REPORT

ON

GRAND RIVER DRAINAGE

ONTARIO

Department of Lands and Forests
ONTARIO

HON. WILLIAM FINLAYSON - - - - - - - - - - Minister

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TORONTO

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1932

TORONTO, February 11th, 1932.

The Honourable William Finlayson,
Minister of Lands and Forests,
Parliament Buildings,
Toronto 5.

RE: GRAND RIVER DRAINAGE

Dear Sir:

The questions of the frequently occurring floods of the Grand River and the water supply and sewage disposal of the municipalities adjoining the river have become matters of concern to the various local authorities. The Grand River Valley Boards of Trade, being representative of the municipalities along the valley, decided to inquire into the general situation, in order that a solution to the various problems could be arrived at. To this end they petitioned the Government of the Province of Ontario, and a meeting was held of a deputation from that body and yourself as Minister of Lands and Forests, on March 6th, 1931.

At the request of the deputation for engineering assistance in the consideration of the problems, the undersigned were requested to proceed with an investigation and report on the following matters:—

Municipal water supply
Sewage disposal
Flood control
Power development possibilities
Afforestation

With the approval of the Chairman of the Hydro-Electric Power Commission, Mr. James Mackintosh, of the staff of the Commission, was deputed, subject to instructions, to carry out the field investigations and prepare the data necessary for such a report. This report has now been completed, and we respectfully beg to submit the same, together with the following comments and recommendations:

It is a matter of record that within recent years very considerable damage has been done to property in the Grand River Valley by flooding, in spite of extensive protective works constructed along the river. From statistics, it appears probable that floods of a magnitude that will cause serious damage to partially protected municipalities will occur with a frequency of five times in one hundred years, and that as frequently as once in one hundred years a flood will occur which will cause serious damage to municipalities with protection in excess of that at present constructed.

The extremely low flows now obtaining during the summer and winter do not provide the necessary dilution to permit of the use of the river as a domestic water supply and for sewage disposal, without extensive treatment of the latter. This condition will become more acute with further increases in the population of the various municipalities.

The logical remedy for these conditions is the creation of storage reservoirs to retain the peak of the floods and to augment the flow during the low water periods. As indicated by the report, the immediate needs of the district can be met by the construction of a storage dam on each of the Conestoga and Grand Rivers and of a water conserving works at the Luther Marsh. These reservoirs would, in our opinion, reduce ordinary floods to limits below the present protective works, but would not be sufficient to provide similar conditions for extraordinary floods occurring at less frequent intervals. The cost of these three works is estimated at $1,359,000.00.

In conjunction with the works for improved river regulation, the opportunity would be offered for improvement of the scenic features of the district. The creation of a bird sanctuary at the Luther Marsh, and the judicious reforesting of the poorer areas and the slopes of the streams would, it is believed, add to the attractiveness of the valley.

By the construction of a further dam on each of the Conestoga and Grand Rivers, a river flow, sufficient to meet the water supply and sewage disposal needs of a population some three times the present, could be provided, and protection secured against any floods likely to occur. These additional works are estimated to cost a further $1,596,000.00.

In view of the total outlay involved, it might be expedient or necessary to spread the expenditure over a period of years, in which case one dam on the Grand River at Waldemar and the conservancy works at the Luther Marsh only, could be undertaken at the present time. This would improve low water conditions and, to a minor degree, reduce the flood flow, and could be completed for an estimated expenditure of $673,000.00.

In considering the expenditures as given above, it is suggested that attention be given to the collective expenditures in the near future of the various municipalities for water supply, sewage disposal and protective works, if some such regulation is not provided. In view of the present industrial conditions, this would appear an opportune time for the carrying out of such works as above described, the cost of which is to a large extent made up of expenditures for labour.

Before the final designs of the structures are undertaken, it will be necessary to carry out a detailed survey of the various sites. If active construction is anticipated within the year, it is recommended that these surveys be undertaken as early in the coming summer as conditions will permit. It is estimated that the securing of this necessary field data would cost approximately $10,000.00.

There is evidence at several locations that the river channel has been encroached on by various works, and it is recommended that careful attention be given in the future to prevent the further impairment of the waterway.

It is recommended that the collection of further stream flow data be undertaken immediately, and that at least four automatic water level recorders be installed to secure continuous records throughout the flood period.

We have the honour to be

Your obedient servants,

(Signed) T. H. HOGG
L. V. RORKE

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Definition of Terms

"C.F.S." is an abbreviation for cubic feet per second.

"C.F.S. per Square Mile" is the average number of cubic feet of water flowing per second from each square mile of area drained.

"Run-off Depth in Inches" is the depth to which a drainage area would be covered if all water flowing from it in a given period were conserved and uniformly distributed on the surface.

"Acre-foot" is equivalent to 43,560 cubic feet, and is the quantity of water required to cover one acre to a depth of one foot.

"Flood ratio" is the rate of peak flow to average flow during the flood period.

"Temperature gradient" is the rate of change in temperature.

Convenient Equivalents

1 C.F.S. equals 6.25 Imperial gallons per second, equals 538,453 Imperial gallons for one day.

1 C.F.S. for one year covers one square mile 13.572 inches deep, equals 724 acre feet.

1,000,000 Imperial gallons per day equals 1.86 C.F.S.

1 C.F.S. multiplied by fall in feet divided by 11 equals net horsepower on water-wheel realizing 80 per cent. of theoretical power.

Report on Grand River Drainage

Introduction

Municipal authorities and others throughout the Valley of the Grand River, realizing that the interests of their communities were, to a very marked degree, affected by the Grand River, and that the floods in spring and extreme low flows in summer were adversely affecting their well-being and were likely to do so to an increased degree in the future, made representation through the Grand Valley Boards of Trade to the Provincial Government of Ontario, advocating that an engineering inquiry be made into the general question of the drainage of the Grand River.

The Provincial Government, through the Honourable Mr. Finlayson, directed that such inquiry be made and reported on. The general features to be dealt with in the report were to be: flood control, increased summer flow, power development, the relation of stream flow to municipal water supply and sewage disposal, fishing possibilities, and also, but incidental thereto, valley roads.

Incidental to such an inquiry, numerous other questions, such as the effects of forest cover and township planned drains, presented therselves, as also the pertinent question of the correct timing of the operation of manually controlled storage basins to reduce the crests of the floods.

Owing to the general interest by the communities concerned in the subject under review, it was considered advisable that the report should be, as far as possible, in such form as to be readily understool by the non-technical reader. For this reason much of the subject matter has been presented at greater length than in a strictly engineering report.

The report of the survey which follows gives a resumé or interpretation of the drainage problem of the Grand River, and considers the geological structure and soil of the valley. It also deals with precipitation and temperature distribution, forest cover, open drainage channels and run-off as affecting stream flow distribution, water supply, sewage disposal, freshets and water power. It conclules by making recommendations for the lessening to some degree of the effects of poor distribution of stream flow. Incidental to the recommendations are the possibilities of fishing rehabilitation and a wild fowl sanctuary. An appendix describes the importance of suitable valley roads and interconnecting highways.

Little of the information on which the report is based is original, a large part being procured from public documents and records. In its presentation, an attempt has been made to arrange the matter so that the arguments leading up to the final recommendatios may be readily followed. The basic information has also been presented in such a manner that engineers, in their capacity as advisers to the interested municipalities, may have at their disposal data on which to base any modification of the scheme of betterment herein considered.

The effect of forest cover and open drains on the stream flow of the Grand River is, of course, necessarily deductive since there are no records available by which the run-off from the deforested areas throughout the basin may be compared with that from the same areas in their forested condition. The same applies to the naturally drained and artificially drained areas. Opinions of recognized authorities on these features are quoted and have been used as far as applicable.

General

Drainage is the term used to signify the manner in which the waters of a country pass off by its streams and rivers. It deals with the precipitation from the time it falls, when a large proportion is absorbed by the soil to later in part support growing vegitation and in part sink down to augment the ground water. The excess flows away on the surface, partly to be lost by evaporation and the further demands of vegitation, and partly to be absorbed by unsaturated soil encountered in its course. The remainder contributes to the volume of the nearest stream.

The drainage problems of the Grand River basin, which is shown on Plate I., have exercised the minds of the people along the valley for many years.

Here, as in other similar locations, the increase in occupation during the past few decades of the frequently rich and easily cultivatable bottom lands along the valleys of the rivers and the phenomenal growth of some of the cities and other communities of lesser size located along these river flats, have multiplied the drainage problems and rendered their solution more and more pressing. There is now on record and available for comparison and study, a considerable amount of literature dealing with drainage in all its phases. The outstanding example of drainage problems of today is that of the Mississippi River basin.

The first settlement in the Grand River basin, in common with other districts, followed the natural water highways. In time, small communities centred around suitable locations for water-operated saw-mills, grist mills, and carding and weaving mills. Farms grew neighbouring these communities and along the roads and paths leading between them. These settlers found the ridges and uplands covered with various types of hardwood and other deciduous trees, the slopes and flats with pine and hemlock, and the marsh and near-marsh areas, which local historical records state covered large tracts of land, with cedar and hemlock.

An author of a recently published historical novel dealing with the early pioneer life of one of the large settlements describes the hardships of travel met with in traversing the well-known Beverley Swamp. The "Parliament of York" finally decided to put a corduroy road through the swamp to assist communication between Hamilton, Galt and the Conestoga.

Another historical writer refers to the building of a dam and saw-mill below Elora in or about 1820. The dam was apparently guaranteed to stand for three years but "in the spring of 1822 the annual floods came in full force, washed out the stones from the deep hole in the centre of the river and thus undermined the whole affair so that it floated downstream."

In 1832, Captain Gilkinson wrote to Simon Fraser, his foreman, with reference to a mill at Elora, that "the mill race must be so constructed that it will contain sufficient water to turn a grist mill and as many other mills as possible." Simon Fraser replied that "should it be your desire to carry the race into effect, I should wish to have 1,000 tin tubes for blasting as we are much troubled with water entering in between the seams of the rocks."

It is interesting to note the opinion of the owners of the well-known Wissler mill at Salem in 1865, "that owing to the deforestation of the land and the drainage necessary for cultivation, the water in the Irvine River which before that time had continued throughout the year in a fairly steady stream thus came in periodic floods."

Numbers of communities in the valleys of the Grand River and its tributaries settled along the banks of the streams. Some of these have encroached well within the limits of the flood line required by the stream to accommodate its periodic extreme high floods. The building of bridges in these communities and also at comparatively short intervals along the river with short spans and solid approaches was not the least of this encroachment. With these conditions, floods reached to higher levels and frequently gave the impression that they were growing in volume. Judging by press reports, these high floods would wholly destroy numbers of bridges, ripoff the deck of others, flood streets, factories and dwellings, and otherwise temporarily regain lost territory. During the past fifty years a rigorous policy of deforestation and land drainage has been pursued, until, at the present time, it is doubtful whether more than five per cent. of the total drainage area of the Grand River remains wooded.

In their early history towns located on the river secured their water supply from this ready source. As the stream later became polluted, due to the depositing of farm, domestic, and industrial waste and sewage, dependence grew on the supply from wells. With the further growth in population, the dependence on wells for water supply is reaching the economic limit, in at least one case. The City of Brantford has again gone to the river for a permanent source of water supply, and has just completed and put into service a modern and well-equipped pumping and filtration station.

With the modern system of a centralized supply of electric light and power at their disposal, most of the smaller mills throughout the watershed have either wholly or in part dispensed with privately generated power. As the population of the drainage basin and the per capita demand for light and power are growing rapidly, it is doubtful whether the present extent of dependence on the Grand River for a power supply will be increasd.

The basin of the Grand River is one of the most densely populated areas of similar size in Canada, and its responsible citizens have come to realize that, to cope with the demands of further increases in population, its problems of drainage must be solved and the present regimen of the river improved.

Geology

An appreciation of the geology or physical features of the territory under consideration is necessary, if one is to comprehend the principal factors affecting drainage and water supply, and also the limitations of the remedial measures which may be undertaken.

The physiography of the watershed is formed of a gently rolling, or slightly undulating country, ribbed in parts by gravel ridges and low hills, and sloping towards Lake Erie at about six feet per mile. The rock lies about one hundred feet below the ground surface, appearing only along the rivers.

This drainage basin presents some extremely interesting geological features. The underlying rock has no commercial value apart from the gypsum and water lime found in parts, but this lack is compensated for by the high fertility of its soil. The pastoral beauty of the valleys and their waterways, together with the gorges at Elora, rich in fossilifera, are well known to the public through the medium of school book, text book and public circular.

The drainage basin of the Grand River is some 2,600 square miles in area, and occupies practically the whole of the counties of Waterloo, Wellington and Brant, with parts of Grey, Dufferin, Perth, Halton, Oxford, Wentworth, Norfolk and Haldimand. The river rises about 30 miles from Georgian Bay, in the neighbourhood of Dundalk, at an elevation of 1,700 feet above sea level, and follows a course of 180 miles to its mouth at Port Maitland, on Lake Erie, at an elevation of 572 feet above sea level. There is then a drop of 1,128 feet, or an average of 6-3/10 feet per mile. This fall may be divided as follows:

Section	Miles	Elev. to Elev.	Drop (Ft.)	Grade (Ft. per Mile)
Dundalk-Elora	50	1700 - 1120	580	11.6
Elora Falls (40′, not included)			540	10.8
Elora-Brantford	75	1120 - 620	500	6.7
Brantford-Lake Erie	55	620 - 572	48	0.87

The following drawings show the various physical features referred to in this section of the report:

Drainage Basin of the Grand River	Plate No. I.
Contour Plan of Equal Elevations above Sea Level for South-Western Ontario	Plate No. II.
Profiles of Grand River and Tributaries	Plate No. III.
Soil and Rock Distribution	Plate No. IV.

The principal tributaries of the Grand River are the Nith, Speed and Conestoga Rivers, amounting to about 1,000 sq. miles in area. The other tributaries, of lesser importance to this report, are the Irvine, Galt Creek, Whiteman's Creek, Fairchild's Creek and Boston Creek, aggregating 550 square miles in area. The gradients of the former are as follows:

River	Miles	Elev. to Elev.	Drop (Ft.)	Grade (Ft. per Mile)
Nith	72	1230 - 720	510	7.1
Speed	24	1134 - 894	240	10.0
Conestoga	40	1530 - 1010	520	13.0

It is suggested that these remarkably high gradients be borne in mind, as they will be referred to later.

The slopes of the general terrain of the district are somewhat similar and parallel to those of the above river, it being understood, of course, that the said slopes are modified by the lateral slopes draining towards the rivers. As a matter of fact, these lateral slopes and drainage channels, while reasonably flat at some distance from the rivers, frequently assume grades exceeding 50 feet per mile within short distances of the rivers.

There are three Government reports dealing with the general geology and soils of south-western Ontario, from which much of the data in the following sections are taken. These are:

The Silurian Geology and Faunas of Ontario Peninsula—by M. Y. Williams—1919.
The Moraine Systems of South-Western Ontario—by Frank B. Taylor—1913.
Preliminary Soil Surveys of South-Western Ontario—by R. Harcourt et al—1923.

Various reports of the Dominion Geological Survey and Provincial Bureau of Mines have also been made use of.

Plate No. IV. has been assembled from the information gathered from these publications. The following is a table showing the classification of the Silurian rocks underlying the Grand River Valley:

Age	System	Group	Formation	Member
Paleozoic	Devonian	Oriskanian	Oriskany Sandstone	
	Silurian	Cayugan	Akron Dolomite	
			Bertie Water Lime	
			Salina	Camillus Shale including Gypsum
		Niagaran	Guelph	
			Lockport	
			Rochester	
		Medinan	Clinton	
			Medina	Cabot Head Shale
			Cataract	Manitoulin Dolomite
	Ordovician	Cincinnatian	Richmond	Queenston Red Shale

A cross-section across the watershed from the Conestoga at Glen Allen through Elora on the Grand to Rockwood on the Speed is also shown on Plate IV. The plan of the watershed, together with the said cross-section, the two well logs, and the above table, will enable one to follow in the desired manner the distribution of the soil and rock over the drainage area.

Evidences from the rock outcrops and quarries in the region of the Grand River indicate a very old geological formation. Its layers of limestone and shale, hundreds of feet in thickness, were deposited on ocean beds during those early geological periods known as Ordovician and Silurian of the Paleozoic age. In the limestone rocks of the region are numerous fossils of brachiopods, trilobites and other forms of marine life, among which are some species peculiar to the neighbourhood of south-western Ontario.

The successive settlements and emergences during the various ages left the underlying rock with undulations of various degrees, which subsequently underwent considerable erosion by glacial action. These glaciers of the Carboniferous, and later, the Pleistocene ages ground off the tops of the ridges, hollowed out the troughs deeper, and their final retiral covered all this up with a great depth of glacial drift. Later, the streams issuing from the distant glacial front dug out channels in this drift, to be again sometimes partially or completely filled in by silts and gravels. It is the channels again scoured out of this drift, gravels and silts, due to the eroding action of varying temperatures and drainage, that have given us the rivers we now know. Numbers of these no doubt follow, or closely coincide with, the older channels, of which the Nith appears to be the most evident. In this regard, an eminent geologist, the late Dr. J. W. Spencer, remarked on the plateau-like appearance of the territory above Elora, and stated that at Galt the present river valley occupies a portion of a broad depression in a country indicating a former and much more extensive valley, "in fact," he said, "the old river valley existed in preglacial times, for the present stream has re-excavated only a part of its own bed at Galt, leaving on the flanks of one of its banks, composed of Guelph dolomites, a deposit of post-tertiary glacial drift in the form of a bed of large rounded boulders mostly of Laurentian gneisses."

The region stretching from London north through Stratford and Guelph to Dundalk and Chesley is known to geologists as "Ontario Island." In the retrogression of the Pleistocene ice field, this area, with its high elevations, appeared above the level of the surrounding ice field first. This has had the effect of giving to it a somewhat different soil and physical features than the area immediately to the east of this.

Surrounding this area are numbers of parallel moraines, with here and there throughout the area short gravel hills and ridges. This material, deposited in the beds of streams flowing through crevices in the ice and round the shores of "Ontario Island," remained after the ice melted. They reach to considerable heights above the general level of the immediate surrounding land, and are easily reconizable. They also form the main drainage slopes of the Grand River above Galt and the Thames River above London. The moraine system influencing the drainage of the Grand River to the greatest extent is known as the "Milverton Moraine," which runs from West Luther Township to St. Mary's and London. Most of the Conestoga River and the upper waters of the Nith find their way through this system. The deep canyon-like character of parts of these river channels is very noticeable.

Two strong moraines, known as the Galt and Paris moraines, extend southward across East Dufferin county, the north-west corners of Peel and Halton counties, East Wellington county, and South Waterloo county, continuing as far as Lake Erie, which they join, one on either side of Long Point. The upper waters of the Speed River drain parts of these moraines, and the Grand River runs between them from Galt to Paris.

Plate No. IV., accompanying this part of the report, shows divisions of the soils from the Grand River Valley. The two principal ones are the Guelph and London. A study of the drawing shows the close relation of this soil division to the eastern shore line of "Ontario Island." An authority states that, although the soils of the Guelph series are typical morainal soils and are found in nearly all of the ice-laid terminal moraines in South-western Ontario, they also occupy large inter-morainal areas, particularly in the northern and eastern parts of "Ontario Island."

In the Guelph series, gravel and small stones are found in the deeper sub-soils and, in many places, stratified sand and gravel, and this gives excellent drainage. It is likely that in that part of the Guelph area underlain by Guelph dolomite, rock is at no great distance below the surface. The outcrops shown on the drawing are in the Guelph section only of the Grand River Valley. The surface of these soils varies from a gently rolling to a steep and hilly character.

Beneath the surface layer of the London series of soils, there is a sub-surface layer of yellowish-brown material, which grades into a yellow-brown and grey mottled heavy clay loam or clay sub-soil. This sub-soil is comparatively impervious and prevents adequate natural under-drainage. The London clay surface is gently undulating to rolling, and, in general, has sufficient relief for surface drainage, but the heavy sub-soil prevents rapid removal of the water in wet seasons by under-drainage. It is represented that artificial drainage improves this condition, and that open ditches may be necessary in some places, as tile may not draw efficiently in the heavy sub-soil. A heavy silty clay is encountered on the east side of the Conestoga River in Peel Township, formed by deposition in a temporary lake during the early stages of "Ontario Island." The surface is gently undulating; there is sufficient relief for fair surface drainage, but the heavy character of the soil makes artificial drainage necessary to remove excess water quickly.

In the territory north and east of Arthur there is a comparatively large level surface, which has many depressions with little or no natural drainage outlets. While they were originally lakes, most of them have been gradually filled in by the accumulation of organic matter mixed with inorganic matter. These areas are classed as muck and peat by agriculturists, and merge into the heavy clays which frequently surround them. In East and West Luther Townships, part of the area is 20 feet or more in depth of peat, and is covered with certain types of grasses and sedges, but does not produce much tree growth. In Plate No. I., showing the drainage basin, the most prominent of these areas are indicated. They are the Luther Marsh, and the Amaranth and Garafraxa Swamps.

