cfs

$$v_2 = \frac{1.49}{0.030} \times 5.88^{2/3} \times 0.00026^{\frac{1}{2}} = 2.6 \text{ ft/sec}$$

Q_2 = 234.5 x 2.6 = 609.7 cfs

$Q = Q_1 + 2Q_2$ = 1228.5 + 2 x 609.7 = <u>2447.9 cfs</u>

b) Spring flow discharge

<u>d = 2 ft</u>

A = 64 ft^2 R = 1.79 ft

$$v = \frac{1.49}{0.030} \times 1.79^{2/3} \times 0.00026^{\frac{1}{2}} = 1.18 \text{ ft/sec}$$

Q = 1.18 x 64 = <u>75 cfs</u>

c) Summer flow discharge

<u>d = 0.5 ft</u>

A = 15.25 ft^2 R = 0.48 ft

$$v = \frac{1.49}{0.030} \times 0.48^{2/3} \times 0.00026^{\frac{1}{2}} = 0.49 \text{ ft/sec}$$

Q = 0.49 x 15.25 = <u>7.5 cfs</u>

PHOTOGRAPHS TAKEN AT SHERRINGTON - STE. CLOTHILDE ORGANIC SOIL AREA (JULY 1975)

PHOTO 1. Water table control dam on Cranberry Creek

PHOTO 2. Channel weeding at low water velocity

PHOTO 3. Lettuce harvesting

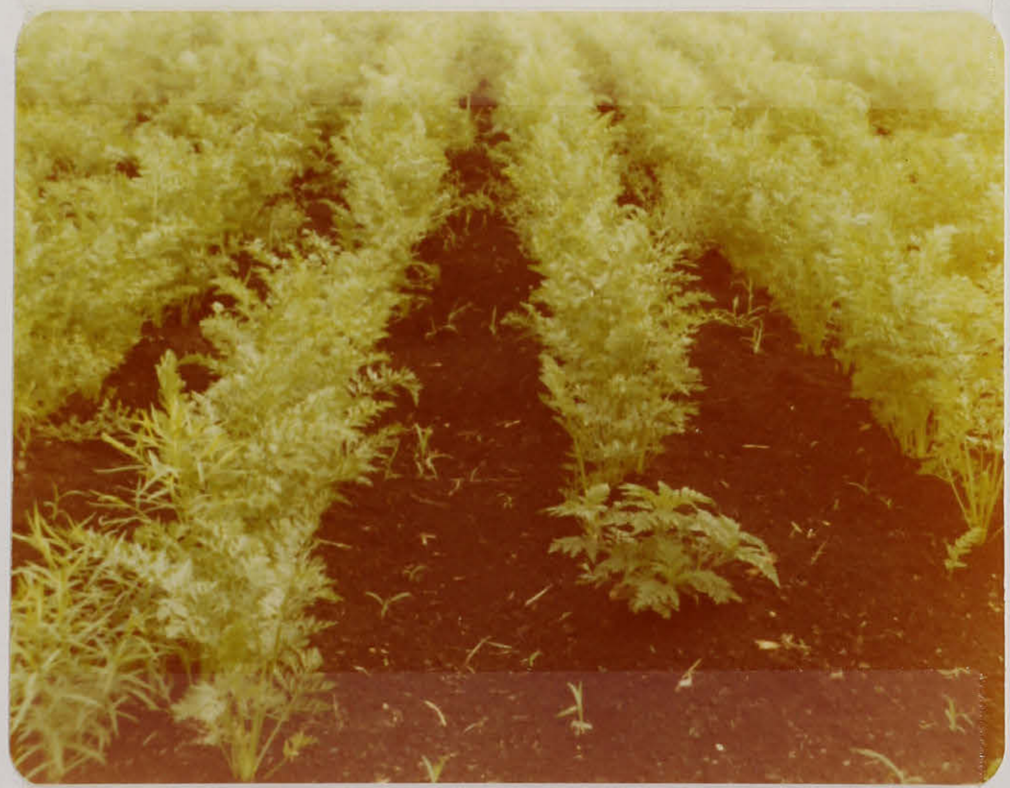


PHOTO 4. Carrot field

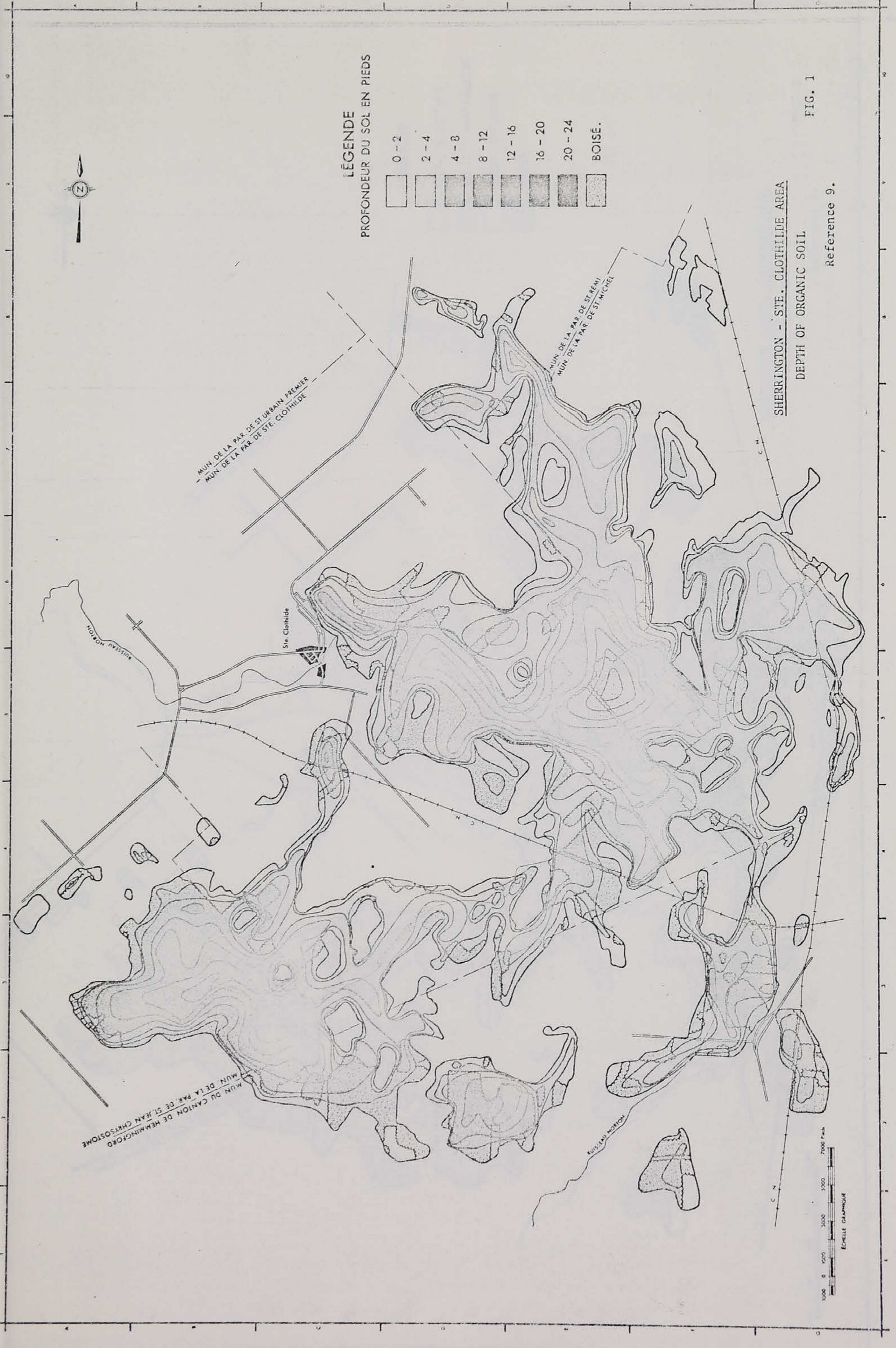
PHOTO 5. Celery field

PHOTO 6. Onion field drained by pump

PHOTO 7. Land clearing

PHOTO 8. New drainage ditch

FIGURES

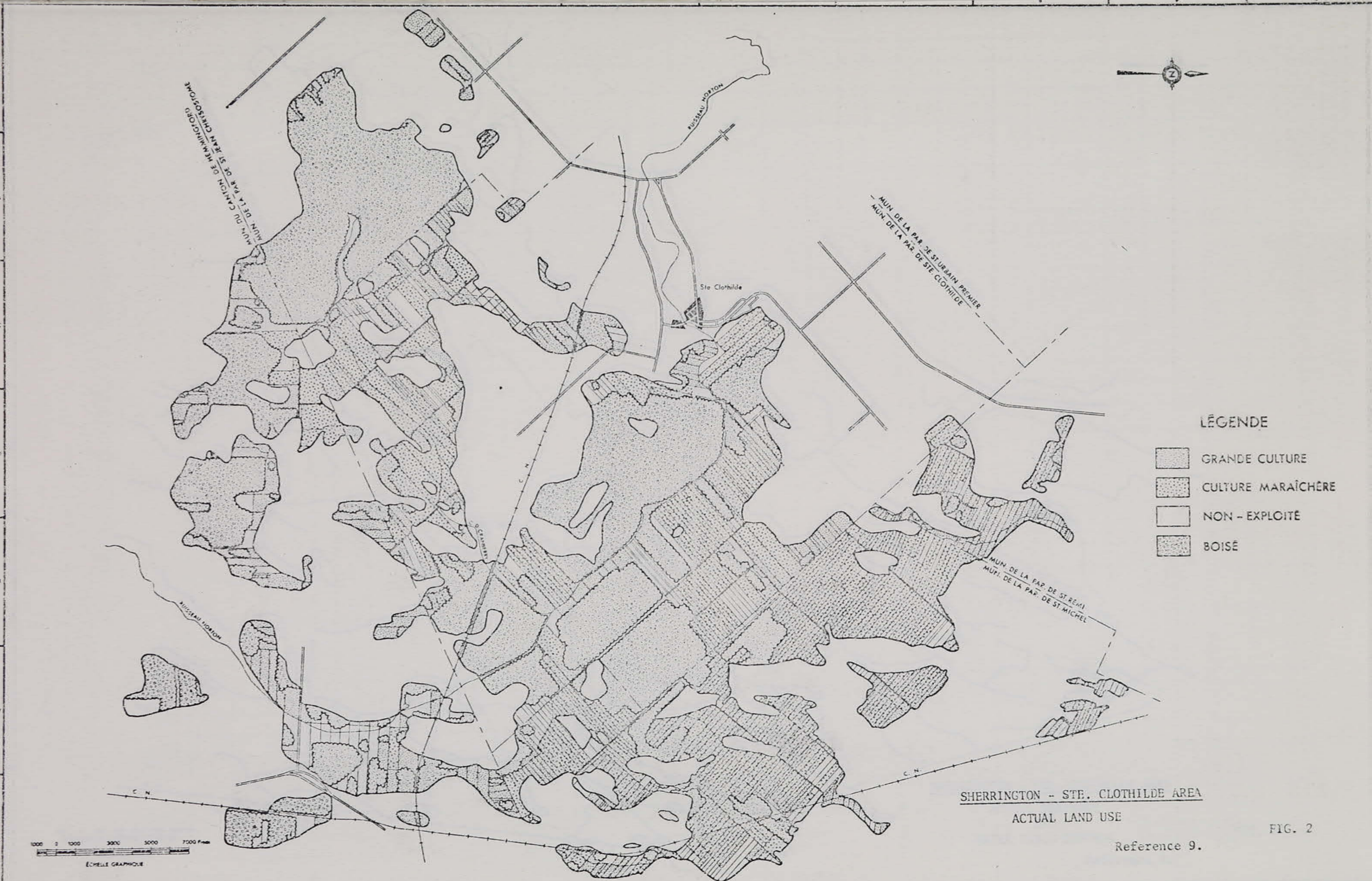


SHERRINGTON - STE. CLOTHILDE AREA

DEPTH OF ORGANIC SOIL

Reference 9.