The rock underlying the deep overburden of glacial drift covering the watershed is the hard compact Guelph dolomite to the east, and the soft Camillus shale of Salina formation to the west. While the ground surface has a general slope in a southerly direction of approximately 8 feet per mile, the strata has a dip in the same direction a few feet per mile greater than this.

It is to be noted that the Fergus and Galt municipal wells have the Guelph dolomite on the surface, while those of Kitchener and Waterloo are topped by a thickness of the Salina-Camillus shale. The following is the information yielded by a log of a well drilled many years ago in the Township of Waterloo:

Surface	Zero to 130 feet
Salina	
Dolomite	130 to 170 "
Gypsum	170 to 187 "
Shale	187 to 207 "
Guelph-Lockport-Clinton	
Dolomite	207 to 547 "
Medina Cataract	
Blue Shales	547 to 661 "
Queenston Red Shales	661 to 1120 "

Well logs of the Kitchener water supply system are as follows.

	Log 1	Log 2	Log 4	Log 6
Surface	186 ft.	170 ft.	175 ft.	175 ft
Shale	—	—	27 "	27 "
Rock-Dolomite	—	—	234 "	73 "

These several well logs will be referred to later in the discussion with reference to municipal water supply.

The Guelph formation, as already stated, is on the surface of the shield over the easterly portion of the watershed, and of course underlies the Salina formation over the westerly portion. The weathered rock is light grey to cream coloured, and generally has a porous-saccaroidal texture. It is highly fossiliferous. In the Salem-Elora section it is about 80 feet thick and about 60 feet thick at Fergus. Sections at Galt and between Guelph and Glenmorris include the highest Guelph beds known to outcrop in Ontario.

The Camillus shale member of the Salina formation is salt and gypsum bearing. A typical section is that already described in connection with the well log at Waterloo. It is essentially a grey or green shale and also frequently contains beds of argillaceous dolomite. Weathered exposures of the shale along the Grand River are grey-green in colour and are generally soft and fissile.

Precipitation and Temperature Distribution

The seasonal distribution of the precipitation and temperature over the valley of the Grand River, together with the Physiography described in a previous part of the report, determined the run-off from the watershed, which appears as stream flow.

Disastrous floods generally result from the following causes, acting either along or in conjunction: excessive rain fall, rapid melting of snow, forming and breaking of ice jams, and breaking of levees.

The following plates have been compiled to show the relation of precipitation, temperature and topography:

Contour Plan of South-Western Ontario	Plate II.
Precipitation Distribution, South Western Ontario	Plate V.
Temperature Distribution, South-Western Ontario	Plate V.

The importance of the influence of precipitation and temperature of flood flow resulting from the rapid melting of snow is shown on Plate XIV.

A study of these plans will disclose hydrological facts not generally appreciated. It will be noted that, while the increase in elevation from Port Maitland, at the outlet of the Grand River, to Dundalk at the headwaters is 1,100 feet, the mean annual precipitation is 33 inches throughout the river valley proper, but varies from 35 inches along the westerly edge of the watershed to 32 inches along the easterly edge. The mean annual temperature ranges from 46 degrees at the outlet to 42 degrees at the headwaters, being equivalent to a change in annual temperature of one degree per 275 feet of elevation, which is about the usual thermal condition throughout this part of the continent.

The mean annual snow fall on the watershed is at a minimum of 45 inches at Brantford, and increases in a southerly direction to 60 inches along the front of Lake Erie, to 100 inches in a north-westerly direction at Mount Forest, and 90 inches in a northerly direction at Dundalk. The average temperature during the snow months of December, January, February and March, drops from 26 degrees at Lake Erie to 20 degrees at Mount Forest and Dundalk, or a drop of one degree per 185 feet difference in elevation.

It would appear very probable from the meterological records that, due to the lower winter temperatures generally prevailing to the north and west of the watershed than is experienced to the south and east, together with the fact that there is about 30 inches greater snow fall in the former section of thewatershed than the latter, there is considerably greater amount of snow remaining on the ground at the end of winter north and west of Fergus than to the south and east of that point.

Although the winter temperature varies to the degree indicated over the watershed, the spring is introduced by a generally uniform rise, so that during the period when the Grand River has its spring freshet flows, cresting sometimes in disastrous floods, the diurnal range in temperature is practically the same throughout the watershed. This is indicated by a comparison of temperature records at London, Southampton and Mount Forest. This means of course that there is a more rapid climb in the rise of the temperature to the north and west than to the south and east.

Were the rise in temperature to move slowly upstream on the Grand River, as it does occasionally, the flood waters would move out comparatively easily. Were the rise in temperature to travel in a downstream direction there would be increasing concentration of floods, as are frequently experienced on such north-flowing streams as the Red River.

Plate No. XIV. has been prepared, giving the relation of the maximum and minimum temperatures and precipitation during the flood periods to the flood flows at Galt. Mass curves of these records are also shown at the bottom of the Plate.

Investigations carried out in various parts of the northern states indicate that the night or minimum temperatures, when they exceed 32 degrees or freezing have a more marked effect on the extent to which the flood will crest, than the maximum or day temperatures. Judging by the relation shown on Plate XIV., this principle also substantially applies to the Grant River. The point at which the flow suddenly jumps is seen to coincide very closely in point of time with the commencement of the shaded areas. The temperature records used were procured from Southampton and Mount Forest, both near to but outside the Grand River watershed. Had similar records been procurable, say, at Fergus, the shaded areas probably would have coincided even closer than that shown with the sudden jump in the flow.

There are sixteen floods shown, ten of which occur in March. Of these, six have major floods exceeding 20,000 c.f.s., and are accompanied by pronounced black areas. The flood for the year 1921 is interesting, in that the high day temperatures are offset by the night temperatures going below freezing point, and thus preventing the flood cresting badly, notwithstanding that there was 1.2 inches of rain in the period. The high night temperatures are also seen to come into play on the occasions of the floods of 1923, 1924 and 1930, all of which are April floods. The springs of 1922 and 1929 saw two floods, one early in March, the other early in April. The first spring floods distinctly show the effect of the high night temperatures. The later floods, particularly that of 1929, are combinations of melting snow and rains. It will be especially noted that in 1929 there must have been sufficient snow left over from the effects of the early flood to be influenced by the sudden jump in the night temperatures, so that, together with the high precipitation of 1.49 inches, it produced one of the highest floods of the period of record. It is the combination of such factors as depth of snow, temperatures and heavy rains that produce the spring floods, the magnitude of which is determined by the magnitude of these factors. The assistance of more accurate temperature records taken by graphic means, together with snow surveys and information of daily flow conditions on the watershed undoubtedly would permit of a reasonably accurate estimate of flood conditions for the succeeding days.

It is of interest to note that in Bulletin No. 79 of the Research Council of the National Academy of Science, Washington, D.C., the forecasting of temperatures as affecting the melting of the snow cover offers considerable assistance in estimating the succeeding run-off. The predetermination of the temperature is arrived at from a study of the air temperature up to 2,000 meters and the barometric pressure.

Forest Cover and Drainage

The general effect on stream flow of deforesting a timbered area has been discussed in various countries for a long time. Even today, when evidence from well-directed experiments is accumulating, disagreements are still marked as to the amount of the influence, if any, of forest cover on stream flow.

There does not seem to be much question that the watershed of the Grand River was originally well timbered. A consulting engineer says, in connection with a previous short report on the drainage of this basin, that most of the area north of Orangeville and Arthur was covered with cedar, tamarac and swamps. Apart from the swamp or marsh areas that still exist throughout this part of the watershed, there are still indications that large areas were of the character described by the above engineer. To a less extent, but still evident, there still remain sufficient traces to enable one to locate the deciduous and coniferous areas that existed over the balance of the watershed previous to its occupation by settlers.

Numerous shallow swamp areas and wet-weather ponds with the rock frequently at or near the surface are yet to be found over the Guelph soil area. Examples of this are the Beverley Swamp and Puslinch Lake and Swamp. Over the London clay portion of the watershed there appears to have been large areas of beaver meadows and other types of wet-weather ponds and marshes. The head-waters of Whiteman's Creek, the Nith, Conestoga and Irvine Rivers drain large tracts of this character. The northerly slopes of the gravel ridges and small hills were covered with the conifers, whose roots protected the soil from erosion, and on the southerly or more favourable slopes were the deciduous trees, the ground in their vicinity covered deep with humus. At that time the snow lay deeper on the ground in winter, and stayed longer in the spring, protected against the effect of the rays of the sun and the rapidly rising spring temperatures.

It is a condition somewhat of this character that the claimants in favour of forest cover suggest had a beneficial effect on stream flow, by decreasing the volume of the floods in spring and maintaining a more uniformly high summer flow. Others dispute this, maintaining that with forest cover, in lieu of cultivation, floods were higher and summer flows lower.

There are no stream flow records of the Grand River by which one can compare the characteristics of stream flow before deforestation took place, with what occurs now. There is a comparatively large amount of literature on this subject as the result of investigations made in different parts of the world, and this has been condensed and appears in various books and papers on the subjects of forestation and hydrology. All writers admit of the difficulties attendant upon all efforts to find the effects of deforestation and cultivation, and similar changes upon any given watershed as reflected in the flow of streams.

As already mentioned in the first part of the section of this report on drainage, of the precipitation which falls upon the land areas, a portion is evaporated, another portion is transpired by plants or used to form vegetable tissue, and the remaining portion finds its way over the surface of the land or through the earth and rock strata to the streams.

German observations indicate that evaporation in dense woods is 45 per cent., and very young trees 80 per cent., of that in the bare open field. Considering the rate of evaporation from the bare ground surface at a given mean temperature as 100 per cent., the rate of evaporation of free moisture from the ground in grain fields may be taken as 80 per cent., for grass lands 70 per cent., for light forests, brush and second growth 60 per cent., and dense forests with abundant herbaceous vegetation from 20 per cent. to 40 per cent.

Meyer states that the normal transpiration loss, as far as can be determined by the character of vegetation on different watersheds, does not vary between wide limits. For tentative purposes, he says the following normal seasonal transpiration may be used as a basic value in estimating water losses for the northern central portion of the United States:

Grains, grasses and agricultural crops	9 to 10	inches
Deciduous trees	8 to 12	"
Small trees and brush	6 to 8	"
Coniferous trees	4 to 6	"

These quantities of course represent inches depth of water over the watershed.

It is not to be inferred, however, from this list of quantities that there are no extremes in the opposite direction, particularly in small areas.

Virgin forest with deep humus cover has considerable absorbtive capacity, and thus will assist seepage. The measure of this assistance is in proportion to the character of the soils and subsoils, in the degree that they are of a sand or clay nature. Percolation is however relatively small in quantity, and also slow in its action. The above writer states that, "although a great many streams are supplied very largely from the ground water supply in the lean months of stream flow, the total quantity of water absorbed by percolation is relatively small when compared with the loss due to evaporation and transpiration."

It may be noted here that the area of the watershed of the Grand River above Galt is 1,360 square miles, and the mean annual precipitation is 33 inches. Of this but 11.6 inches, or 35 per cent., appears in the Grand River at Galt, so that 21.7 inches, or 65 per cent., is lost due to evaporation, transpiration and deep seepage.

The effects of these three major influences and the amount of the residue appearing as stream flow varies with the annual precipitation, and also its seasonal distribution. When comparing opinions regarding the vexed question of the relation of forest cover to drainage, the amount of precipitation should be kept in view for, as will be appreciated, the residue left for stream flow is less in the case of 25 inches precipitation than that of 35 inches, the physiography being the same in both cases.

Van Ornam states that "it seems evident from an analysis of records that the effect of forest cover in reducing the volume of flood flow and increasing the volume of low water flow exists in extremely varying amounts, being typically considerable in the streams of small watersheds, and relatively small in rivers draining large areas; so slight indeed, because of the various equalizing influences which have been found particularly to occur in great river basins, that they may become imperceptible by being obscured."

McCarthy, Director of Forest Service, U.S. Department of Agriculture, states, that the present trend is to abandon farm land rather than to extend its present acreage by further clearing, due to the inability of production on poor land to compete with that on farms more favourably situated as to soil, topography and market, and also due to the severe erosion and destruction of the steeper fields. The relation of the forest to run-off, he says, "is most closely established through its relation on erosion, since it is through the washing away of the finer soil particles that channels are established for the flow of water. The first place to seek control of a flood is at its source, where every small impediment is most effective in delaying the flood run-off, in support of which contention a large amount of evidence has been accumulated." He quotes a Swiss study which was made of forested and non-forested watersheds of small area, and which found that the crest of the flood was not only delayed but the total run-off per square kilometer was also reduced. He also mentions a study of the "Run-off From Small Agricultural Areas" by Ramser, which states that his enquiries show quite conclusively that, on comparing the run-off from two adjoining 100-acre lots with 14 per cent. and 39 per cent. forest cover respectively, the run-off during moderate showers was about 30 per cent. greater from the former than the later. His result also tends to show that the effect of timbering in reducing run-off is slight in the case of heavy concentrated rains.

Hazen says that "undoubtedly forests affect stream flow in many ways, but there is no evidence that they materially modify major flood flows, and there is no reason to think that clearing of land and putting it under cultivation has materially increased the flood quantities over those that existed in previous centuries."

It should be noted that the great interests of true forest conservation and reforestation are very real economic necessities, and the justification of a scientifically developed forestry policy is not dependent upon the assumption that it has a notably beneficial, effect upon the regimen of rivers. The average influence of forests upon stream flows is usually beneficial, particularly in lessening their excessive fluctuations in volume—although the opposite effect is sometimes produced, as in the case when the melting of snow in spring is delayed by forest cover and overlaps the early spring rain, which, jointly, frequently cause the extreme, but happily infrequent, disastrous floods.

Reforestation, therefore, may be carried out for two remedial purposes as affecting drainage. First, there are tracts of agriculturally unprofitable lands which with advantage may be planted with commercial trees such as pine and hemlock. When planted, particularly on slopes, tree growths of this character form impediments to rapid flood run-off. Secondly, by planting varieties of trees such as elms, poplars, hazels, willows, and others of similar nature, along the water's edge and banks of creeks and headwaters of the tributaries, a mechanical aid is given to retarding the cresting of floods. This effect is well demonstrated on Whiteman's Creek.

As pointed out in a later section of this report, however, such beneficial effects as are practicably obtainable from reforestation would be negligible when compared with storage.

General Chittenden, of the United States Engineer Corps, says that in formulating plans for flood control, engineers would not dare to reduce in any degree the effectiveness of direct measures such as reservoirs or levees by any possible measure of reforestation.

Open Drainage Channels and their Influence on Stream Flow

Although the action of artificial and improved natural drainage channels or ditches on stream flow has been debated in various drainage reports in a manner similar to that of forest cover, it has an advantage over the latter that the influence is more capable of proof.

Forest cover over the Grand River basin probably does not exceed 5 per cent. of the area. While the question of afforesting a greater percentage is largely a matter of an economic constructive policy yet to be determined and quite apart from its influence on drainage, the question of the effect of artificially constructed ditches and improved natural drainage channels on the stream flow, is a very live one, for the policy of constructing these ditches and channels is being pursued actively at the present time.

The discussion on the geology of the basin described in a previous part of the report showed by Plate IV. that there are two somewhat distinctive soil areas. To the east is a sandy loam, known as the Guelph soil area, which is underlain by gravels, and which permits of ready percolation and deep seepage. To the west and north is a clayey loam underlain by gravelly silts high in clay, and known as the London soil area. This London area generally has to be underdrained and frequently open-drained, in order to make it commercially workable. The Townships of Arthur and West Luther in the County of Wellington, East Luther, Amaranth and Melancthon in the County of Dufferin, and parts of Proton in the County of Grey, lie in this belt, and are largely drained by sub-surface drains, open drains and improved natural drainage channels.

This area is shown on Plate VI. The Luther, Amaranth and Garafraxa Marshes are included in this area, which embraces some 360 square miles, contains 150 miles of open ditches of various dimensions, and 62 miles of improved natural drainage channels or streams. This amounts to 0.59 mile of drainage channels per square mile of area, which is very high, and it is doubtful whether it can be exceeded outside an artificially irrigated area. This does not include a large mileage of lateral or feeder drains of small section. In quoting opinions of authorities on drainage, this important fact of the percentage of ditching per square mile must be borne in mind. In the usual cases quoted, the percentage of land drains is comparatively small. On the other hand, the total area of the basin of the Grand River thus drained is about 500 square miles, or equal to 35 per cent. of the watershed area at Galt.

This report does not question the policy of the establishment of the majority of these drains, for unquestionably the profitably workable area has been very largely increased thereby. An excessive amount of low marshy areas, which undoubtedly existed in this territory in its virgin condition or in the early days of settlement, surrounded with close cedar and tamarac growths, reduced the potential growing period considerably. During the early spring and late fall, when the high temperatures of the day caused the evaporation of large masses of these waters, the moisture of which was converted into low-lying fogs by the early night frosts, the surrounding country area was generally affected detrimentally. Extant history of early settlers is replete with records of the miasmic fevers of malarial character against which these pioneers struggled. There is therefore, no question that over a large part of the area under consideration, ditching is the advisable policy.

There are areas, however, that have been drained and have since been abandoned through the course of economic events, and it appears as if still other areas are likely to be drained from which no large agricultural benefits will accrue. Areas of this character have largely been converted into pasture lands for stock raising, but the ditches have been permitted to lapse in that they are now lined with strong herbaceous growth which, to a certain extent, defeats the object for which the ditches were established.

Van Ornam states that ditching reduces the retarding effect of ground storage, but this is largely neutralized and even exceeded by the effect of preventing the saturation of the upper layers, thus permitting rain to penetrate instead of running off the surface. The amount of land so affected is usually small in proportion to the total storage capacity of the soil, so that, all things considered, the modifying effect of drainage averages a comparatively small amount, although sometimes it is locally quite considerable.

Meyers states that both open and tile drains facilitate and hence increase surface run-off, but on the whole have an equalizing tendency. In so far as tile drains intercept water which has already passed beneath the surface and bring it into open channels again, they must inevitably increase the total surface run-off and reduce the seepage flow. During heavy rains or rapid melting snows, the rate of absorption of water by even the best drained heavy clay soils (such as the London clays) is altogether too slow to prevent excessive surface run-off. Open ditching under such circumstances facilitates rapid surface run-off, and increases flood flows.

The question of the drainage of the swamp areas, such as above mentioned, has frequently been discussed. Meyer's opinion regarding this matter is quoted in full, as it is the generally accepted one. "The drainage of swamps and bogs, particularly those having a heavy covering of peat vegetation and the water table near the surface of the ground, usually has an equalizing effect upon are flow of streams. Peat vegetation quickly absorbs large quantities of precipitation, and, as the porous spaces are large, such soil rather readily delivers up its burden of gravity water to the drains below. The temporary storage capacity of such vegetable soils is greatly increased by drainage. Drainage of swamps and bogs with peaty soils thus usually reduces the ordinary flood run-off, increases the total run-off and does not materially decrease seepage flow. In short, the drainage of such soils tends to equalize stream flow."

Hazen more or less supports the above view that drainage takes the water out of the swamp soil and creates a storage space where none had existed. The effect of soil storage is greatest in taking care of run-off from summer or early autumn storms after the soil has been thoroughly dried out, but it may be much less with respect to late winter or early spring flood flows.

While no measurements of the discharge of the drainage ditches in the area of the Grand River basin under review have been made, a series of excellent photographs were taken during the spring of 1929 depicting these drains running full. These appeared to be functioning like ordinary drainage streams, carrying away the flood waters in a rapid manner and depositing them in the main natural drainage channels, some of which are improved, thus expediting the removal of the freshet waters in as efficiently a manner as possible. It is evident to anyone who has examined the drainage system of this area that it must add substantially to the flood discharge of the main stream, both in volume and peak. The ground water plane is generally above the level of the bottom of the ditches during the open months of the year, and these ditches then provide a means of carrying ground water from a lower level than otherwise. This somewhat compensates in low flow for the reduction in ground water level, due to the action of these ditches during the freshet season.

Run-off and Stream Flow Distribution

Run-off is the amount of water which a drainage basin supplies to the open stream, and is the excess of precipitation over evaporation, transpiration and deep seepage. It is the purpose of this section of the report to deal, in a general way, with the hydraulic features of flood discharge, the effect of minimum flow on municipal water supply and sewage disposal, and with the possibilities of power development.

If the spring flood moved out in a fairly uniform manner, and the stream flow during the remaining part of the year was of sufficient dimensions that it could meet all reasonable demands made by the adjoining municipalities, there would be no problem to solve. It is because of the extremes in stream flow experienced on the Grand River from the destructive floods in spring to the low, comparatively valueless, flow in summer that the municipalities have asked for this report, in order that the fluctuations may be corrected in some measure.

The previous sections of the report all lead up to this section, as it is the geological structure, precipitation and temperature distribution, forest cover and artificial drainage systems that decide the characteristics of stream flow.

Until 1914, no continuous attempt was made to obtain stream flow records of the Grand River and its tributaries.