FIG. 1

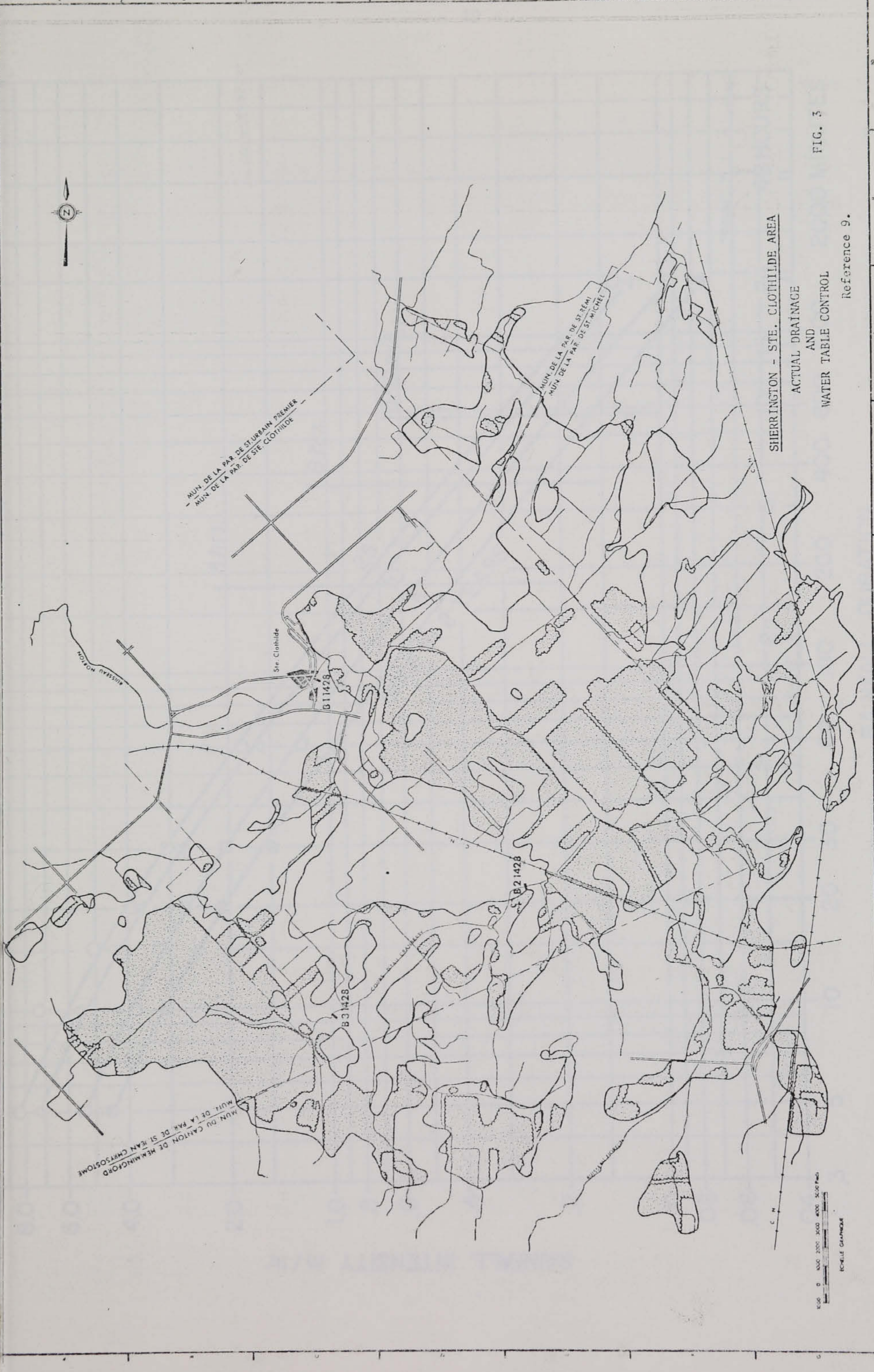


SHERRINGTON - STE. CLOTHILDE AREA

ACTUAL LAND USE

FIG. 2

Reference 9.