Impressed with the effect of the spring flood of 1912, the Provincial Government, through the Hydro-Electric Power Commission, established several stream flow measurement stations at locations that would give the necessary information regarding flood flows and also the possibilities of power development. These stations, together with the periods that they supplied records, are as follows:

Main Stream at Belwood	1914 to 1923,	inclusive
Main Stream at Conestoga	1914 to 1923	"
Main Stream at Galt	1914 to date	"
Main Stream at Glen Morris	1914 to 1920	"
Main Stream at Brantford	1914 to 1922	"
Main Stream at York	1914 to 1923	"
Irvine River at Salem	1914 to 1916	"
Conestoga River at St. Jacobs	1914 to 1916	"
Speed River at Hespeler	1914 to 1923	"
Galt Creek at Galt	1914 to 1916	"
Nith River at Canning	1914 to 1926	"
Whiteman's Creek at Burford	1914 to 1916	"
Fairchild's Creek at Onondaga	1914 to 1916	"

From 1914 to 1919, the stream flow records of these stations were published in the Hydro-Electric Power Commission's Annual Reports. In 1919 the work of measurements was taken over by the Water Power Branch of the Department of the Interior, and the subsequent records appear in that Department's periodical issues of the St. Lawrence River Drainage.

The station at Galt is still in service, and the comparatively long period over which records have been taken make them more valuable than the shorter period records of the other stations. For this reason, Galt has been selected as a master station, to which all other stations and various hydraulic influences throughout the watershed have been related. The continuous hydrograph of the flow at Galt is shown on Plate VII. The hydrographs of various other parts of the streams of the watershed are similar to this, the fluctuations being generally more marked and extreme towards the headwaters and less so towards Lake Erie.

The table which follows shows the more important characteristics of the run-off from various parts of the watershed as reflected in the stream flow records of the stations noted.

GRAND RIVER DRAINAGE

Summary of Monthly Means and Extremes in Stream Flow in C.F.S.

		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly
Grand River at Belwood (Dr. Area = 280 sq. mi.)	Mean	208	107	1055	952	227	76	90	35	47	53	111	200	264
	Max. Monthly	1137	273	1828	1750	690	185	557	279	391	225	243	607	1828
	Min. Monthly	2	11	483	472	70	7	4	4	3	7	7	7	2
	Max. Daily	5200	1960	8760	7640	3780	930	1910	1042	1350	704	1510	3020	8760
	Min. Daily	0	0	2	77	2	2	2	1	1	2	3	0	0
Conestoga River at St. Jacobs (Dr. Area = 305 sq. mi.)	Mean	542	313	1220	878	112	165	30	125	188	86	261	165	340
	Max. Monthly	1379	579	1491	1497	234	474	50	354	548	229	362	260	1497
	Min. Monthly	56	137	732	429	38	4	4	5	7	6	82	89	4
	Max. Daily	5120	3182	12000	4800	1750	1550	313	1898	4370	990	2220	820	7400
	Min. Daily	6	11	37	82	5	4	4	2	4	4	4	4	2
Speed River at Hespeler (Dr. Area = 250 sq. mi.)	Mean	152	163	607	547	253	186	161	125	134	123	139	142	228
	Max. Monthly	500	336	997	955	508	517	468	367	426	219	203	274	997
	Min. Monthly	59	64	284	301	118	96	55	62	67	47	64	68	47
	Max. Daily	1300	2190	3790	2750	1680	1470	1760	1065	1820	506	455	765	3790
	Min. Daily	37	45	60	141	75	55	27	12	6	18	19	10	6
Grand River at Galt (Dr. Area = 1360 sq. mi.)	Mean	815	821	3850	3385	1229	554	455	307	322	422	909	846	1160
	Max. Monthly	3029	3160	6430	7250	2540	2052	2494	1361	1735	1230	3900	2070	7250
	Min. Monthly	155	158	2167	1100	300	87	99	93	95	182	183	263	87
	Max. Daily	13710	9520	30090	29720	12700	5340	10450	5760	8789	3040	13010	10600	30090
	Min. Daily	131	140	215	530	109	52	49	49	55	73	109	124	49
Nith River (Dr. Area = 430 sq. mi.)	Mean	403	367	1115	808	373	284	228	157	128	160	284	361	389
	Max. Monthly	1239	710	1410	1240	798	683	958	561	290	270	468	755	1410
	Min. Monthly	146	103	875	542	150	108	73	66	86	94	106	170	66
	Max. Daily	3240	2480	4900	4280	2940	1830	3222	1362	985	880	2150	3500	4900
	Min. Daily	100	36	100	157	63	40	36	46	16	50	77	100	16
Grand River at Brantford (Dr. Area = 2000 sq. mi.)	Mean	1471	1755	6430	4280	1685	1142	1023	604	637	691	1103	2435	1938
	Max. Monthly	6337	5628	13895	7820	3898	3387	4820	2357	2214	1508	1645	10010	13895
	Min. Monthly	265	388	3069	2932	765	485	230	197	290	342	573	563	197
	Max. Daily	19860	17330	37360	31820	13840	6440	22625	7214	9800	4160	6260	15180	37360
	Min. Daily	24	154	380	1044	392	170	70	30	70	140	340	250	24

The annual run-off is very uniform, only varying from 0.85 c.f.s. per square mile at Galt to 1.11 c.f.s. per square mile on the Conestoga River.

Monthly maximum run-off varies from 3.3 c.f.s. per square mile on the Nith River to 7.0 c.f.s. per square mile at Brantford.

The monthly minimum run-off varies from practically nothing at Belwood and on the Conestoga River, to 47 c.f.s. and 66 c.f.s. on the Speed and Nith Rivers respectively, and to 197 c.f.s., or 0.1 c.f.s. per square mile, at Brantford.

The daily maximum flow varies from 11.4 c.f.s. per square mile on the Nith to 39.3 c.f.s. per square mile on the Conestoga River.

The daily minimum flow goes down very low, being practically nil at Belwood and on the Conestoga River. Galt has registered as low as 49 c.f.s. and Brantford 30 c.f.s.

The outstanding features to be gathered from the above table is that the watershed characteristics of the Nith and Speed Rivers, which contribute to their low daily and monthly maximum run-off, enable these rivers to have the highest daily and monthly minimum run-off. In the reverse way, the watershed characteristics of the Grand River at Belwood and of the Conestoga River, which contribute to their high daily and monthly maximum run-off, likewise contribute to their experiencing months with practically no stream flow.

In order to show the corresponding characteristics of the spring floods in detail, the hydrographs shown on Plates VIII. and IX. have been prepared. They show the floods of the main stream at Belwood, Conestoga, Galt and Brantford, and also the floods of the tributary streams Irvine, Conestoga, Speed, Nith and Whiteman's. The stations for each year are arranged in the order of their geographical occurrence, the Grand River at Belwood being at the top of the sheet, and the Grand River at Brantford at the bottom. These graphs indicate one of the most important hydraulic facts of the watershed, namely, that the peak of the run-off of the spring freshets is approximately coincident at all stations. There is probably a lag of a number of hours in the run-off from the upper part of the watershed as compared with that from the lower, but as the gauge heights were taken but once each day, and not necessarily at the same time, the peak might be registered as arriving at any two stations either on the same day or a day apart. As the distance from Belwood to Galt is about fifty-six miles, and as the surface velocities have been found to exceed eight miles per hour in some cases, it is quite understandable how the crest of the flood waters at Belwood will pass the outlets of the Irvine, Conestoga and Speed within a few hours before or after the discharge from these of their flood crests, and, augmented by the run-off from the residual area, give a crest at Galt but a few per cent. less in gauge height than would have occurred had all the individual crests been actually coincident at Galt. Appendix "A" gives the salient information of the floods shown graphically on Plates VIII. and IX.

The following is a summary of the data contained in the tables of Appendix "A."

Location	Area of Watershed (Sq. Mi.)	Average of Flood Peaks		Average Discharge During Flood Periods			Flood Ratio
		C.F.S. Total	C.F.S. per Sq. Mi.	C.F.S. Total	C.F.S. per Sq. Mi.	Inches Depth on Watershed	$\frac{\text{Peak}}{\text{Mean}}$
Grand River at							
Belwood	280	3800	13.5	1500	5.2	4.2	2.6
Conestoga	550	7000	12.7	2700	5.0	3.9	2.6
Galt	1360	18000	13.7	5900	4.4	4.3	3.4
Brantford	2000	24000	11.9	8400	4.2	3.3	2.8
Tributaries							
Conestoga	305	6200	20.4	1300	4.2	3.8	4.9
Speed	250	2300	9.1	950	3.8	3.0	2.4
Nith	430	3700	9.2	1500	3.6	2.9	2.5

The term "Inches Depth on Watershed" signifies that if the flood were spread uniformly over the watershed it would have the depth in inches noted.

The factor "Flood Ratio" is a measure of the degree to which a flood crests. It is equal to the twenty-four hour crest of the flood divided by the average amount of the flood. For example: if the flood ratio were unity (1) there would be no crest. Again, if the ratio is 2.6, it means that the crest of the flood is 2.6 times, or 160 per cent. greater than, the average daily flow during the period of the flood.

It will be noted that the Conestoga River crests very much higher in proportion to its watershed area and volume of flood than do any of the other sections of the river. The Grand River at Belwood comes next, in that it both crests high and has the largest volume of flood water for its watershed area. Galt, of course, reflects the crests of both these areas, and Brantford passes a comparatively large amount of water for its crest. The Nith and Speed Rivers are the lowest in point of both crest and average flood, and may be considered well regulated rivers in comparison with the Conestoga and upper reaches of the Grand River.

The data used is taken from the published records already mentioned.

The Conestoga River station was stopped in 1916, and the data for the balance of the period, 1916 to 1923, has had to be arrived at deductively and in the following manner:

The area of the basin at Galt is 1,360 square miles, formed of 550 square miles of the Grand River at Conestoga, 250 square miles of the Speed River, 305 square miles of the Conestoga River, and 155 square miles of residual area, data for which is available for all but the latter two portions. The residual area was given the same flood characteristics as the Speed River, and the remainder of the flow was credited to the Conestoga River, the amount being arrived at after adding the flood crests and the mean flows from the Grand River at Conestoga, the Speed River, and from the residual area, and deducting the same from the crest and mean flow at Galt. With regard to the accuracy of this method of deriving the lacking data of the Conestoga River, it may be said that, as flood waters from the several areas have a higher crest as they pass their individual stations than they have when they jointly pass Galt, the proportion of Galt's flood crest credited to the Conestoga River would have to be increased somewhat, in order to get the precise height of the Conestoga River flood crest passing its own station. It is therefore evident that the flood cersts of the Conestoga River as they are plotted, which are higher in proportion to its watershed area than are the other tributary floods, are nevertheless conservative estimates. The average flow of the various floods of the Conestoga, derived in a similar manner, are more probably near the correct values.

As the only station operating from 1924 to date is Galt, the problem presented itself of knowing what occurred at the other sections of the watershed during these years. If temperature, snow and precipitation factors are reasonably uniform over a given territory, flood crests at all stations within that territory or within a reasonable distance of it should bear a reasonably close relation to one another. This is borne out by Plate XIII., which gives the relation of maximum peak discharge at Galt to that at Belwood, Conestoga and Brantford, and to the tributary streams Conestoga and Nith. The various smooth lines drawn through the points on which the graphs are based are established sufficiently close to warrant the flood crests being derived for Belwood, Brantford and the Conestoga and Nith Rivers for the years 1924 to date.

For ready comparison of the relative discharges, Plate XI. has been prepared, which gives, in the form of bargraphs, the flood crests and the average flood flows of the several stations under consideration. The derived flood crests for the years 1924 to date are shown on the said plate by broken lines.

The stream flow records analysed and summarized as above show the important part that geology, or physiography, has in determining the various flood characteristics. The University of Illinois recently carried out investigations into the run-off from small watersheds in the State of Illinois. The conclusions arrived at with respect to flood discharge from small areas were that, while the size of the watershed is an important factor, topography, geology, temperature and moisture content of the soil are in many instances the controlling factors in determining the rate of flood discharge. Stream flow records of the Grand River confirm this.

The large volume of the Conestoga River floods and the exceedingly high crests are due to the comparatively impervious clay soils and sub-soils of its watershed and canyon-like valleys which readily shed the water; its high snowfall of 90 inches, a large proportion of which is probably carried through until the break-up in early spring; the low average winter temperature of 21 degrees; and the high gradient of its main stream of 13 feet per mile coming from a rise in altitude of about 520 feet.

The volume of the flood at Belwood, and also probably at Fergus, if one is to judge by historical and press records, is, as already mentioned, the highest for its watershed area. This is due to its general high altitude of over 1,500 feet above sea level, to its being located in the London clay belt, to its snowfall of at least 90 inches, and to its low winter temperature of 20 degrees or less. The section of the river from Fergus to Keldon has a solid rock bed and banks, and a river reach of this character, with its gradient of 11 feet per mile, is an important contributary factor in giving the floods relatively high crests.

The flood crests per square mile of the Grand River just above the outlet of the Conestoga River are lower than at Belwood, because the intervening tributary area is of the Guelph gravels, has a winter temperature of 21 degrees and snowfall of some 65 inches. The wide area in the river bottom between Elora and the outlet of the Conestoga tends to lessen considerably the flood crest.

The Nith winds and twists its way around morainal hills and through principally the Guelph gravels for a distance of over 70 miles. Its river course is about 80 per cent. longer than that of the Conestoga for but a 40 per cent. larger watershed. The resultant comparative low gradient of 7 feet per mile, together with the many wide flats and marshy areas, prevents the floods cresting in the manner of the Conestoga and the Grand River above Galt. Its winter temperature is about 23 degrees, or 2 degrees higher than the aforementioned areas, and its snowfall is only 60 inches, all of which reduces the volume of the floods and also its crest.

The Speed River flows entirely from the previous Guelph gravel areas, which counteracts the effect of its gradient of 10 feet per mile, resulting from a difference in altitude of 240 feet. Its winter temperature is 22 degrees, but this is offset by a comparatively low snowfall of 60 inches. These compensating conditions, together with the many marshy areas along its course and throughout its watershed, make both the volume and crest of its floods low like those of the Nith.

In order to emphasize the influence of geology or topography on flood crests, the following comparison is interesting:

	Nith River (Sq. Miles)	Grand at Belwood (Sq. Miles)	Conestoga River (Sq. Miles)
Topographic Area	430	280	305
Area in Proportion to Flood Crest	430	630	950

The percentage proportions of the average flood flows at Galt, furnished by the areas tributary to that point, as distinguished from their geographic areas, are as follows:

	Grand at Belwood	Conestoga River	Speed River	Remainder
Geographical Area of Watershed	280 sq. mi.	305 sq. mi.	250 sq. mi.	525 sq. mi.
Percentage	20.5	22.5	18.5	38.5
Percentage of Flood Crest at Galt	24.4	36.8	16.4	22.4

Although the areas of the Grand River at Belwood and the Conestoga River form 43 per cent. of the watershed at Galt, they contribute 61 per cent. of the average flood crest there. This relation becomes more marked the higher the flood crest is at Galt, and will be referred to later when the matter of remedial measures is discussed.

During the period of record—1914 to 1931—the major floods occurred either in March or April. High flows occurred, however, during other periods of the year. The largest of these latter are given below:

Grand River at Galt—Watershed Area 1,360 Square Miles

Year	Date of Peak	Flood Peaks		Average Discharge During Flood Periods			Flood Radio
		C.F.S. Total	C.F.S. per Sq. Mi.	C.F.S. Total	C.F.S. per Sq. Mi.	Inches Depth on Watershed	Peak / Mean
1915	Sept. 13	8789	6.46	3174	2.33	0.78	2.77
1916	Jan. 28	13710	10.10	5378	3.96	1.92	2.55
1917	July 2	10450	7.65	2896	2.13	0.85	5.00
1917	July 10	8314	6.11	3727	2.74	1.33	2.23
1918	Dec. 15	10600	7.90	3177	2.34	1.39	3.38
1920	Dec. 5	6480	4.76	2852	2.10	0.70	2.27
1921	Dec. 18	10260	7.54	3359	2.47	0.64	3.05
1925	Nov. 14	7250	5.33	3134	2.30	1.54	2.32
1926	Aug. 24	5760	4.24	2811	2.07	0.54	2.05
1926	Nov. 27	13010	9.57	4309	3.17	2.24	3.02

It will be noted that the maximum of these, amounts to 13,700 c.f.s., which occurred in January, 1916. Six occurred during the period November to January, and were in large part, due to the melting of snow. Of the remaining four, two occurred in July, one in August and one in September.

Stream Flow, Water Supply and Sewage Disposal

This report does not purpose to deal at any length with the relation of stream flow to water supply and sewage disposal. These questions are largely matters for the individual municipalities to consider; but, to the degree that the general health of one community bears on neighbouring communities, and to the extent that the disposal of its domestic and trade wastes affects the health of others, it becomes a matter for the district, as a whole, to deal with.

Water Supply

The history of the growth of many of the cities of this continent indicate that dependence for a common water supply was first placed upon the local stream. With the desire for increased convenience, individual and municipal wells were established. As these became limited in their ability to meet the demands made on them, the growing municipalities either went to the local stream or to some neighbouring stream. This type of progress in usage is reflected in the Grand River municipalities.

Paris takes its municipal water supply from deep seepage or springs issuing from a gravelly-clay bank overlooking the Nith River. This supply is augmented at times by pumping raw water from the Nith, which, by an ingenous use of the local topography, is allowed to filter through the gravelly-clay overburden until it is trapped by the natural deep seepage channels, and thus strengthens the flow of the above springs.

Fergus, for a number of years, has procured its water supply from deep wells immediately adjoining the river. The principal source of the replenishment of these wells is river water, which percolates through the fossiliferous limestone beds of the Guelph formation. Intermittent beds of this formation have a high percentage of pores, and, within reasonable limits, provide means for a good well supply. To safeguard wells of this character against contamination, the adjoining river must not be polluted.

Galt depends entirely on deep wells sunk adjoining the river. These wells have all the advantages and disadvantages of wells of this character. The supply per well is generous when first sunk, but, due to silting up caused by the breaking down of the internal structure of the drainage channels in the rock, and the drawing in of silt from the river, its output frequently becomes restricted. The freer the supply from the river the greater is the danger of contamination from the same source. On the other hand, the restriction by silting is frequently compensated for by an increased degree of filtration.

Guelph obtains its water supply from springs issuing from a gravelly bank adjoining the Eramosa River, a branch of the Speed River. The supply of these springs comes from the general ground water of the Guelph sub-surface formation, which is high in gravels. It apparently is also influenced by local upstream ponds of the Eramosa River. Before this seepage or spring water was trapped by the municipal collecting basins, it ran down a gravelly valley into the above river. In order to preserve as much as possible of this seepage from loss, the municipality has reforested the valley. While the tree growth is dense, tending to make the transpiration loss large, it would appear, from an examination of the soil during an extremely warm day in the summer of 1931, that the water plane was near the surface in the bottom of the valley, and that the general effect of reforestation was beneficial.

Brantford discarded its entire dependence on well supply quite a number of years ago. It later pumped raw river water into gravel-filled trenches, from which the filtered water was drawn by sub-surface drains to a filtered water basin, and from thence into the city mains. The water demand later increased to an extent that required the building of a modern filtration and pumping plant, which is equipped in a manner that will safeguard the city against any moderately contaminated or turbid river water.

Kitchener and Waterloo depend entirely on well water. These wells are sunk through the glacial overburden of 175 feet to the surface of the rock shield, and in some few cases into the rock for a considerable distance. The water-bearing sandy gravels are about 40 feet in depth, topped generally by 120 feet of gravelly clays, and are frequently underlain by 15 feet of hardpan. When the well is sunk into the Camillus shale, high in magnesium and calcium carbonates, the pumped water is exceedingly hard, and dependence for a domestic supply is placed on rain water cisterns.

As the above municipalities grow in population, they will eventually graduate from well supply, as has Brantford, and put their dependance on a river supply of highly potable water procured from the Grand River. The Grand River from Fergus to Galt lends itself readily to a gravity water supply, and in the near future, municipalities along that section may unite themselves into a Water District with the end in view of obtaining a common and pure water supply, neither too alkaline nor acidulous, from the Grand River from a source far enough upstream to be free from contamination.

Deep Seepage and Well Supply

Another feature of drainage on which the geological structure has a large bearing is the question of shallow and deep well supply. It was mentioned in a previous part of the report that of the 35 inches of total precipitation that falls on the 1,360 square miles of watershed above Galt but 11.6 inches or 35 per cent. appears later as stream flow. The difference is accounted for by evaporation, transpiration and deep seepage.

The term "deep seepage" is used to distinguish the seepage which sinks down through the deep overburden of glacial deposits and partly trickles through the rock strata to still lower levels, from the seepage which finds its way into artificial sub-surface drains, or is arrested by the clay beds and thence drains into the open streams.