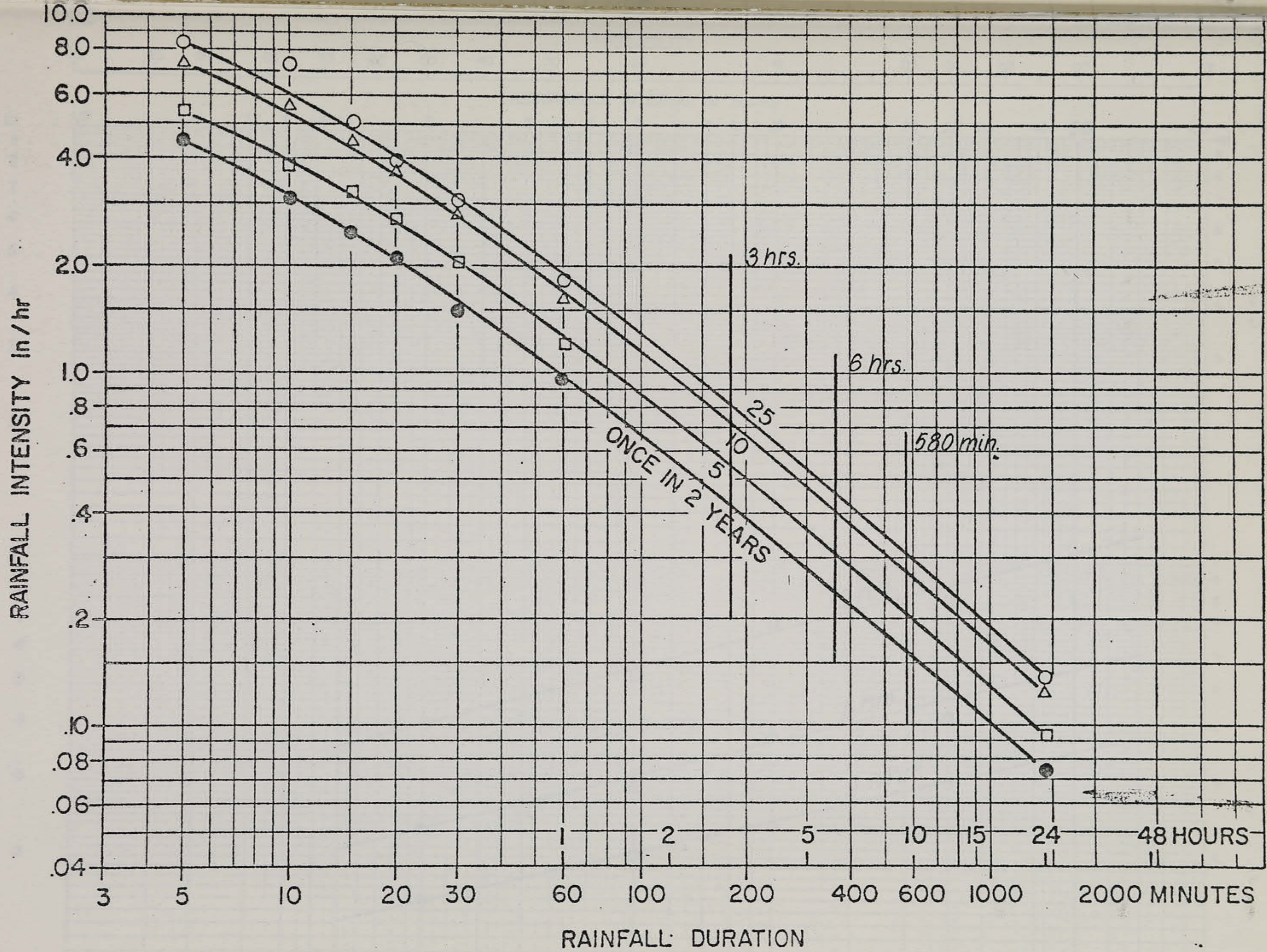


SHERRINGTON - STE. CLOTHILDE AREA

ACTUAL DRAINAGE
AND
WATER TABLE CONTROL

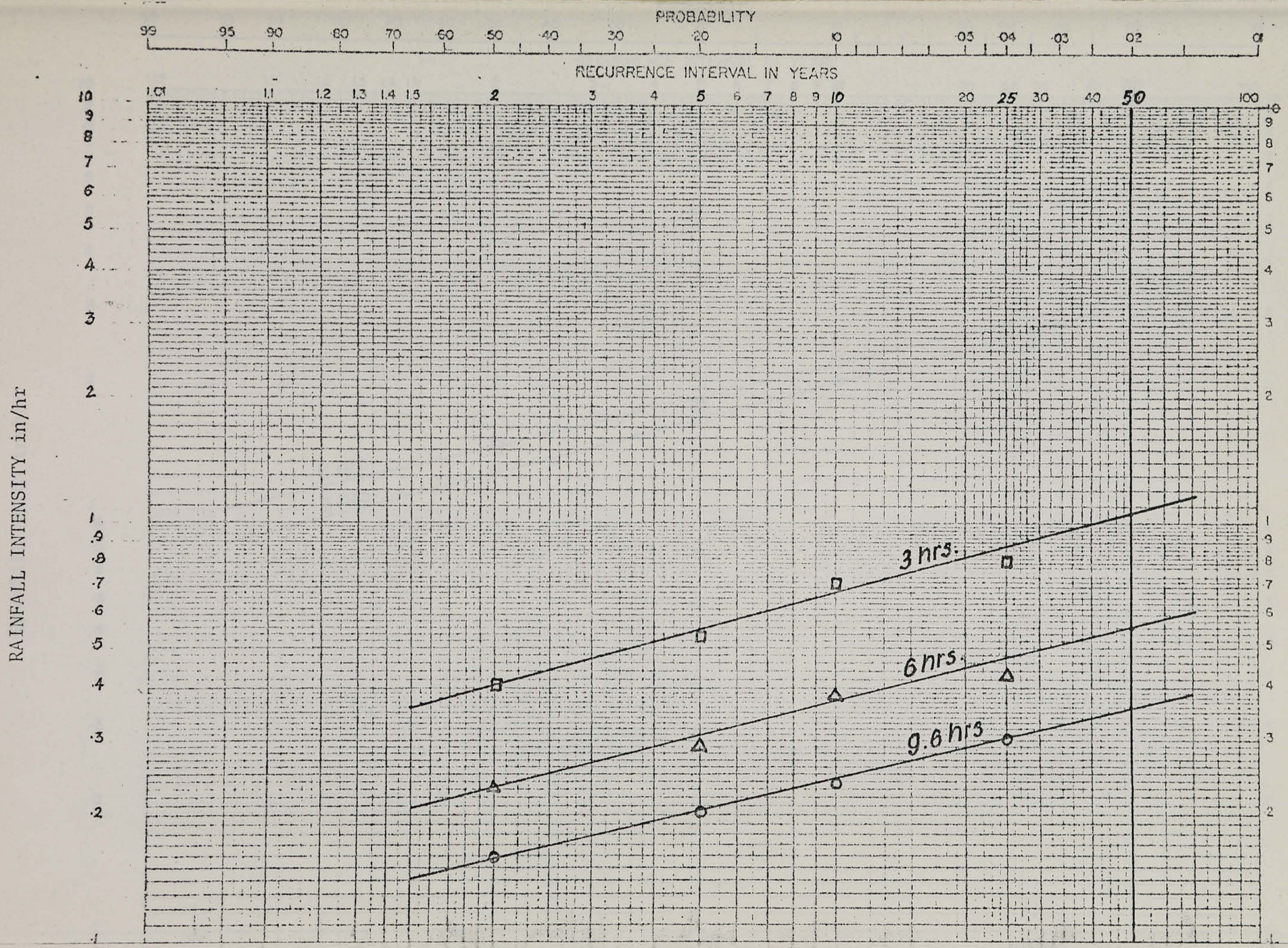
FIG. 3

Reference 9.