There is in all probability a greater amount of deep seepage in the Guelph gravel areas than in the London clay areas. Of the deep seepage in the former, a large percentage probably does not appear on the surface until it seeps directly into Lake Erie, for while the general slope of the surface is 8 feet per mile towards Lake Erie, the slope of the underlying rock exceeds that figure. The London clay is interbedded with heavy clays, and of the comparatively little seepage that occurs in this relatively impervious soil a small amount may find its way to the underlying rock surface and thence in a general southerly direction. The greater percentage undoubtedly finds its way to the open stream. Artesian wells are found more frequently in the London clay belt, due likely to subsurface pools of water between the beds of impervious clays. As the rock is nearer the surface generally in the Guelph soil area, it apparently is not difficult to get water anywhere. The log of one of the Kitchener wells indicates water as being found below 121 feet of gravelly clays and for a depth of 42 feet in gravels and sands with little clay. This water bearing bed is underlain with 18 feet of clay and 6 feet hardpan.

Water taken from the top of a clay bed, filtered by the overlying beds of a more open gravelly structure, is always palatable. To get any large quantity, it apparently has been found necessary at Kitchener and Waterloo to sink the wells there, to the surface of the rock. The overburden of clay and gravels is largely derived from limestone and forms an alkaline filter. The surface of the underlying rock is covered with an indurated clay formed largely of the washings of the overburden and high in hard water qualities. Analysis of the Guelph dolomite on the surface of the rock shield over 50 per cent. of the watershed is as follows:

Calcium carbonate (Ca CO_3)	54.2%
Magnesium carbonate (Mg CO_3)	45.2%
Ferous carbonate (Fe CO_3)	0.2%
Sulphate of Lime	0.3%
Alumina	trace
Insoluble Matter	0.1%

The Municipalities of Fergus and Galt get their water from deep wells sunk in the Guelph formation adjoining the river, which formation has a texture varying from "porous-saccaroidal" to "compact and fine grained." The interbedded formation and the fossiliferous pores of the rock immediately adjoining the river are saturated to a greater degree with river water than are the more distant beds. They are also in a better position of having this supply replenished than rock formations not so favourably located. This continued movement of river water through the rock to the wells at velocities very much in excess of natural velocities leaches out of the rock large quantities of the magnesium and calcium carbonates which give to the waters derived from this source their characteristically alkaline or "hard" qualities.

Wells of this character very slowly, but ultimately experience restricted outputs. The extra work placed on the local drainage channels in the rock by the insertion of wells establishes gradients in all directions leading to the well. This tends to set up a silting action, which increases the cone of depression necessary on all deep wells to secure the supply. In time this further increases the silting and it is necessary in order to remedy conditions to frequently "blow out" the well or deepen it. The upper surface of the rock forming the river bed probably also becomes plugged up due to the silt and finer material in the river bed gradually being drawn into the crevices or openings of the channels leading to the well. After the well has reached a certain age in terms of millions of gallons, its flow therefore diminishes, and it is a question of deciding whether to continue to deepen or to sink a new well. One geologist stated to the writer that he doubted whether a well could be sunk beyond 100 feet in the rock, particularly in the Camillus shale area, without encountering saline or brackish waters. This feature would form a limit to the depth which a well could be sunk in the rock.

Sewage Disposal

The relation of the stream flow of the Grand River to sewage disposal is of more immediate importance than is the Grand River as a source of municipal water supply.

The Grand River is the final means of disposal of all effluent from sewage and trade wastes of the municipalities that line the valley, irrespective of the degree of refinement the sewage and wastes are put to before the effluent reaches the stream.

Fergus is still at the individual septic tank stage, the effluent from which seeps into the river a safe distance below the source of the municipal water supply.

Until the summer of 1931, Waterloo treated its sewage in municipal septic tanks and filter beds, and disposed of the frequently highly charged effluent into a small stream which enters the Grand River at Bridgeport. Since then a modern disposal plant has been built close to the river and a little downstream from Bridgeport.

The sewage from Kitchener is taken care of by two disposal plants adjoining the Grand River, one of which has just been put into service.

At the Waterloo and Kitchener plants, over 90 per cent. of the sewage, after preliminary screening, passes through sedimentation basins, and on being aerated, passes into the river.

At Preston, Galt, Paris and Brantford, the sewage passes directly into the river after passing rapidly through septic tanks and receiving some treatment by chlorination.

Under the present system of natural regulation, the stream flow between Bridgeport and Preston not infrequently goes down to some such figure as 25 cubic feet per second for a period of a month at a time. There are also occasional periods extending probably to a week, during the winter season, when the low stream flow is practically frozen up. Galt and Brantford are a trifle better off, as the flow at both places has never dropped below 50 cubic feet per second for a day, or an average for the month of 90 cubic feet per second at the former and 200 cubic feet per second at the latter. The degree of pollution and visible suspended matter for long distances below the points of discharge of the various effluents is considerable under such conditions of low flow.

As these communities and others along the Grand River grow in population, the amount of sewage to be disposed of will correspondingly grow. The industrial waste will probably increase even more rapidly, accompanied by special problems of disposal incidental to these wastes. Extreme low flows of the above dimensions will be entirely incapable of taking care of the sewage effluent under such conditions, unless measures are taken to purify the effluent to a greater degree than is now done.

It will require a considerably greater study than has been given by this report to determine the proper amount of stream flow between, say, Bridgeport and Galt that will dilute the sewage and trade waste effluent from a population somewhat larger than is the present population, so that there will be a pratical absence of visible suspended particles and odors in the river a few miles downstream from the point of discharge, and so that the downstream municipality may take its municipal water supply for manufacturing purposes, at least, from the river with but a reasonable amount of purification treatment.

It may be assumed, however, that the population of Kitchener, Waterloo and the immediate vicinity will reach 100,000, and that of Preston and Galt, 50,000, in the next twenty-five years. This means that the former section will be discharging some 15 millions of gallons, and the latter section some 7½ millions of gallons of sewage effluent per day into the Grand River. To insure the necessary degree of dilution of this efflulent to protect downstream municipalities will probably require at least 300 cubic feet per second in the Grand River opposite Kitchener and Waterloo, and 350 cubic feet per Second at Galt.

The Grand River at Paris will contain the diluted and partly aerated effluent from the upstream municipalities on the Grand and Nith Rivers. Paris probably will not add an amount of raw or partly treated sewage to this, beyond the ability of the stream between Paris and Brantford, including the inflow of Whiteman's Creek, to sufficiently purify the same.

To fully protect the water supply and take care of the sewage effluent disposal for Brantford's population of twenty-five years hence, will probably require a stream flow of 500 cubic feet per second. There may be occasions then, on the recurrence of poor water years, such as 1930 and 1931, when the stream flow entering Brantford may be considerably poluted and tax the capacity of the filtration plant at the "incoming" end and the sewage disposal plant at the "outgoing" end.

The stream flow at Caledonia will probably always be in a reasonable state of purification, for the long river reach of thirty miles of slow-moving water between it and Brantford will provide the necessary complete dilution and oxygen content for that purpose.

In communities with large populations, the sewage disposal problem is often accentuated by the difficulty of disposing in a satisfactory manner of trade wastes, and municipalities on the Grand River may be faced with the choice of increasing the minimum flow beyond the figures quoted above, or compelling the industries to purify their effluent to a greater degree.

By the use of the mass curves of the mean monthly stream flow, it is found that 40,000 acre feet of storage would have provided a flow of 350 cubic feet per second at Galt and 500 cubic feet per second at Brantford for all years of records other than the following, for which the flow is given:

	1914-15	1916-17	1919-20	1922-23	1925	1930
Galt	330	340	310	300	290	300
Brantford	440	—	—	—	—	—

Stream Flow and Power Development

The comparatively large drop in the Grand River of 1,128 feet in a distance of 180 miles would lead one to surmise, at first glance, that it was highly adaptable to power development. Such is not the case however—the opportunities for power development are very few, and for several reasons. Apart from the drop of 38.5 feet at Elora Falls, there are no natural concentrations of head. The unusually steep gradients have been put to use in some cases by placing collecting dams across the river, and running canals downstream from the same for considerable distances.

The only rock appearing on the river bed extends from Elora to approximately the northerly boundary of the Luther townships, and from Galt to Glen Morris. Low dams of stable character are found in these sections.

At all other places and where the contours along the banks of the river lend themselves to canal building, the dams have had to be built on a river bed of glacial drift and boulders. To avoid scour and excessive leakage, and in order to be of reasonable economical design, dams built on this nature of river bed seldom exceed 15 feet in height. As the slope is 6.7 feet per mile from Elora to Brantford, 7.1 feet per mile on the Nith, 10 feet per mile on the Speed and 13 feet per mile on the Conestoga, the possible heads for one mile of canal cannot generally exceed 22 feet, 25 feet and 28 feet respectively. Some such heads as these are the usual ones that have been adopted in the existing developments on the river.

The comparatively wide sweeping valley through which the river runs, together with the roads paralleling the river and the many bridges, also preclude the possibilities of building high and sufficiently cheap dams for the purpose of power development only.

Not only are possibilities of economic concentration of head lacking on the Grand River, but the absence of lakes as natural storage basins result in an extremely variable flow.

The mean monthly stream flow goes down to 20 c.f.s at Fergus, 90 c.f.s at Galt and 200 c.f.s. at Brantford, and for some days at a time sinks down still further. These figures of flow are equivalent to 20 horsepower at Fergus, 70 horsepower at Galt and 100 horsepower at Brantford, per mile of river.

It has already been pointed out in the part of this report dealing with stream flow and sewage disposal that 350 c.f.s. would be required in the future at Galt and 500 c.f.s at Brantford, and that with the provision of 40,000 acre feet of storage above Galt, mean monthly stream flows of these dimensions would have been available in all years of records other than the following, for which the flow is given:

	1914-15	1916-17	1919-20	1922-23	1925	1930
Galt	330	340	310	300	290	300
Brantford	440	—	—	—	—	—

This degree of regulation is equivalent to about 150 horsepower per mile at Fergus, 280 horsepower per mile at Galt, and 300 horsepower per mile at Brantford. These figures are for 24-hour power.

Schemes of major power development on the Grand River have been suggested. One of these proposed to dam the river above Preston and by aqueduct, tunnel and canal, to carry the diverted water to an artificial headpond to be created on the escarpment overlooking Dundas. Pipe lines were then to carry the water from the pond to a power house to be erected on the Burlington Canal at the foot of the escarpment. This scheme depended for its regulation on a large storage to be established between West Montrose and Elora. It was proposed to generate an average of 15,000 horsepower.

The second scheme proposed to dam the river near Glen Morris, and, again by tunnel and canal, to covey the flood waters not otherwise stored to the Beverley Swamp, where a large artificial lake was to be constructed. By means of a pressure tunnel, it was proposed to convey the water to a power house to be established at the foot of the escarpment in the Dundas Valley, and from there to approximately the level of Lake Ontario by a long tailrace. The average power to be developed here by this scheme was about 28,000 horspower.

While schemes of the above ambitious nature may be tenable in certain parts of Canada, they are not so in regard to the Grand River and in this portion of Ontario, for the following reasons:

The proposed power developments involve the diversion of Grand River waters from Lake Erie, to which they are naturally tributary, to Lake Ontario. Such diversion would be subject to international ratification in view of its bearing on the Niagara River flow.

The suggested diversion of the surplus waters of the Grand river to Lake Ontario would be developed under a head of approximately 350 feet. This same flow, however, is at present made use of at Niagara under a head of some 300 feet. The net gain in power therefore would be merely that represented by the extra 50 feet of head available in the suggested diversion and not by 350 feet of head.

Estimates of the cost of the above schemes of development indicate that, regardless of the present use of the water at Niagara, power from these plants would be considerably more expensive than that from other existing sources.

Apart from other considerations, heavy costs would be involved in compensating riparian owners downstream from the point of diversion of the Grand River waters.

In the light of the above facts it is evident that major power schemes such as these are impracticable.

Floods and Flood Control

The variation from the heavy flood flows of the spring months to the extreme low flows during the remaining months of the year are the cause of considerable damage, and much concern to the citizens living in the basin of the Grand River. Much effort has been spent in the past on works to improve the conditions at various points on the watershed. In some areas ditches and channel improvements have been undertaken to expedite the run-off of the excess water during the spring, resulting in an increase in the maximum flow of the main river, which in turn has been met by the urban centres erecting barriers, such as dykes and walls, to confine the river to its low water channel.

The effect of the former of these classes of work has been not only to increase the rate of the flood flow, but also to reduce the flows during the remainder of the year, and the correction of these two features of the river flow is the prime reason for the investigation under review in this report.

In the spring of 1929, one of the highest floods during the period of record occurred. On this occasion, at its highest stage, the water was considerably below the level of the top of the levees at Paris, was dangerously near the top of part of the levee system at Brantford, and washed over a part of the top of the riverwall system at Galt. The records of the flow during this period, which are available, indicate that a maximum rate of 30,000 cubic feet per second was attained at Galt. The profiles of the water surface at these three points are shown on Plates Nos. XV., XVI. and XVII. On Plates Nos. VIII. and IX. the hydrographs of the spring floods from the years 1914 to 1931 are shown. Since the records for this entire period are complete only for the Galt Section, the studies in connection with flood prevention have been centred on this point.

Analysis of Floods of Record

The floods at Galt and upstream therefrom have already been discussed in considerable detail in the section of the report dealing with Stream Flow Distribution. It was shown by the table appearing on page 16 that the averages of the March and April peaks in cubic feet per second per square mile for several points on the watershed were as follows:

Grand River at	Average of Flood Peak in C.F.S. per Square Mile
Belwood	13.5
Conestoga	12.7
Galt	13.7
Brantford	11.9
Tributaries	
Conestoga	20.4
Speed	9.1
Nith	9.2

The highest flood at Galt during the remaining ten months, viz, May to February, inclusive, was 13,700 c.f.s., or 10.1 c.f.s. per square mile.

The two highest floods at Galt for the period of record were those of March 1919, and April 1929, when the run-off reached maxima of 30,100 c.f.s. and 29,700 c.f.s. respectively.

	Discharge	
Year	Max. C.F.S.	Max. C.F.S. per Sp. Mi.
1919	30,100	22.1
1929	29,700	21.8

The various parts of the watershed contributed the following amounts to the 1919 flood:

	Discharge	
Grand River	Max. C.F.S.	Max. C.F.S. per Sq. Mi.
Belwood	5,300	19.0
Conestoga	10,400	19.0
Galt	30,100	22.1
Brantford	37.360	18.7
Tributaries		
Conestoga	12,000	39.4
Speed	3,800	15.2

The outstanding feature of the above is the large percentage of the flood at Galt and Brantford contributed by the sections of the watershed above the confluence of the Grand River with its tributary the Conestoga River, and particularly the large amount contributed by the Conestoga.

It is evident therefore that storage works for the reduction of flood peaks should be located in the area above Galt.

Probability of Floods Exceeding Any Given Amount

In the study of flood control the question of the frequency of the occurrence of floods of various magnitudes naturally arises. It is not sufficient to define the maximum flood as the greatest which has existed during the period of records. Combinations of temperature gradients, depth of snow and rainfall during the period of records may have been such as to give floods of considerably less dimensions than would have occurred or are likely to occur were the combinations more favourable.

There are recognized methods of determining this probability of occurrence which are made use of by actuaries, engineers and others. The upper part of Plate XII., with the accompanying table, has been prepared in order to obtain a measure of what to anticipate in the way of floods at Belwood, Galt and Brantford on the Grand River, and at points on the Conestoga River.

The flood crest of April 1929 at Galt was 30,000 c.f.s., which topped the protecting walls and caused considerable damage and loss. Plate XII. indicates that floods of this size and over will probably occur 6.5 times in one hundred years of 36,000 c.f.s. or over probably twice in each hundred years, and of 38,000 c.f.s. or over probably once in the same period. An examination of Plate XVII. and the gauge relations shown thereon will enable one to appreciate what floods of these dimensions really mean.

The writer was informed that this flood of April, 1929, came very near to topping parts of the levee system at Brantford. Plate XV. gives the layout of the river in the vicinity of Brantford, together with the profile of the above flood and its relation to the levee system. There were indications that, due to ice jam, the reach above the municipal dam rose two feet higher for a short time than the level indicated on Plate XV. During the winter of 1930-1931, this city carried out extensive additions to its levees, and raised the low portions of the then existing levees by some 3 feet. The flood crest on that occasion was 38,000 c.f.s. Floods of this size and over will probably occur five times in one hundred years.

The floods at Brantford will probably reach 41,000 c.f.s. twice in each one hundred years, and 44,000 c.f.s. once in the same period. The gauge discharge graph shown on Plate XV. shows the relation of floods of these dimensions to the levees in that neighbourhood. It should be borne in mind that, due to a repetition of the ice conditions present in the flood of 1929, these gauge heights might be exceeded by 2 feet.

The flood crest of April, 1929, passed through Paris with little inconvenience apparently. Certain weak portions of the levees there have since been strengthened. No attempt has been made to establish the relations between the 1929 flood and the height of the levee system here, but from partial enquiries it would appear that the levees have the same freeboard protection as have the levees in Brantford.

Some old gauge heights taken above the municipal dam at Brantford have been converted approximately into terms of flow at Brantford and Galt. It would appear from these that the size of the 2 per cent. floods above referred to was approximately reached in May 1894, when the precipitation was about 260 per cent. greater than usual, and floods of the one per cent. size appear to have been reached in April, 1912, and March, 1899, when the precipitation was very much greater than normal, coinciding probably with high night temperatures and melting snow.

The probability that the flood of 1929 will be exceeded at some future date cannot be too strongly presented.

Remedial Measures

It will be appreciated that much has been done by authorities on the Grand River in devising ways and means of ridding the watershed of its spring flood water and protecting riparian property. Among the protective measures generally applicable are improvements of the main channel by straightening and otherwise increasing its capacity and construction of levees to confine the flood flows to the low water channel. The construction of storage reservoirs, wherein a portion of the flood flow will be retained, is an additional measure that is available.

In the section of the report dealing with stream flow, water supply and sewerage, reference has been made to storage works, and has been shown that 40,000 acre feet of storage, properly disposed, will enable satisfactory summer flows to be maintained. The efficacy of this storage in improving conditions during freshets is to be considered.

Studies were made of the operation of the proposed storage works during the progress of floods, and rules of operation devised and applied to floods of record. The results of these studies are summarized on Plate XIII., on which, in the upper diagram, it is shown that a storage of 40,000 acre feet correctly administered would reduce to 18,000 c.f.s. the crests of all the recorded floods at Galt. It also shows that, provided the 2 per cent. floods have crests of the quantity shown, this amount of storage will also reduce such crests to 18,000 c.f.s. If, on the other hand, the volume of the 2 per cent. floods assume a slope parallel to that of 1917, the crest of 36,000 c.f.s. would be reduced to 22,000 c.f.s. Considering also the extreme flood of once in 1,000 years, the storage of 40,000 acre feet will probably reduce its crest to 25,000 c.f.s., and if it also assumes the form of the 1917 flood, will reduce it to a flood of about 30,000 c.f.s., or that of 1929. It is not considered economical to provide storage to fully safeguard against all damage from the infrequent but extreme flood, but the damage in that case would be materially reduced by the use of 40,000 acre feet of storage.

At Brantford a storage of 40,000 acre feet will curb the 2 per cent. flood estimated at 41,000 c.f.s. to levels well below that of 1929, and the one per cent. flood of 44,000 c.f.s. to levels approximately 1 foot below that of 1929. The flood of once in 1,000 years may be dangerously near the crest of the levees in some places, but probably will not expose it to a greater hazard than did the flood of 1929 without the assistance of the suggested storage.

A storage of 20,000 acre feet, plus the use of 10,000 acre feet at the Luther Marsh, will reduce the various floods above mentioned by the following amounts. At Galt the 1929 flood will be reduced to 20,000 c.f.s., or a reduction of 4 feet, and the 2 per cent. flood to 26,000 c.f.s., or a reduction of 2.5 feet. The flood of once in 100 years will be reduced to that of 1929, and the extreme flood of once in 1,000 years will be well above the top of the river walls.

At Brantford, the 1929 flood will be reduced to 27,000 c.f.s., or a reduction of 2 feet, and the 2 per cent. flood to 32,000 c.f.s., or a reduction of 1 foot. The flood of once in 100 years will be reduced to a little below that of 1929, but the extreme flood of once in 1,000 years will be about 1.5 feet higher than the 1929 flood.

Levees

There is approximately a margin of three feet between the water levels of the 1929 flood at Brantford and the general height of the crest of the levees there. The clearance amounts to 5 feet at the point of the river giving the relation between flow and elevation shown on Plate XV. A margin of freeboard of from 3 to 5 feet is not too much, considering the rather slim cross-section of the levees generally at Brantford, in fact, a margin of 5 feet may be considered the standard practice in earth dams and similar works.

The principal and fundamental weakness of levees such as are found at Galt and Paris is that floods of the dimensions of 1929 may be passed safely, but a crest of 6 inches higher may wash out a large section of the levee, with the result that when protection by levees are most required it is not available for that purpose. The point to be emphasized in regard to levees is that to be proper safeguards they have to be of generous dimension, and carefully maintained. Apart from failure due to overtopping, levees have been known to fail from various other reasons. If the river is of sufficient height during a part of the winter that the levee becomes water-logged and freezes, it is in danger of collapse in spring when it thaws out. Heavy rains, which generally precede and accompany floods of extreme dimensions, have been known to erode minor channels across the crest of levees reducing the margin of safety at these points.