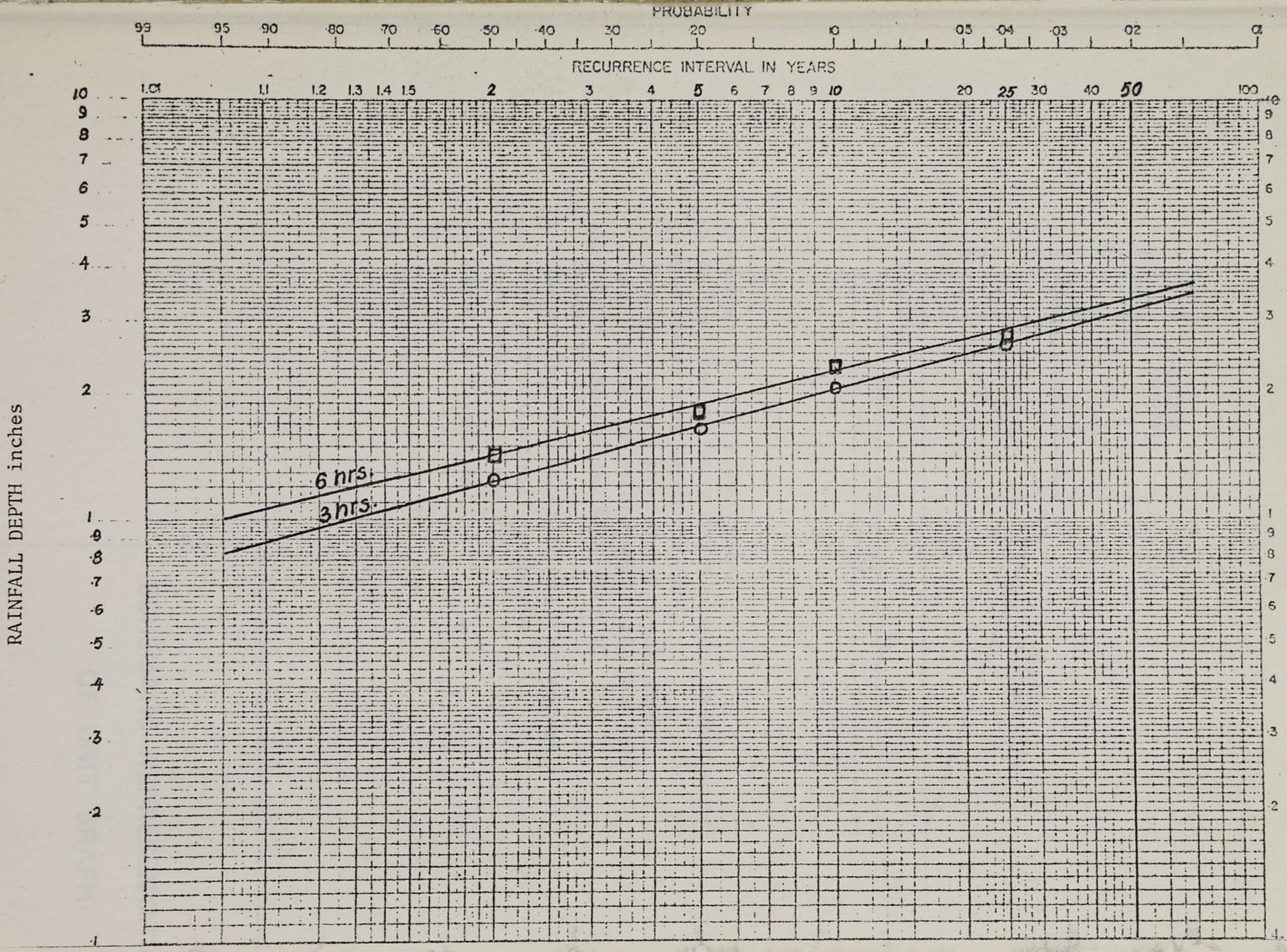
SHORT DURATION - RAINFALL - INTENSITY - FREQUENCY DATA FOR MONTREAL (DORVAL)
BASED ON 25 YEARS OF RECORDS

FIG. 4



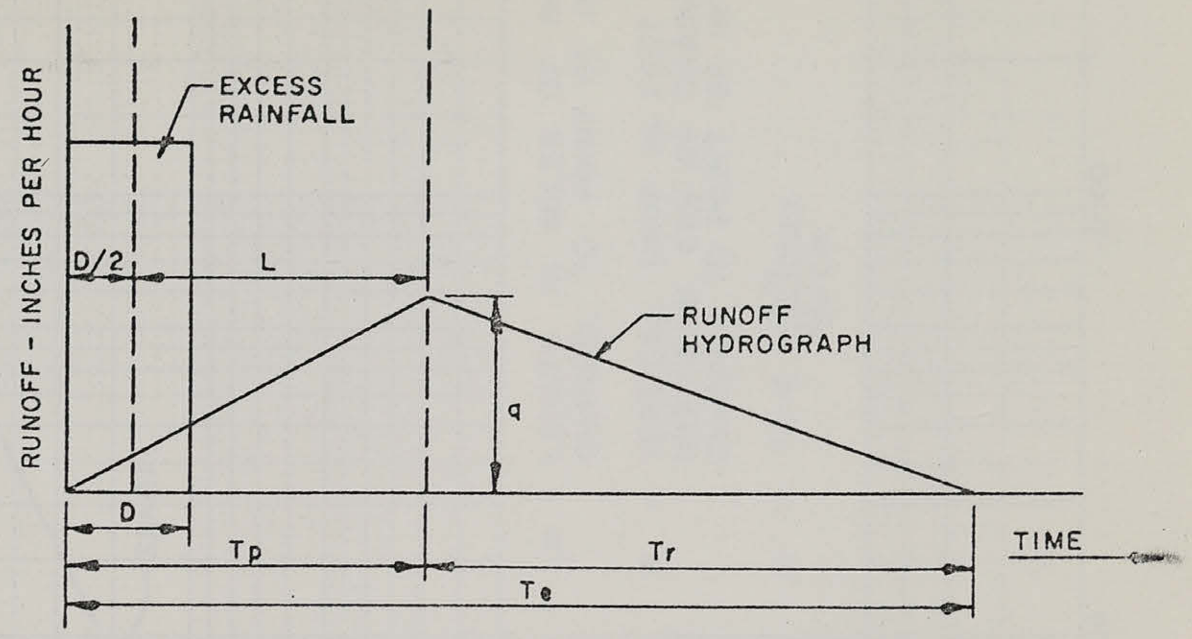
GUMBEL PROBABILITY GRAPH OF FREQUENCY OF RECURRENCE
TO BE EXPECTED OF 3-HOUR, 6-HOUR AND 9.6-HOUR RAINFALLS
AT MONTREAL (DORVAL) INTERNATIONAL AIRPORT

FIG. 5



GUMBEL PROBABILITY GRAPH OF FREQUENCY OF RECURRENCE
TO BE EXPECTED OF 3-HOUR AND 6-HOUR RAINFALLS
AT MONTREAL (DORVAL) INTERNATIONAL AIRPORT

FIG. 6



D = RAINFALL EXCESS PERIOD, HOURS.

L = LAG, TIME FROM CENTRE OF EXCESS RAINFALL TO PEAK, HOURS.

q = PEAK RUNOFF RATE, INCHES PER HOUR.

Tp = TIME IN HOURS FROM START OF RISE TO PEAK RATE.

Te = TIME IN HOURS FROM START OF RISE TO END OF RUNOFF.

Am = AREA OF TRIBUTARY DRAINAGE BASIN IN SQUARE MILES

Tr = TIME IN HOURS FROM PEAK RATE TO END OF TRIANGLE.

q_p = PEAK RATE IN CUBIC FEET PER SECOND.

Q = TOTAL RUNOFF IN INCHES.

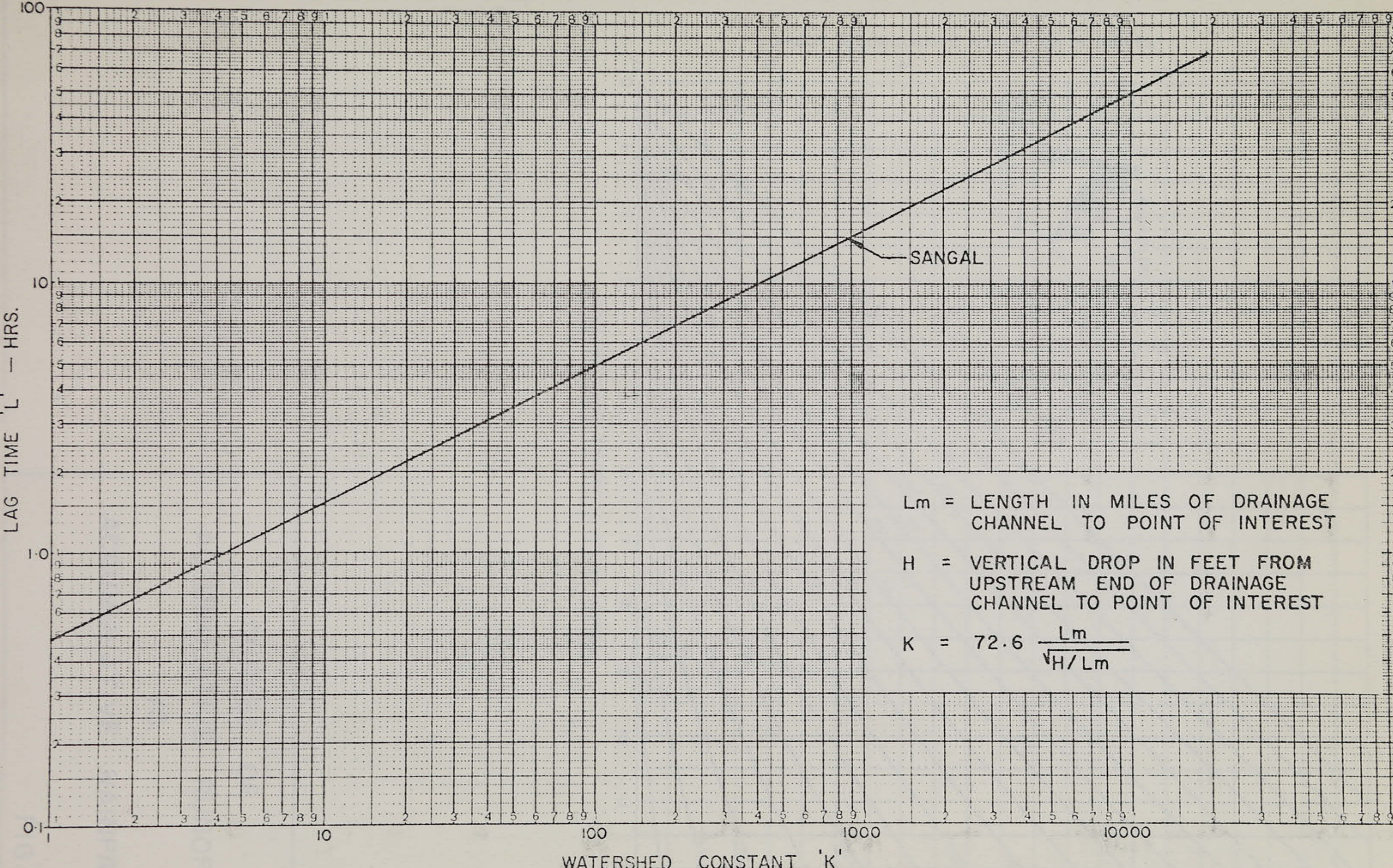
$Tr = 1{\cdot}67\ Tp$ & $Te = 2{\cdot}67\ Tp$