The burrowing of animals is also a not infrequent source of failure. It has also been recommended that a margin of more than 5 feet should be provided for levees in a river exposed to ice scour, or in lieu of increased margin that the upper 8 feet should be ripraped or otherwise lined.

The survey of the levees at Brantford and Paris showed that the greatest flood they could pass—but not with any great assurance that it would always pass safely, was that of 1929. This report has demonstrated that a flood of this size will be exceeded five times in the 100 years.

Reforestation

Reforestation and conservation of existing forest cover have not been included in the practical ways and means of remedying the existing lack of regulation in the stream flow of the Grand River, for the reasons that the degree to which reforestation can be carried out would have a very minor effect when compared with storage, the cost of a major reforestation scheme is prohibitive if charged to stream regulation, and the time it would take for forest growth to reach the point of usefulness prevents it being considered of immediate importance.

Forest cover would have to be extended over some 50 per cent. of the watershed area above Galt, or 700 square miles, of which but approximately 10 per cent., or 70 square miles, is already forested, in order to be considered, in any degree, as a means of stream flow regulation.

It is not to be inferred from this that "the great interests of forest conservation and reforestation are not very real economic necessities, and that the justification of a scientifically developed forest policy is dependent upon the assumption that it has a notably beneficial effect upon the regimen of rivers."

The planting of a certain amount of tree and brush growth particularly along the banks of the Conestoga River and its tributaries is recommended for the joint purpose of fish protection and as a mechanical means of retarding flood discharge.

As mentioned in an earlier section of the report the planting of pine, hemlock and other commercial trees, particularly on slopes, provides impediments to the run-off from melting snows and heavy rains. The extent to which such a policy could be economically applied would undoubtedly be insufficient to provide a measure of control comparable to the more direct method of regulating dams. But reforestation should be encouraged as generally beneficial to the watershed and as possessing commercial possibilities.

Fishing Possibilities

An examination of certain authentic historical records indicates that the streams tributary to the Grand River were well stocked with fish when the pioneers first peopled the valleys. Records of angling associations demonstrate that numbers of the small tributary streams provided good supplies of bass and trout some twenty years ago. Some of these still produce a small intermittent supply of small-mouthed black bass and brook trout.

As already pointed out in a previous part of this report, the effect of the original well-timbered conditions of those valleys was to lessen the frequency of the smaller floods and space at wider intervals the larger and more damaging floods. The general effect also was to insure a larger supply of low temperature ground water in streams during the summer than is at present available. All this tended to give fish a chance to exist, and probably some were strong enough to survive the occasional heavy freshets and thus enabled the streams to be well stocked for a considerable number of years before being depleted by the larger floods.

Under the existing regimen, with its annual repetition of fish-destroying floods and extreme low water in the summer, it is futile to think at present of stocking these streams in an attempt to provide and encourage fishing. As a part of the general scheme of development, however, it is possible to so remodel many reaches of these tributary streams that the fishing possibilities will be greatly increased. Any steps taken in this direction will also contribute toward cutting down the peaks of the freshets and maintaining an increased summer stream flow.

It is well at this point to set forth the conditions of a stream which will insure an annual and sufficient supply of fish to meet, in a fair measure, the demands of an ever-growing mass of people to whom this sport appeals. While much has been done in raising fish in hatcheries, comparatively little has been done on the physical conditions of the streams themselves as relating to fish life.

Authorities agree that comparatively few remedies are necessary to encourage the culture of fish for sporting purposes. The most important of these are: a reasonable supply of water throughout the summer and fall; never too acid; temperatures never exceeding 72 degrees Fahrenheit for brook trout and 78 degrees for brown trout; a reasonable number of large areas of water with velocities not exceeding 200 feet a minute; good hiding places protected by shade trees at all times of the year; security from freshets; abundance of fish food; and, finally, good spawning ground and rearing places.

It is difficult to supply these conditions under the present regimen of the Grand River and its tributaries for the most destructive influence on fish life and fish food are the extreme floods and low flows which exist in the valley streams at present. The existing low flows during the summer and fall make it difficult for the younger and smaller fish fry to survive. There is a lack of food, the older fish prey on the fry, and in the shallow waters the fry get reduced in great numbers by hawks and other types of bird life.

It is believed that streams such as the Conestoga can be changed somewhat in regimen with respect to floods and stream flow by major structures created for that special purpose. These same structures, together with a number of smaller dams provided for the conservation of fish, will also lend themselves to increasing the fishing possibilities of such a stream to a measure of what it was formerly.

Geological formation exerts marked influence on the character of streams and the ability of streams to hold and support fish life. These streams along the Grand River valleys have limestone rock bases, and the overburden, largely of glacial origin, is also of limestone origin. This limestone character of the terrain gives the water the necessary alkaline content desirable for fish. Many prolific sources of fish food will grow only in non-acid waters. The hydraulic gradients of most of the tributary streams, which at present are productive of extremes in floods and midsummer low flows, by reasonable expenditures can be made into pools in some places, and rapids and gravel runs in others. Numbers of the smaller of the streams are spring fed, and, while more acid than the larger streams, have the necessary low temperatures and lend themselves to bass culture at small cost.

Parts of the smaller streams could at once be taken over and, by means of small retarding dams, form fishing reaches. Among these is a branch of the Grand River coming from the north-east through the Township of Amaranth and joining the parent stream at Waldemar. Another is the northerly tributary of the Irvine. The principal one, of course, on which general attention should be concentrated for the purpose of fish culture to a reasonable degree, is the Conestoga with its tributaries north of Wallenstein. On this river, the larger retarding dams referred to in this report could provide the most desirable types of pools, the water reaches being from 3 to 5 miles long. The upper reaches would have depths running from 3 to 5 feet, and widths varying from 200 to 250 feet. These shallow parts could be planted with rapid-growing willows and hazels, thus providing, in a few years, the most desirable form of shade for the fish.

One or more of the smaller streams feeding the Conestoga where floods are now of a minimum character, and could be still further reduced by retarding dams and which are fed by springs during the summer, can be selected and converted into a supply pool, carrying the parent fish over from year to year.

With experience on the Conestoga, gained over a few years, the most desirable reaches could be selected and, under proper supervision, fishing possibilities could be developed.

The following suggestions are made in connection with the development of the fishing possibilities:

(a) Creation of areas of water to the greatest possible extent, making sure that these areas can be reasonably maintained in low water periods. This can be done by the use of suitable dams, ponds, or otherwise controlled streams.

(b) Selection of desirable reaches on the smaller spring-fed streams for the culture of game fish. In this way the natural spawning possibilities of the stream will provide all the small fish, and the largest can grow to maturity. Natural fish, if properly guarded, will always show a much better yield than hatchery fish in the stream.

(c) Increase in water vegetation in every way possible, both by planting and making places suitable for its growth. Compare the wooded stretches of Whiteman's Creek to the denuded condition of the Amaranth Creek.

It must be realized that every stream has only so much fish-growing capacity, and if this is overtaxed the stock and average size are reduced. The limitations of the Grand River and of its tributaries would have to be determined by experience both on trial streams and from results obtained in other localities, and an investigation by competent authorities on this work should be made before embarking on any large programme of fish culture or development.

The geological and topographical features of the upper waters of the tributary streams of the Grand River, when compared with improved streams elsewhere, indicate the possibility of providing a desirable source of game fishing. Certain reaches of these tributaries might be taken over and converted into fishing preserves such as are already found in various parts of the Dominion.

Means For Providing Regulation

Storage

It has been suggested that if 40,000 acre feet of storage be constructed upstream from Galt, it will enable the stream to be regulated in the necessary manner to provide the following:

Municipal water supply.

Sewage and trade waste disposal.

Water for existing power developments.

Reduction of most of flood crests to low levels and the infrequent, exceptionally high floods, to within the confines of existing levees and river walls.

The Grand River and its tributaries do not offer any areas that can be converted readily into storage basins. The various valleys all have the same general uniformity of cross-section and, with some exceptions, provide practically the same volume per mile-foot.

The flats extending from Blair for some miles upstream are occupied by a railway and the modern sewage disposal plant at Kitchener. The large flats, or river bottom lands, midway between West Montrose and Elora, as shown on Plate XX., offer the largest individual area for storage purposes on the river. Unfortunately, there is no rock available at, or apparently near, the surface for the foundaion of an economically high dam, so that these flats cannot be used for the purpose of supplying, at reasonable costs, the full amount of storage which that part of the watershed warrants. Investigations have been limited to a dam 32 feet in height, providing 10,000 acre feet of storage. a geophysical survey and test pits might disclose a more suitable dam site than the one now selected, which would enable a higher dam, and increased storage to be used.

Rock appears on the river bed from Elora to the northerly boundary of the Luther Townships, or over a distance of 30 miles. A combination of a reasonably broad section of the river valley, a few bridge complications, and the above rock makes an area extending from 5 miles above Belwood to Waldemar possible as a storage site. This area, together with the sections of a dam capable of holding a head of water of 52 feet, is shown on Plate XIX., and which would have a capacity of 10,000 acre feet.

In the Luther Swamp there is an area of some 3,000 acres, which is very flat and which can be utilized for a further storage basin. This area is shown on Plate XVIII. The watershed area of the swamp is insufficient to make the best use of the possible storage. It may be possible to divert some of the neighbouring streams, draining in an opposite direction, into the swamp, but the survey of the territory did not extend to this phase. It is doubtful whether this tributary watershed can supply more than 10,000 acre feet of storage during the spring of a normal year.

An earth dam eight feet high at the location shown on the above plate will accommodate this 10,000 acre feet and form an artificial lake approximately 3,100 acres in area.

The surface of this area is covered with burned peat, which will hold water and give it up by underdrainage, in the same manner as does any other humus. The under part of the area is formed of a highly colloidal peat, which holds permanently 90 per cent., or more, of moisture. That is to say, it will give up by underdrainage only 10 per cent. of its volume in water. As the drains and creeks running through the bog are some 5 feet deep, the moisture holding content available for drainage is equivalent to 6 inches of water on the area drained.

The valley of the Conestoga does not offer any particularly advantageous sites for the development of storage. The lower part of the valley is too developed to permit of its use for storage purposes. The upper part of the valley is generally uniform, and the storage opportunity per mile is very much the same throughout this portion of the river. Had a profile been run along the river, and sufficient contours taken, certain definite areas may have been selected as being relatively superior for storage purposes. As the river above Hollen had already been surveyed in 1914, as shown on Plate XIX., estimates have been taken out as indicative of the cost of creating storage at several places on the Conestoga.

A knowledge of the distance of rock below the surface of the river bed in the Conestoga River would have assisted substantially in obtaining a better solution to deriving the most economical manner of developing that river, but the limitations of the survey precluded the obtaining of that information. From a study of the geology of the region and available records, it is believed that the rock is at no place on the river less than 20 feet, or more than 50 feet, below the surface of the river. For the typical storage basin proposed to be located at Hollen a dam under a head of 50 feet has been considered. Estimates of the cost of this storage have been prepared as outlined in the summary.

The percentage of the flood crests of the probable floods at Galt, supplied by the watershed of the Grand River above Conestoga and the watershed of the Conestoga River, is about the same, although the watershed areas are 550 square miles and 350 square miles, respectively.

The 40,000 acre feet required for the purposes of regulation therefore may be divided in the following manner: Waldemar and Elora storages on the Grand River, each 10,000 acre feet; and Hollen and one other on the Conestoga River, 10,000 acre feet each.

Plates XIX., XX. and XXI. show the areas flooded by the proposed dams at Waldemar, Elora and Hollen.

As a means of providing a cheap margin of storage over the 40,000 acre feet provided for as above, it is recommended that a pond be established in the Luther Swamp, which will provide an additional 10,000 acre feet. If this area is to be retained as a park area and bird sanctuary, it may not be possible to use much or any part of this water for purposes of augmenting the low summer and winter flows. The artificial lake can, however, be drawn down about the middle of March each year to assist in reducing the spring flood run-off. Sufficient lake area can be left so that, together with the small natural pond in the south-east corner of the marsh, water fowl will still be able to remain in the park area through the interval between the partial emptying of the lake and its refilling.

In lieu of controlling the Conestoga River by two dams of the dimensions shown on Plate XXI., it may be possible to replace them by a series of low head timber dams, each providing some 2,000 acre feet of storage. The perimeter of the several areas thus flooded, and also the banks of the reaches of the river between these areas can be planted with a suitable growth of willows, hazels, etc., which will act as a means of retarding the cresting of the floods. Smaller dams may also be placed at selected sites on the tributaries of the Conestoga. Remedial work of this character has met with success in parts of Switzerland and in California. Before work of this alternative character would be proceeded with, it would be necessary that considerable investigation and experiment be carried out to determine the suitability of low head dams of this character for purposes of flood control and low stream flow regulation.

The above dams on the Grand River and the Conestoga River will also have the effect of increasing the ground storage, not only in their immediate vicinity but for considerable distances in a lateral direction. During periods of comparatively wet years, when stream flow high enough to require but little implementing, the water level in the several storages will be high enough so that the neighbouring ground, and particularly the gravel beds, will absorb large quantities of water. This ground water will return to increase the flow during periods of low water.

Summary

The report opens by outlining the need of remedial measures for the purpose of regulating the present highly fluctuating flow of the Grand River. The extreme low flows in summer and winter affect the disposal of municipal sewage and trade wastes and the future prospects of using the Grand River as a source of water supply. The spring floods do a great deal of damage to urban and rural areas bordering the river, and to bridges and all low-lying property.

Contributary factors to these extremes are then dealt with in considerable detail. These are: the geology and topography of the watershed, the precipitation and temperature distribution, both annual and seasonal, and the deforestation and open drainage ditches. The portions of the watershed consisting of the basins of the Conestoga and of the Grand above Elora contribute to the extremes of low water and flashy floods to an extent out of proportion to their areas. Among the factors producing the above condition may be cited the steep gradients; the impervious clay composition of the soils and sub-soils; the compacted boulder river bed in the former, and the thirty miles of solid rock river bed in the latter; the extensive ditching and the absence of natural reservoirs.

The municipal water supply and sewage disposal systems are dealt with. The present frequent low flows are inadequate for purposes of diluting the present sewage effluent.

It is estimated that it would require ultimately a minimum flow of 350 c.f.s. at Galt, and 500 c.f.s. at Brantford, to provide the necessary dilution of the sewage effluent for a population about three times larger than at present, and to insure that water extracted from the river a reasonable distance below the point of sewage disposal could be used, for manufacturing purposes at least, without any further purification or other treatment. Such dilution would also be necessary to permit its use for municipal purposes with the same degree of treatment as the municipal supply of water at Brantford from the same source now receives.

It is also demonstrated that 350 c.f.s. at Galt and 500 c.f.s. at Brantford would so augment the existing low stream flow as to insure present power developments their necessary water supply.

It is shown that 40,000 acre feet of storage, properly administered, will insure in practically all years the above minimum flows. This amount of storage will reduce the crests of the majority of floods to comparatively low levels and confine the infrequent, but higher, floods to the levels of the present river walls at Galt and levees at Brantford, unless these flood crests are abnormally high, due to bad ice jams. The forming of jams would it is believed be somewhat prevented by the proposed regulating basins.

Twenty-thousand acre feet of storage, located at storage sites at Elora and Waldemar, and a corresponding amount at two sites on the Conestoga River, would be necessary for the purpose of supplying the above 40,000 acre feet of storage. In addition to this, and as a margin of safety, a further 10,000 acre feet of storage can be established as an artificial lake in the Luther Swamp.

The report points out that forest cover, to the degree that it can be proceeded with economically on the Grand River, can have only a minor effect on the regimen of the river. It further states, however, that this is not to be taken in any way reflecting on the economic advisability of the reforesting of certain areas in the upper parts of the Grand River watershed now poorly suited for agricultural purposes. The reforesting of such areas would have a beneficial effect on the flow conditions of the Grand River and would undoubtedly add to the scenic beauty of the district. Reforesting could we believe be carried on in sections adjacent to the roads and on the slopes to the stream with similar scenic advantage. The popularity of a road system is dependent not only on the quality of the highway itself, but to a large measure on the scenic attractiveness of the district. In connection with the roadways of the Grand River valley, there is attached as an appendix an interesting historical outline of the development of the highways in this area.

It is suggested that the section of the Conestoga River containing the regulating reservoirs be taken over as a Provincial Park and administered for that purpose.

The creation of the additional storage in the Luther Marsh would permit of the establishment of a bird sanctuary of some 20,000 acres.

The four storage reservoirs plus the work necessary to provide 10,000 acre feet of storage in the Luther Marsh are estimated to cost approximately $2,955,000 with annual charges of approximately $284,000 made up as follows:

Location	Acre Feet	Capital Cost	Annual Charges
Luther	10,000	$ 50,000	$ 4,500
Waldemar	10,000	623,000	60,600
Elora	10,000	805,000	76,900
Hollen	10,000	686,000	66,200
Conestoga No. 2	10,000	791,000	75,600
	50,000	$2,955,000	$283,800

It must be understood these estimates are based on preliminary data only, and are subject to revision on securing the information necessary to prepare a final estimate.

As already pointed out, the storage estimated as required is based on increasing the low flows to an amount sufficient to meet the water and sewage disposal requirements of a population of approximatedy three times that of the district at present. The damage from floods would it is reasonably expected be much greater with this increased population with the attendant increased development of the area. Consideration should be given to the progressive development of the remedial measures above outlined to meet the immediate needs for the improvement of low water conditions, and to keep the expenditures commensurate with the probable damage from floods at the present stage of growth of the community.

Any works undertaken on such a programme would ensure permanent benefits to the extent completed, and would offer an opportunity of judging the value of the results as compared with the cost.

As an indication of the results that might be expected from a progressive scheme along the lines suggested, the following table has been prepared. This shows the effect on flood flows and low water conditions of various amounts of storage, together with the capital and annual cost of the same.

The reductions in flood flows are for a flood equivalent to that of 1929 and the annual costs include sinking fund charges based on a forty-year period.

Stage of Development	Location	Acre Ft.	Reduction in 1929 Flood Galt C.F.S.	Galt Ft.	Brantford C.F.S.	Brantford Ft.	Regulated Low Flow Galt	Regulated Low Flow Brantford	Capital Cost	Annual Cost
1	Luther Waldemar	10,000 10,000	5,000	2.5	7,500	1.3	200	320	$ 673,000	$ 65,100
2	Luther Waldemar Hollen	10,000 10,000 10,000	10,000	4.0	10,500	2.0	220	350	1,359,000	131,300
3	Luther Waldemar Hollen Conestoga No. 2	10,000 10,000 10,000 10,000	12,500	5.0	14,500	2.9	290	430	2,150,000	206,900
4	Luther Waldemar Hollen Conestoga No. 2 Elora	10,000 10,000 10,000 10,000 10,000	15,000	5.6	18,500	3.6	350	500	2,955,000	283,800

While Stage No. 1 has been shown as giving a reduction in flood of 2.5 feet at Galt and 1.3 feet at Brantford, the determination of this could only be approximately arrived at and, to a similar degree, its effect on water supply and sewage disposal over that of the present regimen will be hardly marked.

Stage No. 2 would permit of the increasing of the low flows to approximately 220 c.f.s. at Galt and 350 c.f.s. at Brantford. These minimum flows are considered sufficient to meet the needs of water supply and sewage disposal of at least the present population of the district, and probably provide for a reasonable increase. The reduction in flood flows with these partial works only would of course be less than for the whole scheme, but would secure a considerable benefit. As a measure of the reduction in flood flow to be expected under these conditions, it is estimated that a flood of the magnitude of the 1929 flood would be reduced to 21,000 c.f.s. at Galt, or equivalent to a drop in elevation of four feet at that place, which would leave a comfortable margin of freeboard on the river walls. At Brantford such a flood could be reduced to 27,000 c.f.s., or equivalent to a drop of two feet in elevation there, or safely below the present levee system. For the greater floods to be expected at less frequent intervals the margin of safety with the present protective works would be open to serious question.

Stages Nos. 3 and 4 will meet the needs of a population approximately twice and three times as large, respectively, as those of the present population.

Stage No. 2 will also assure the present installed water-wheel capacity along the Grand River, from Fergus to its mouth, of approximately its designed output, as far as can be determined at present.

The benefit of the storage in the Luther Marsh, while not susceptible of accurate calculation, will, in our opinion, give results in keeping with any of the other stages in proportion to the cost, and in view of the relatively small expenditure involved, we believe it should be included with the first stage constructed.

The annual cost of the proposed works could, we believe, be properly assessed against the various interests benefitted: the townships for protection of roads and bridges; the municipalities for sewage and water supply betterments, also for flood protection; the power owners for improved flow conditions; and the various townships with large drainage systems as compensation for the amount which such drainage has contributed to the problem.

It is strongly recommended that immediate steps be taken for the securing of further data in regard to the stream flow on the Grand River and its tributaries. Such information is essential for the accurate determination of the benefits to be derived from any remedial works undertaken, and will be necessary for the proper study of the problem whether such works be undertaken at the present time or at some future date.

(Signed) J. MACKINTOSH.

GRAND RIVER DRAINAGE
DRAINAGE BASIN
HYDRO-ELECTRIC POWER COMMISSION
OF ONTARIO
HYDRAULIC DEPARTMENT
4th DECEMBER 1931 FILE-46-e-21

PLATE I.

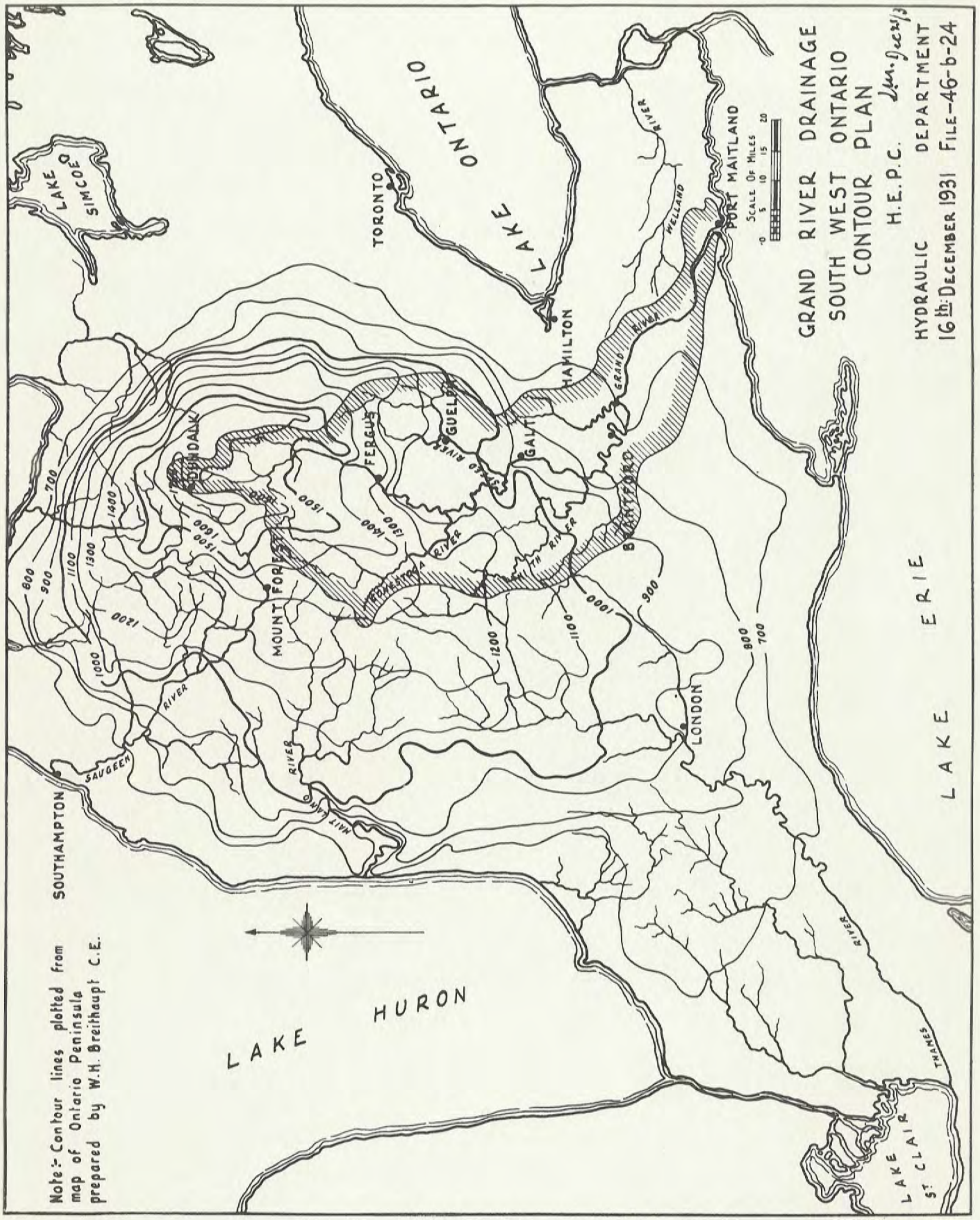

GRAND RIVER DRAINAGE
SOUTH WEST ONTARIO
CONTOUR PLAN
H.E.P.C.
HYDRAULIC DEPARTMENT
16th December 1931 File-46-6-24
Scale of Miles
0 5 10 15 20
Note:- Contour lines plotted from map of Ontario Peninsula prepared by W.H. Breithaupt C.E.
LAKE SIMCOE
TORONTO
LAKE ONTARIO
HAMILTON
PORT MAITLAND
GRAND RIVER
WELLAND
GUELPH
FERGUS
DUNDALK
GALT
BRANTFORD
MOUNT FOREST
LONDON
SOUTHAMPTON
SAUGEEN RIVER
MAITLAND RIVER
CONESTOGA RIVER
NITH RIVER
SPEED RIVER
LAKE HURON
LAKE ERIE
LAKE ST CLAIR
THAMES RIVER
700
800
900
1000
1100
1200
1300
1400
1500
1600

PLATE II.

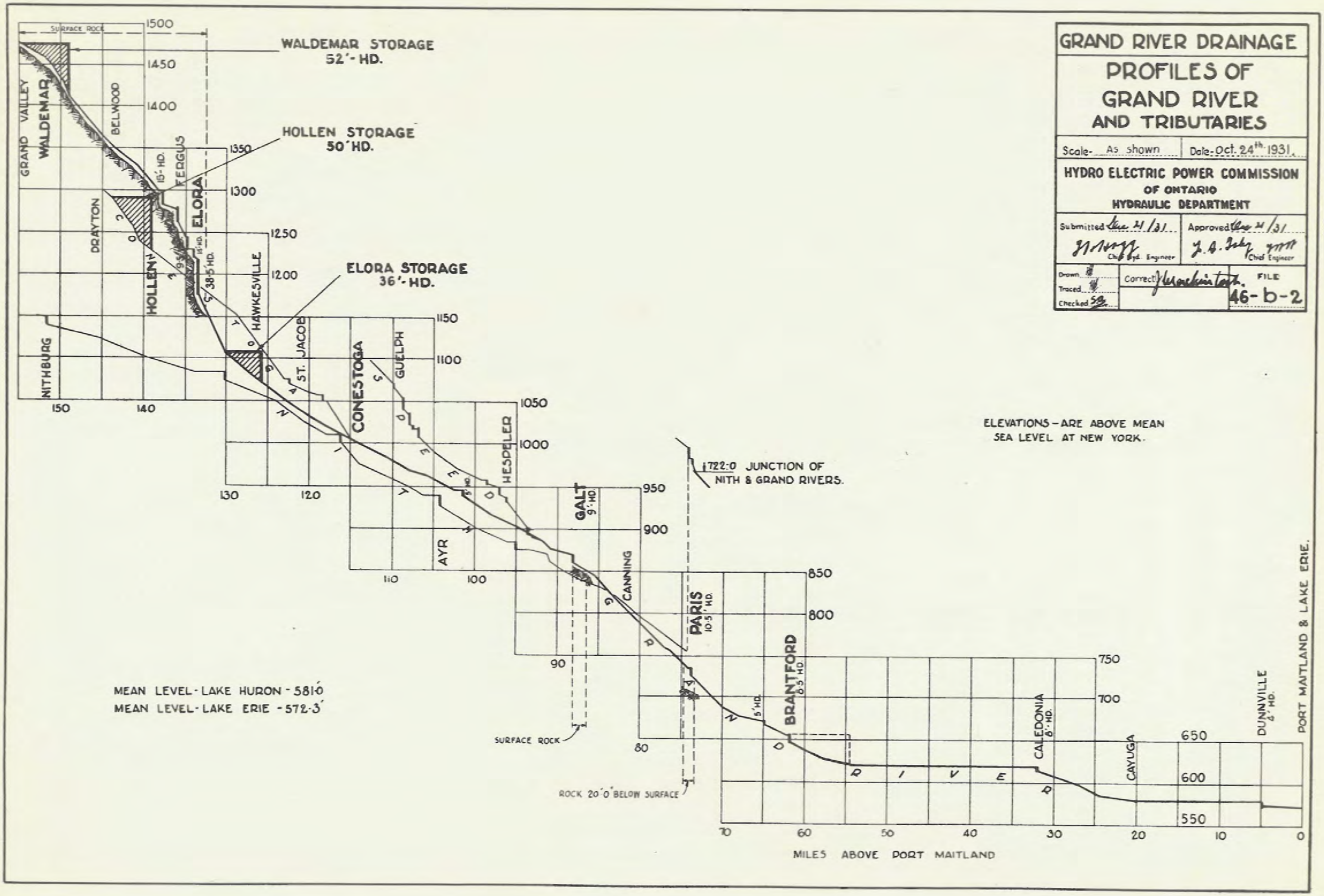

GRAND RIVER DRAINAGE
PROFILES OF GRAND RIVER AND TRIBUTARIES
Scale- As shown
Date- Oct. 24th 1931.
HYDRO ELECTRIC POWER COMMISSION OF ONTARIO
HYDRAULIC DEPARTMENT
Submitted Dec 21/31
Chief Hyd. Engineer
Approved Dec 21/31
Chief Engineer
Drawn
Traced
Checked
Correct
FILE
46-b-2
WALDEMAR STORAGE 52'-HD.
HOLLEN STORAGE 50'HD.
ELORA STORAGE 36'-HD.
SURFACE ROCK
GRAND VALLEY
WALDEMAR
BELWOOD
FERGUS
15'-HD.
ELORA
DRAYTON
HOLLEN
15'-HD.
38.5' HD.
HAWKESVILLE
NITHBURG
ST. JACOB
CONESTOGA
GUELPH
HESPELER
AYR
GALT
9'-HD.
CANNING
PARIS
10.5' HD.
BRANTFORD
6.5' HD.
5' HD.
CALEDONIA
6'-HD.
CAYUGA
DUNNVILLE
4'-HD.
PORT MAITLAND & LAKE ERIE.
CONESTOGO
SPEED
NITH
GRAND RIVER
1722.0 JUNCTION OF NITH & GRAND RIVERS.
ELEVATIONS - ARE ABOVE MEAN SEA LEVEL AT NEW YORK.
MEAN LEVEL - LAKE HURON - 581.0
MEAN LEVEL - LAKE ERIE - 572.3'
SURFACE ROCK
ROCK 20'0" BELOW SURFACE
1500
1450
1400
1350
1300
1250
1200
1150
1100
1050
1000
950
900
850
800
750
700
650
600
550
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
MILES ABOVE PORT MAITLAND

PLATE III.

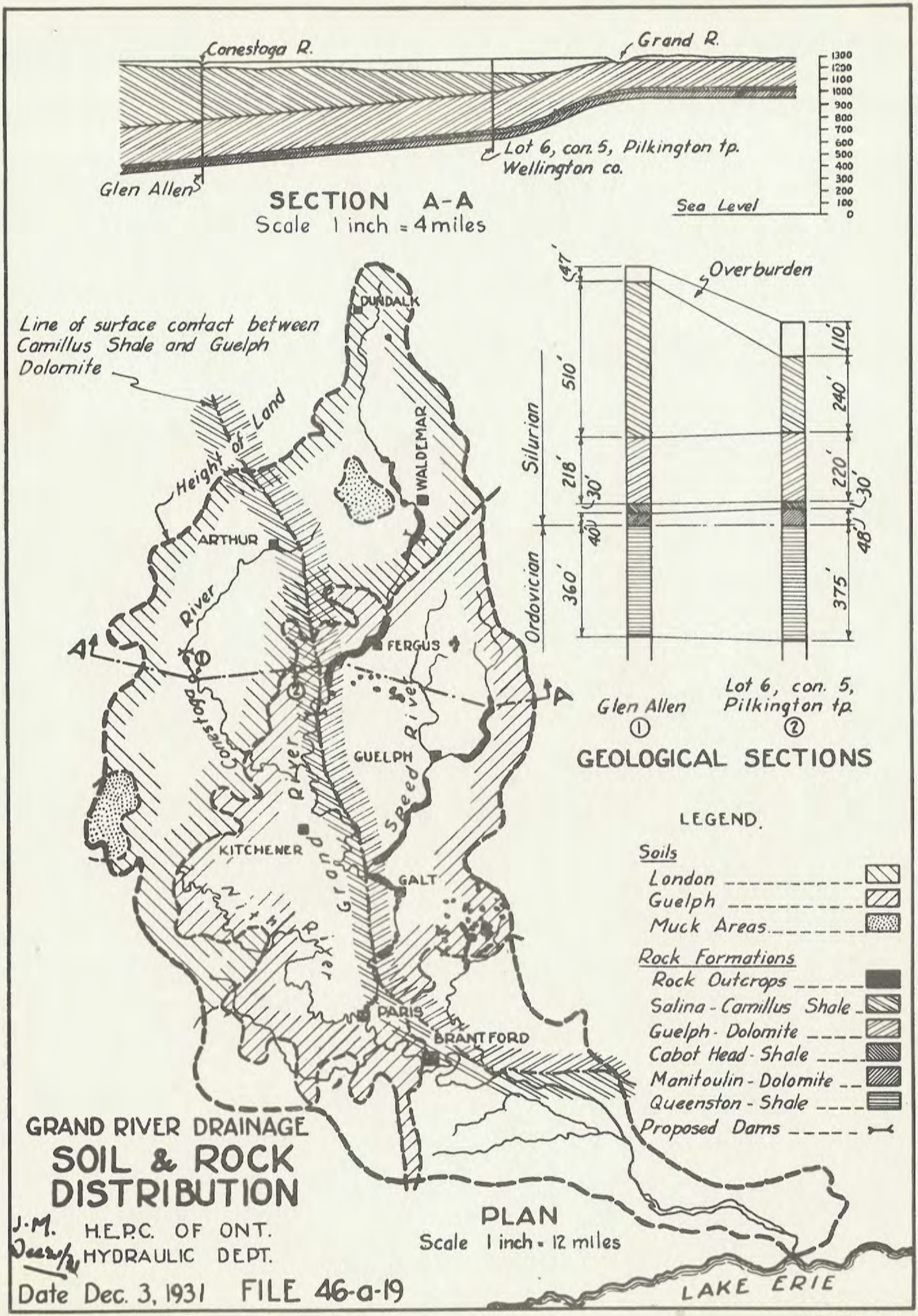
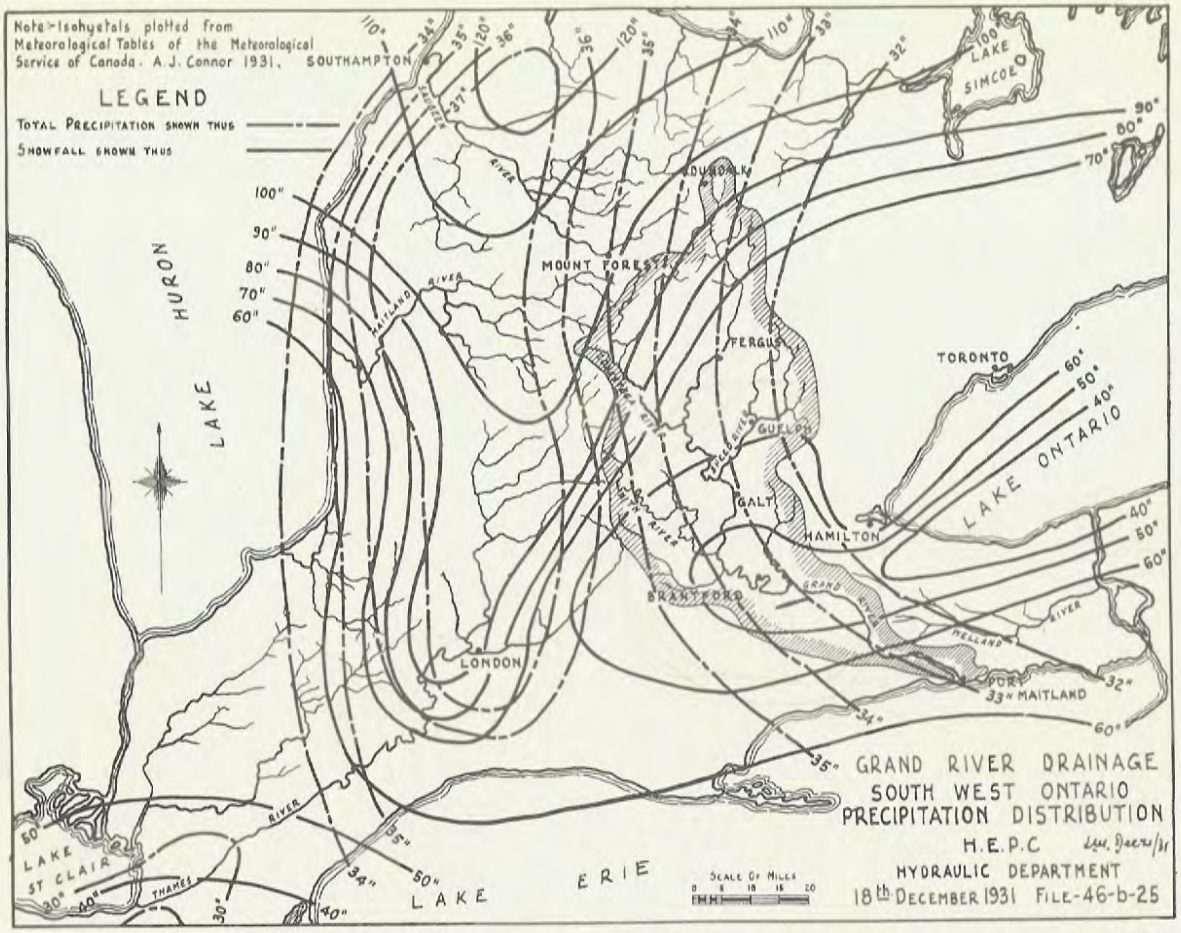
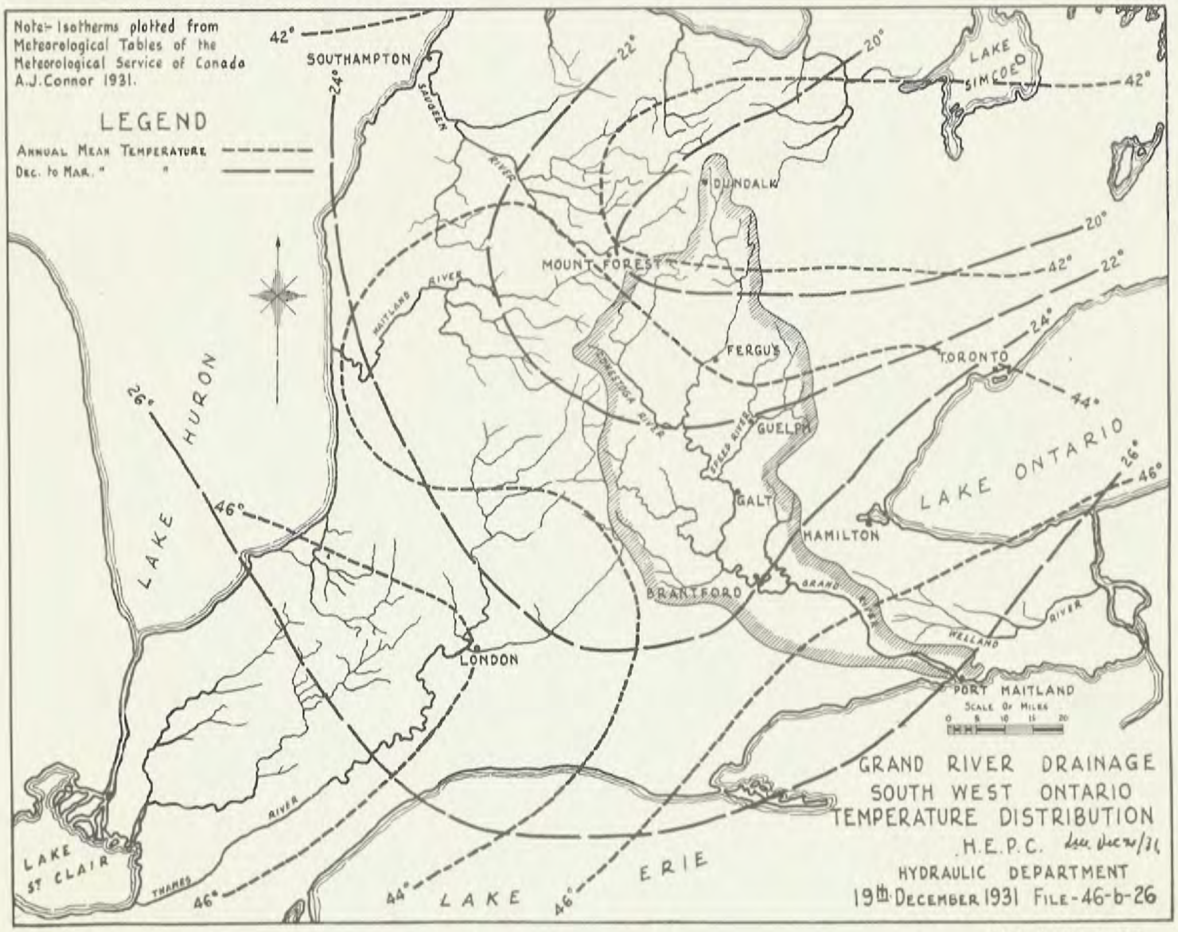

Conestoga R.
Grand R.
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Lot 6, con. 5, Pilkington tp.
Wellington co.
Glen Allen
SECTION A-A
Scale 1 inch = 4 miles
Sea Level
Overburden
47'
510'
218'
30'
40'
360'
110'
240'
220'
30'
48'
375'
Silurian
Ordovician
Glen Allen
①
Lot 6, con. 5,
Pilkington tp.
②
GEOLOGICAL SECTIONS
Line of surface contact between
Camillus Shale and Guelph
Dolomite
Height of Land
DUNDALK
WALDEMAR
ARTHUR
FERGUS
GUELPH
KITCHENER
GALT
PARIS
BRANTFORD
River
Conestoga
Grand River
Speed River
Nith R.
A
A
①
②
LEGEND.
Soils
London ▨
Guelph ▨
Muck Areas ▒
Rock Formations
Rock Outcrops ■
Salina - Camillus Shale ▨
Guelph - Dolomite ▨
Cabot Head - Shale ▨
Manitoulin - Dolomite ▨
Queenston - Shale ▤
Proposed Dams ⊢
GRAND RIVER DRAINAGE
SOIL & ROCK
DISTRIBUTION
J.M.
Dec 2/31
H.E.P.C. OF ONT.
HYDRAULIC DEPT.
Date Dec. 3, 1931 FILE 46-a-19
PLAN
Scale 1 inch = 12 miles
LAKE ERIE

PLATE IV.