$Tp = D/2 + L$

$$q_p = \frac{484\ AmQ}{Tp}$$

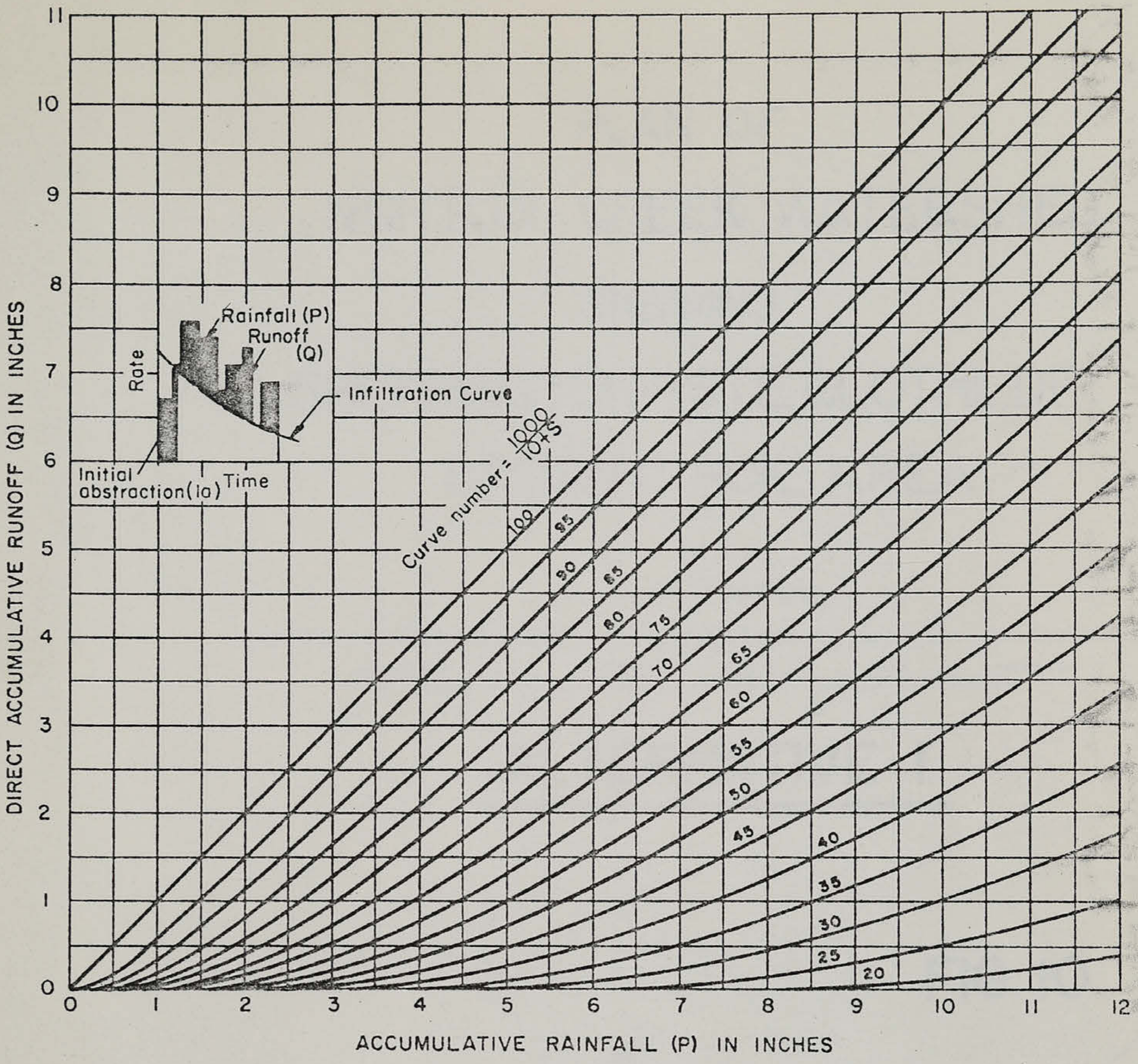
SCHEMATIC REPRESENTATION OF UNIT GRAPH

FIG. 7



LAG TIME 'L' VS. WATERSHED CONSTANT 'K'