Note:- Isohyetals plotted from Meteorological Tables of the Meteorological Service of Canada. A. J. Connor 1931.

GRAND RIVER DRAINAGE
SOUTH WEST ONTARIO
PRECIPITATION DISTRIBUTION
H.E.P.C
HYDRAULIC DEPARTMENT
18th December 1931 File-46-b-25


Note:- Isotherms plotted from Meteorological Tables of the Meteorological Service of Canada A. J. Connor 1931.

GRAND RIVER DRAINAGE
SOUTH WEST ONTARIO
TEMPERATURE DISTRIBUTION
H.E.P.C.
HYDRAULIC DEPARTMENT
19th December 1931 File-46-b-26

PLATE V.

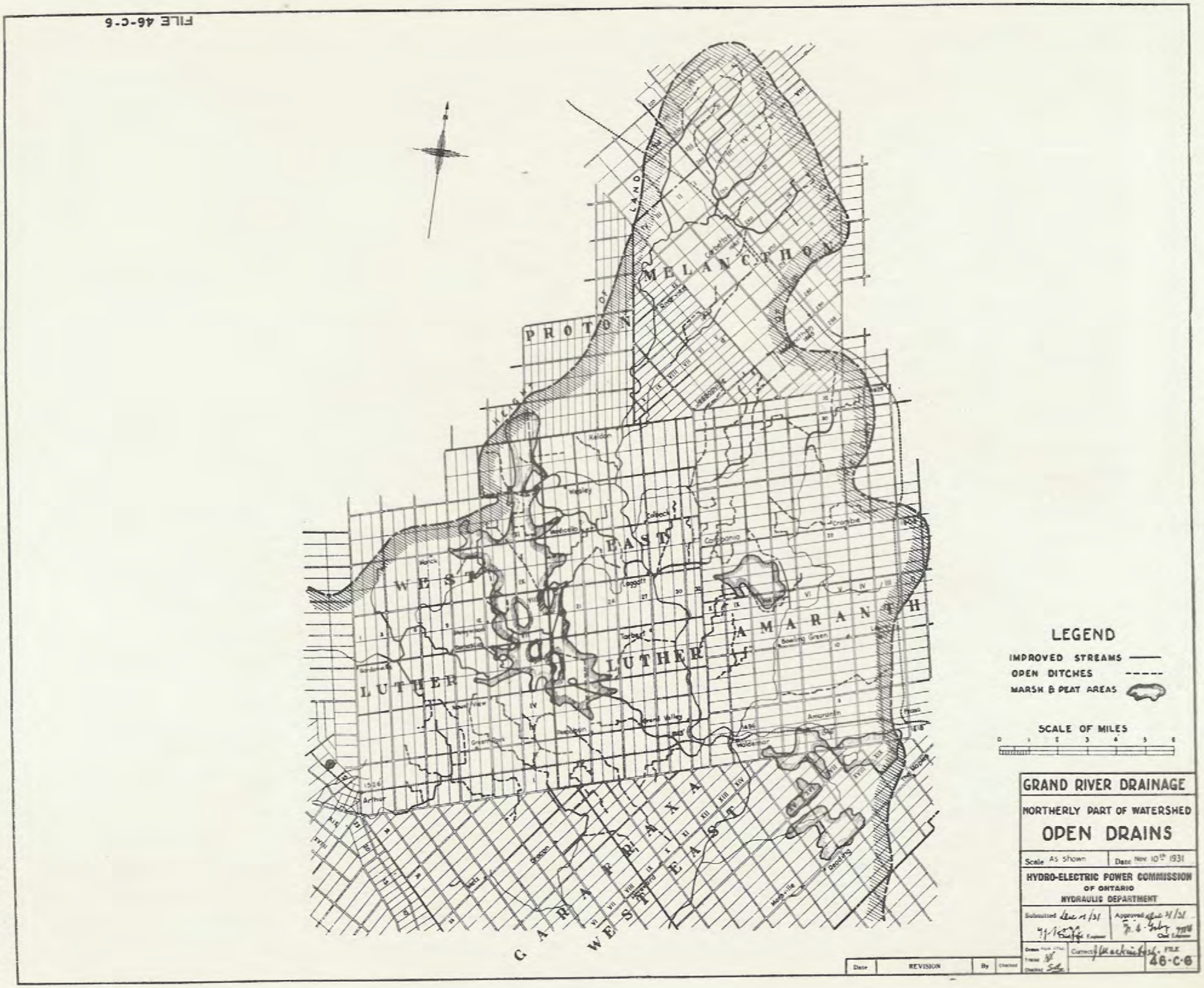

FILE 46-C-6
PROTON
MELANCTHON
LAND OF
EAST
LUTHER
WEST
LUTHER
AMARANTH
GARAFRAXA
WEST
EAST
Keldon
Colbeck
Leggatt
Crombie
Corbetton
Bowling Green
Amaranth
Grand Valley
Waldemar
Arthur
LEGEND
IMPROVED STREAMS
OPEN DITCHES
MARSH & PEAT AREAS
SCALE OF MILES
0 1 2 3 4 5 6
GRAND RIVER DRAINAGE
NORTHERLY PART OF WATERSHED
OPEN DRAINS
Scale As Shown
Date Nov 10th 1931
HYDRO-ELECTRIC POWER COMMISSION
OF ONTARIO
HYDRAULIC DEPARTMENT
Submitted Dec 1/31
Engineer
Approved Dec 3/31
Chief Engineer
Drawn
Traced
Checked
Correct
FILE
46-C-6
Date
REVISION
By
Checked

PLATE VI.


GRAND RIVER DRAINAGE
GRAND RIVER AT GALT
HYDROGRAPH
Nov. 26th 1931
FILE·46·b·14
SHEET No. 1 OF 2 SHEETS
FOR SHEET No. 2 SEE 46·b·15
11700
8826
13710
19700
5340
25390
10450
2770
10600
30090
5760
20150
6480
17030
8560
10260
14010
23850
17400
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
FLOW IN THOUSANDS OF C.F.S.
0
1
2
3
4
5
DEC.
JAN.
FEB.
MAR.
APR.
MAY
JUN.
JUL.
AUG.
SEP.
OCT.
NOV.


16120
16660
7250
16520
5760
13010
20610
26750
29720
11350
1924
1925
1926
1927
1928
1929
1930
19
FLOW IN THOUSANDS OF C.F.S.
0
1
2
3
4
5
DEC.
JAN.
FEB.
MAR.
APR.
MAY
JUN.
JUL.
AUG.
SEP.
OCT.
NOV.
SHEET No. 2 OF 2 SHEETS
FOR SHEET No. 1 SEE 46·b·14
GRAND RIVER DRAINAGE
GRAND RIVER AT GALT
HYDROGRAPH
H.E.P.C.
HYDRAULIC DEPARTMENT
Nov. 26th 1931
FILE·46·b·15

PLATE VII.

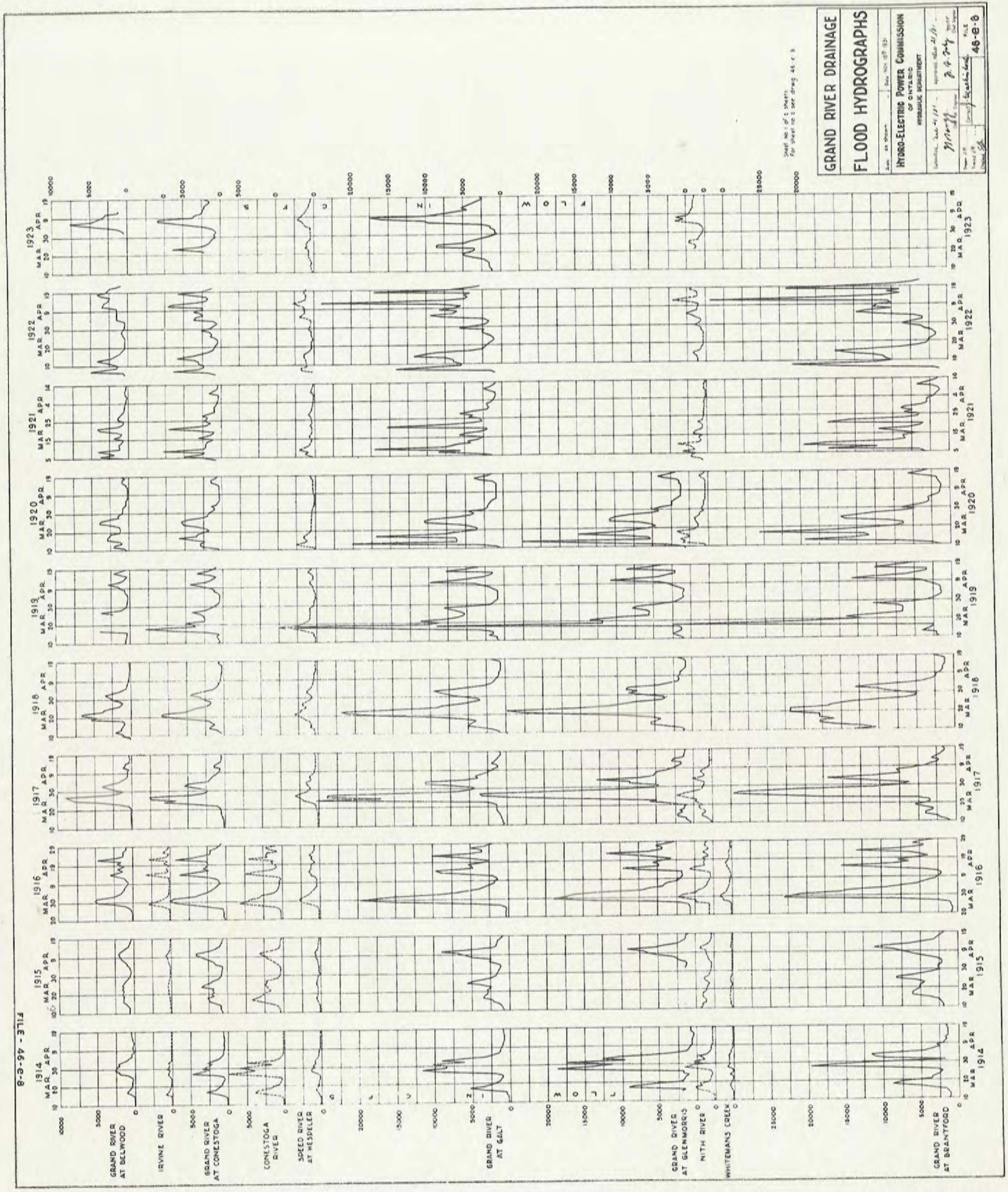
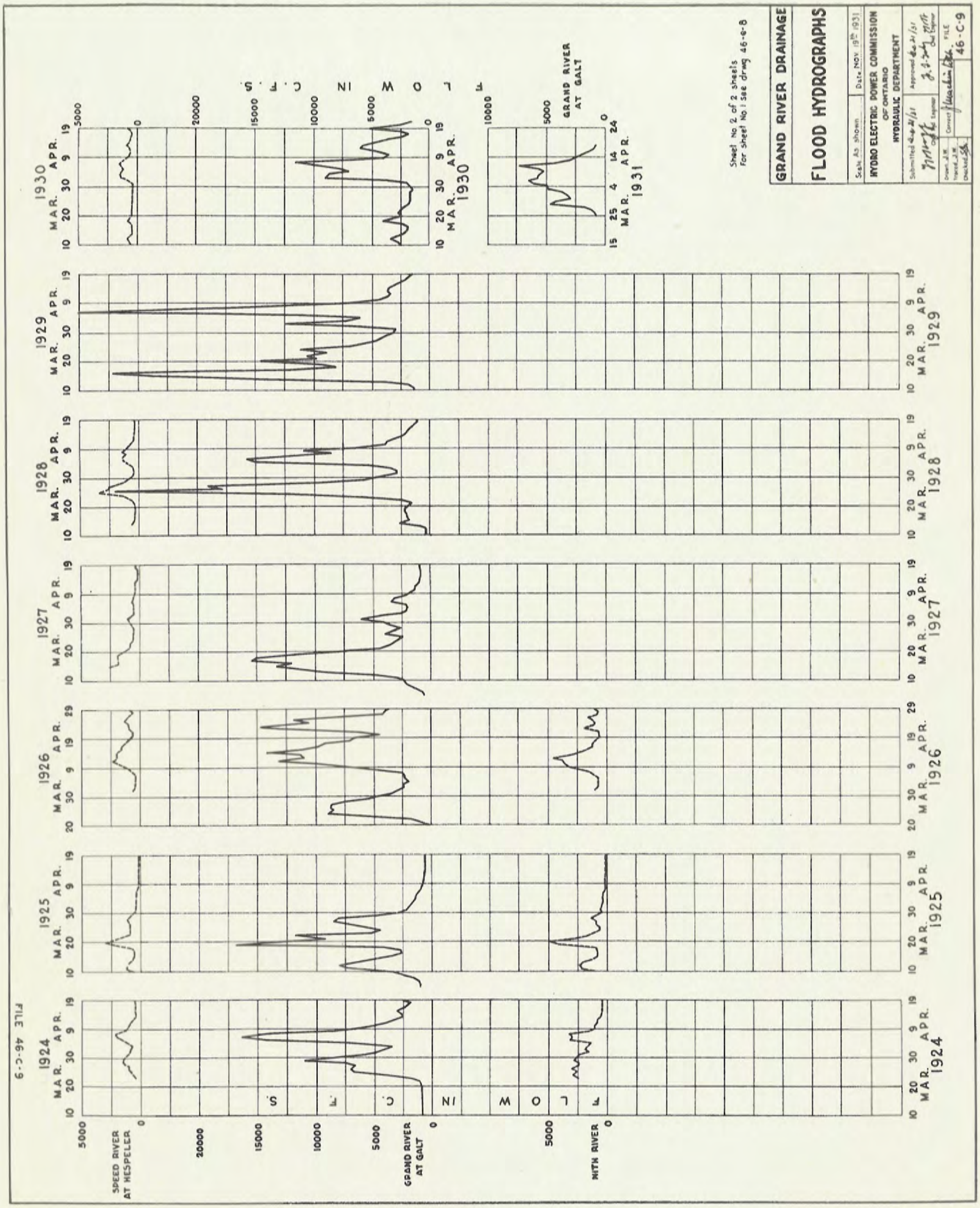

GRAND RIVER DRAINAGE
FLOOD HYDROGRAPHS
HYDRO-ELECTRIC POWER COMMISSION
OF ONTARIO
HYDRAULIC DEPARTMENT
FILE
46-e-8
FILE - 46-e-8
Sheet no 1 of 2 sheets
For sheet no 2 see drwg 46-c-9
GRAND RIVER AT BELWOOD
IRVINE RIVER
GRAND RIVER AT CONESTOGA
CONESTOGA RIVER
SPEED RIVER AT HESPELER
GRAND RIVER AT GALT
GRAND RIVER AT GLENMORRIS
NITH RIVER
WHITEMANS CREEK
GRAND RIVER AT BRANTFORD
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
MAR
APR
NO FLOW
NO RECORD
0
5000
10000
15000
20000
25000

PLATE VIII.



Sheet No 2 of 2 sheets
For sheet No 1 see drwg 46-C-8

GRAND RIVER DRAINAGE

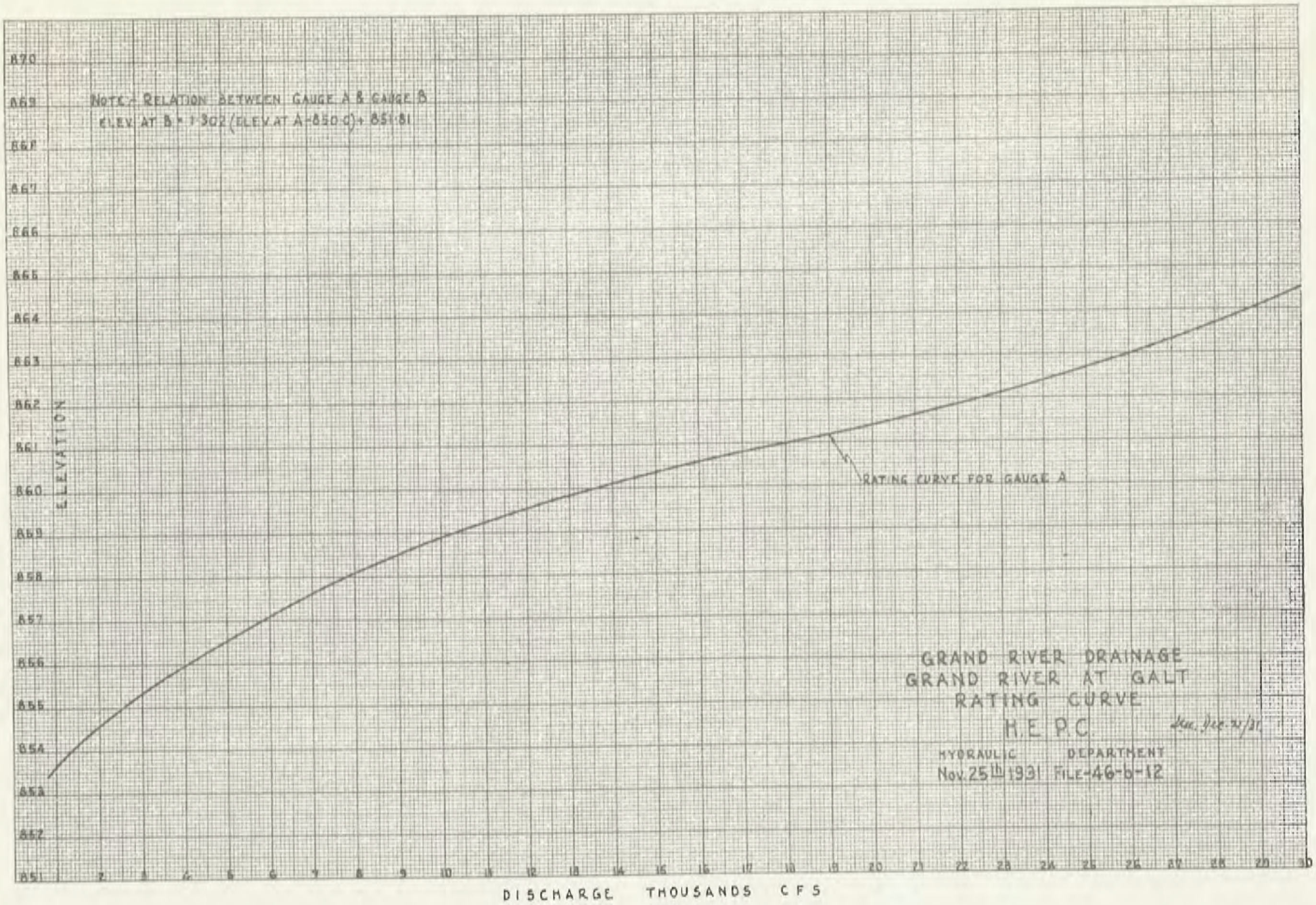
FLOOD HYDROGRAPHS

Scale As shown
Date Nov 19th 1931

HYDRO ELECTRIC POWER COMMISSION
OF ONTARIO
HYDRAULIC DEPARTMENT

Submitted Dec 21/31
Approved Dec 21/31
Engineer
Chief Engineer
Drawn J.M.
Traced J.M.
Checked
Correct
FILE
46-C-9