FIG. 8



CURVES OF
ACCUMULATIVE RUNOFF
VS.
ACCUMULATIVE RAINFALL

FIG. 9

PLAN OF

NORTON CREEK WATERSHED

SHOWING

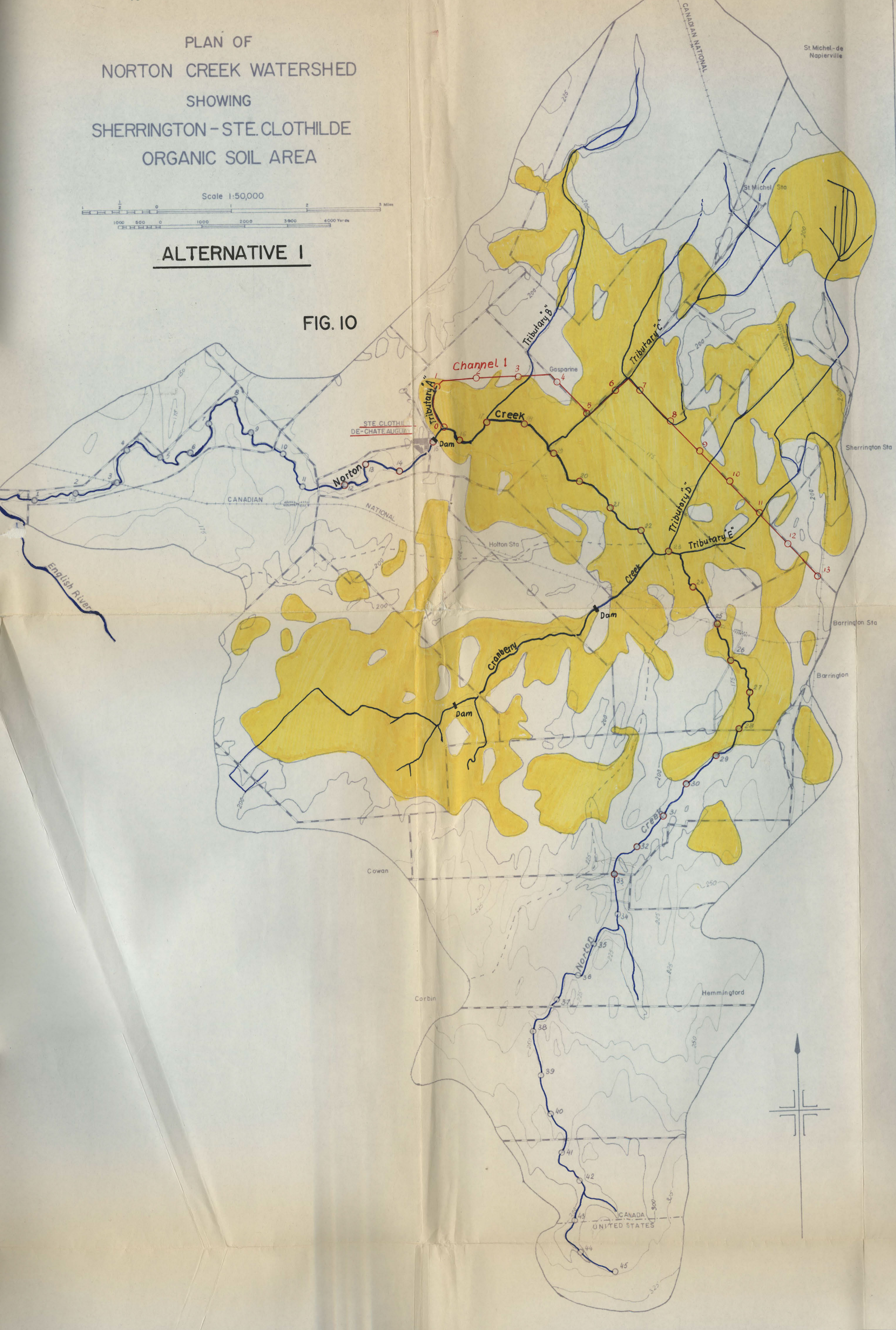
SHERRINGTON - STE. CLOTHILDE

ORGANIC SOIL AREA

Scale 1:50,000

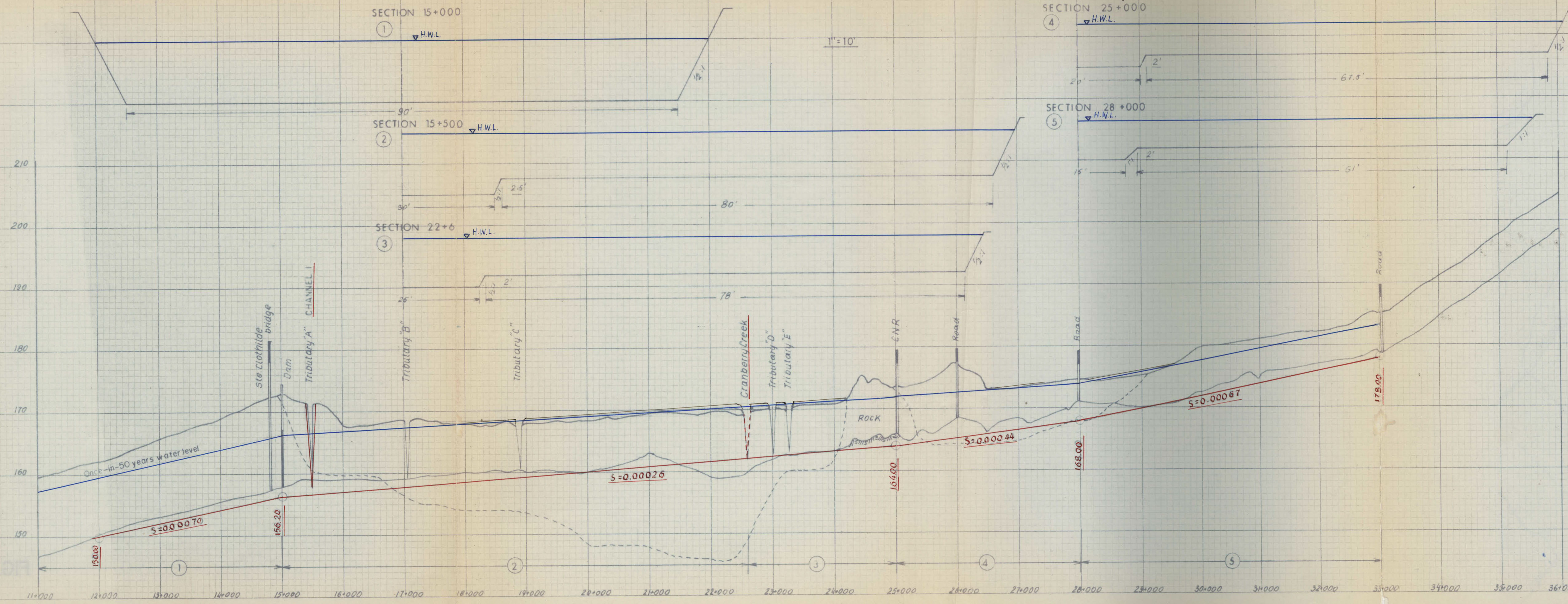
ALTERNATIVE I

FIG. 10



ALTERNATIVE I

NORTON CREEK PR
AND CROSS SECTIC



LEGEND

- Land level near the stream
- Stream bed
- Designed stream bed
- Organic soil
- Water level
- Land grading

DISTANCE IN THOUSANDS OF YARDS

FI

ALTERNATIVE 2

(WITH RESERVOIR)

NORTON CREEK PROFILE AND CROSS SECTIONS

FIG. 13

PLAN OF NORTON CREEK WATERSHED SHOWING SHERRINGTON - STE. CLOTHILDE ORGANIC SOIL AREA

Scale 1:50,000

ALTERNATIVE 2

FIG. 11

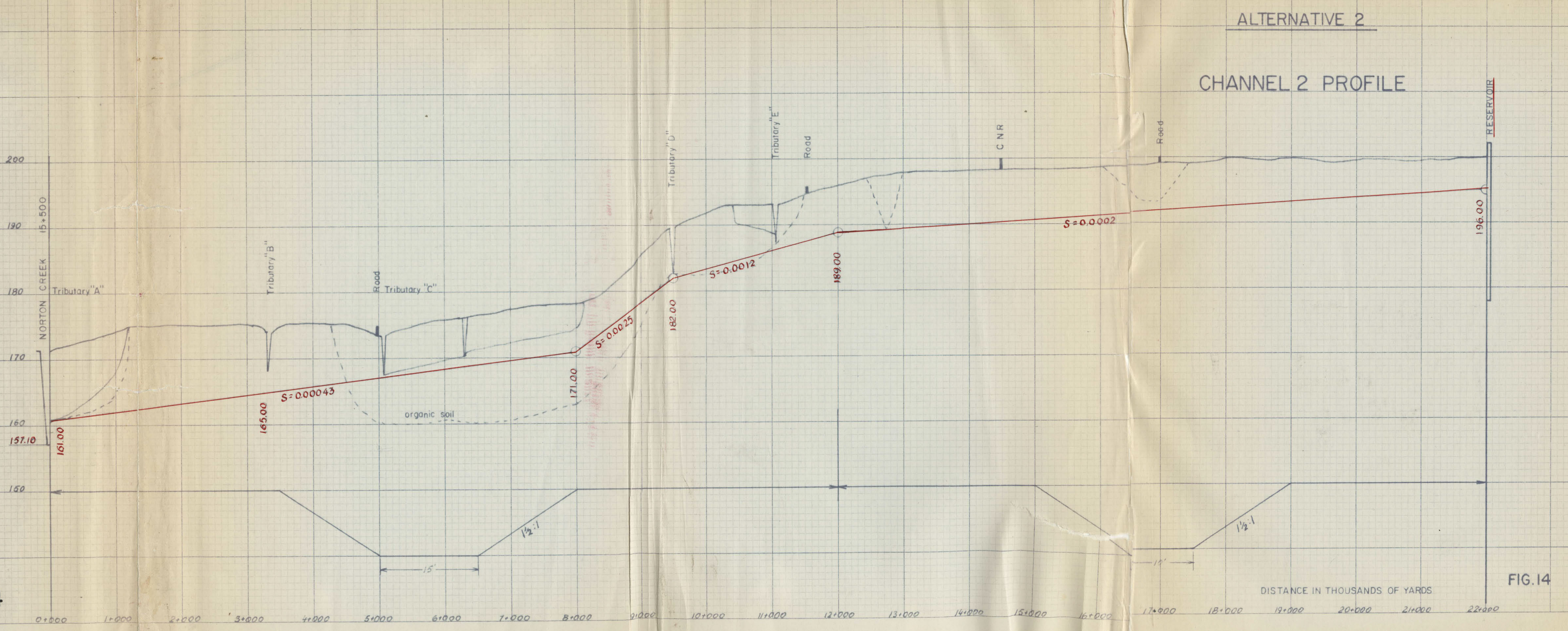

ALTERNATIVE 2
CHANNEL 2 PROFILE
NORTON CREEK 15+500
Tributary "A"
Tributary "B"
Road
Tributary "C"
Tributary "D"
Tributary "E"
Road
C N R
Road
RESERVOIR
200
190
180
170
160
157.10
150
161.00
165.00
171.00
182.00
189.00
196.00
S= 0.00043
S= 0.0025
S= 0.0012
S= 0.0002
organic soil
1½:1
15'
1½:1
15'
DISTANCE IN THOUSANDS OF YARDS
0+000
1+000
2+000
3+000
4+000
5+000
6+000
7+000
8+000
9+000
10+000
11+000
12+000
13+000
14+000
15+000
16+000
17+000
18+000
19+000
20+000
21+000
22+000
FIG.14

FIG.14