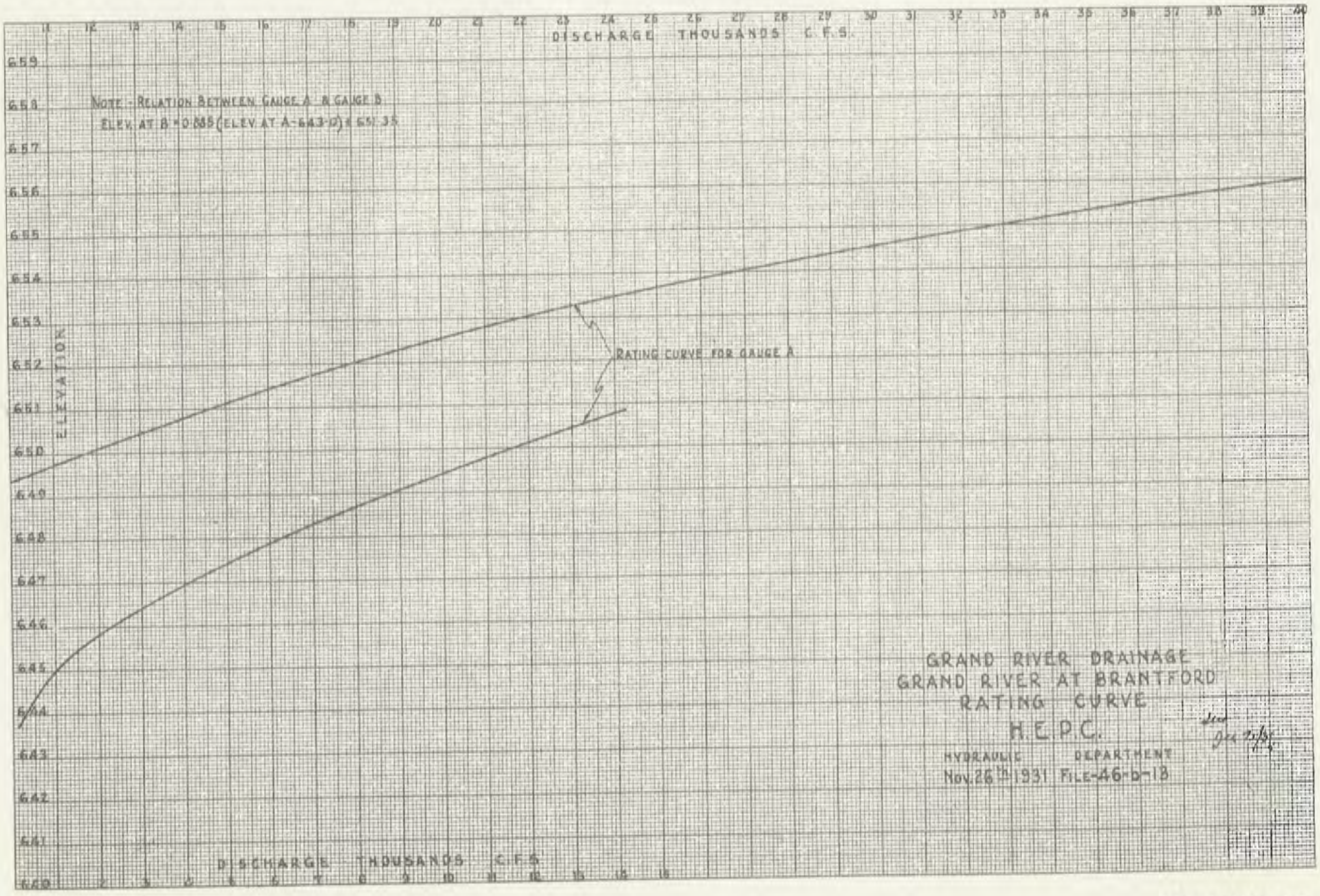
PLATE IX.



NOTE - RELATION BETWEEN GAUGE A & GAUGE B
ELEV. AT B = 1·302 (ELEV. AT A - 850·0) + 851·81

GRAND RIVER DRAINAGE
GRAND RIVER AT GALT
RATING CURVE
H.E.P.C.
HYDRAULIC DEPARTMENT
Nov. 25th 1931 FILE-46-b-12

Rec. Dec. 21/31

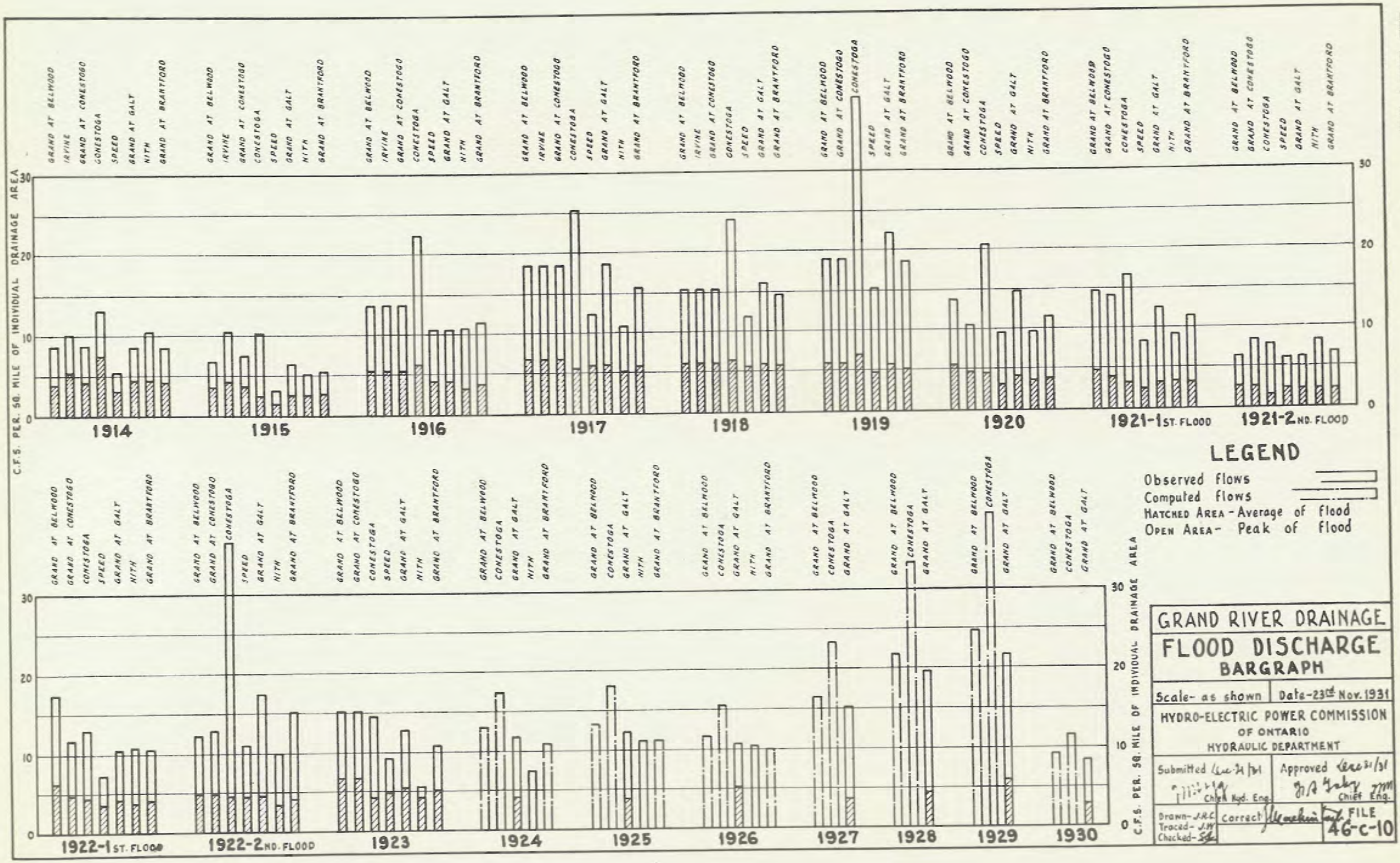


NOTE - RELATION BETWEEN GAUGE A & GAUGE B
ELEV. AT B = 0·885 (ELEV. AT A - 643·0) + 651·35

GRAND RIVER DRAINAGE
GRAND RIVER AT BRANTFORD
RATING CURVE
H.E.P.C.
HYDRAULIC DEPARTMENT
Nov. 26th 1931 FILE-46-b-18

Rec. Dec. 21/31

PLATE X.



LEGEND

Observed flows
Computed flows
HATCHED AREA - Average of flood
OPEN AREA - Peak of flood

GRAND RIVER DRAINAGE
FLOOD DISCHARGE
BARGRAPH

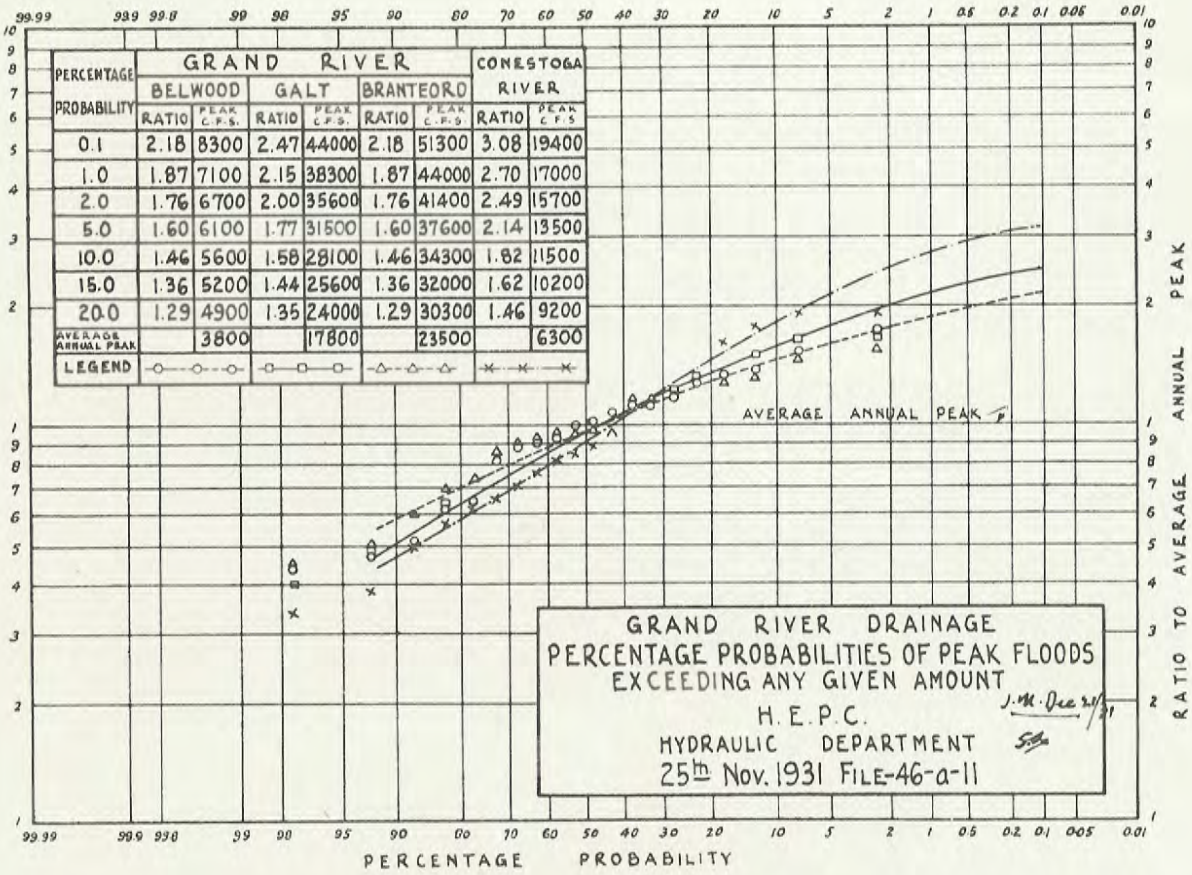
Scale- as shown	Date-23rd Nov. 1931

HYDRO-ELECTRIC POWER COMMISSION
OF ONTARIO
HYDRAULIC DEPARTMENT

Submitted Dec 31/31 Chief Hyd. Eng.	Approved Dec 31/31 Chief Eng.

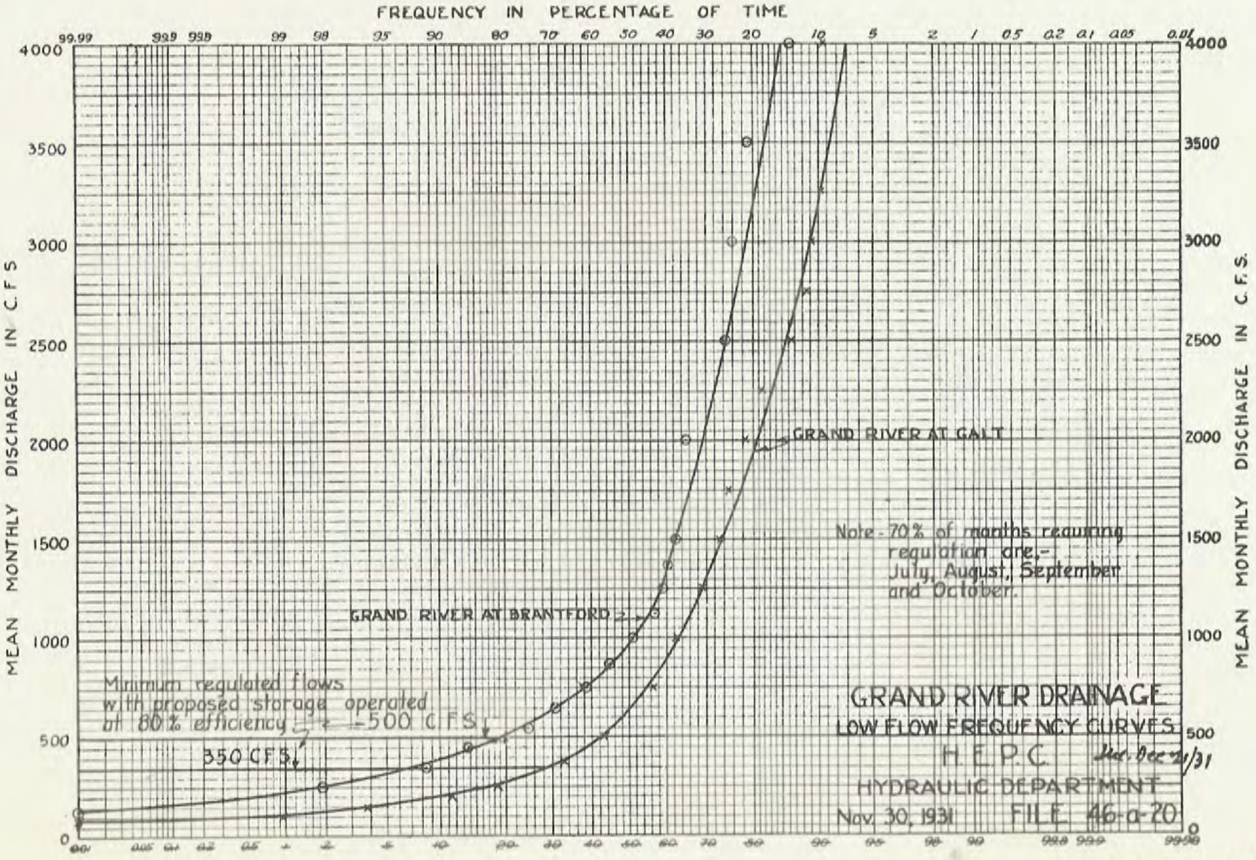
Drawn- J.R.C. Traced- J.W. Checked-	Correct	FILE 46-C-10

PLATE XI.



PERCENTAGE PROBABILITY	GRAND RIVER						CONESTOGA RIVER	
	BELWOOD		GALT		BRANTFORD			
	RATIO	PEAK C.F.S.	RATIO	PEAK C.F.S.	RATIO	PEAK C.F.S.	RATIO	PEAK C.F.S.
0.1	2.18	8300	2.47	44000	2.18	51300	3.08	19400
1.0	1.87	7100	2.15	38300	1.87	44000	2.70	17000
2.0	1.76	6700	2.00	35600	1.76	41400	2.49	15700
5.0	1.60	6100	1.77	31500	1.60	37600	2.14	13500
10.0	1.46	5600	1.58	28100	1.46	34300	1.82	11500
15.0	1.36	5200	1.44	25600	1.36	32000	1.62	10200
20.0	1.29	4900	1.35	24000	1.29	30300	1.46	9200
AVERAGE ANNUAL PEAK		3800		17800		23500		6300
LEGEND	-○--○--○-		-□—□—□-		-△--△--△-		-×·-×·-×-	

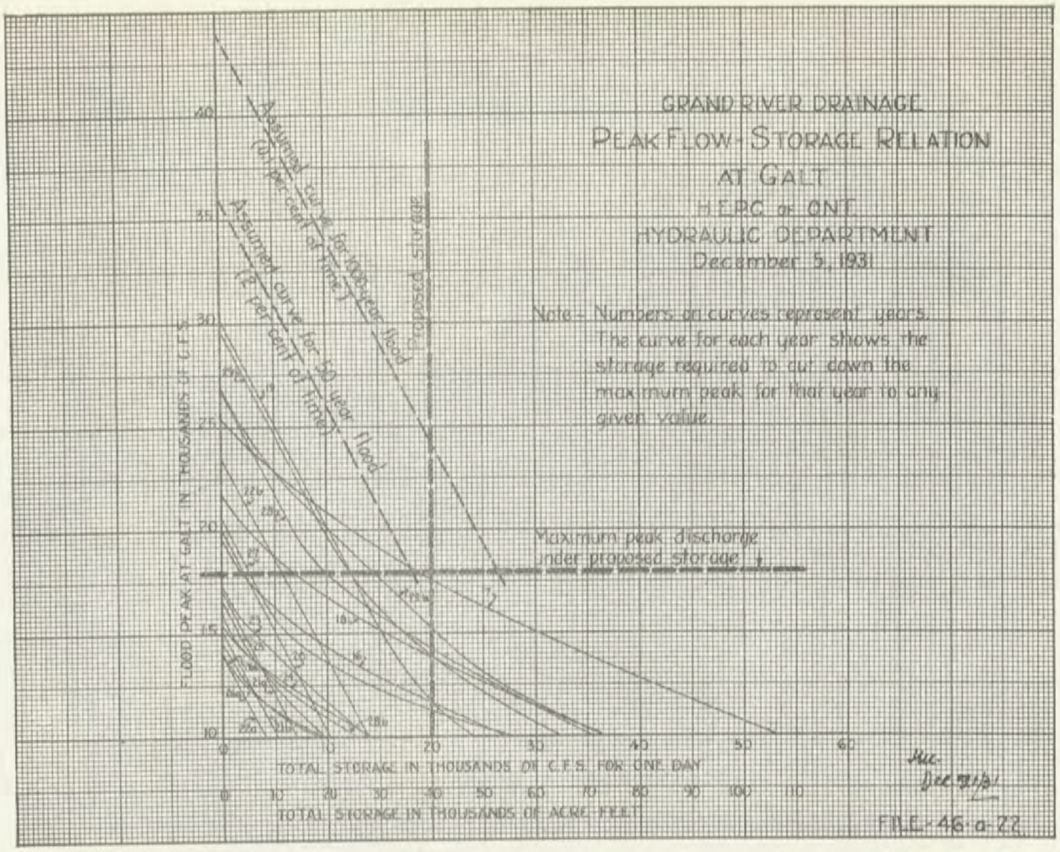
GRAND RIVER DRAINAGE
PERCENTAGE PROBABILITIES OF PEAK FLOODS
EXCEEDING ANY GIVEN AMOUNT
H. E. P. C.
HYDRAULIC DEPARTMENT
25th Nov. 1931 FILE-46-a-11



Note - 70% of months requiring regulation are,- July, August, September and October.

GRAND RIVER DRAINAGE
LOW FLOW FREQUENCY CURVES
H. E. P. C.
HYDRAULIC DEPARTMENT
Nov. 30, 1931 FILE 46-a-20

PLATE XII.


GRAND RIVER DRAINAGE
PEAK FLOW - STORAGE RELATION
AT GALT
H.E.P.C. of ONT.
HYDRAULIC DEPARTMENT
December 5, 1931
Note - Numbers on curves represent years. The curve for each year shows the storage required to cut down the maximum peak for that year to any given value.
Assumed curve for 1000 year flood (0.1 per cent of time)
Assumed curve for 50 year flood (2 per cent of time)
Proposed storage
Maximum peak discharge under proposed storage
FLOOD PEAK AT GALT IN THOUSANDS OF C.F.S.
10
15
20
25
30
35
40
0
10
20
30
40
50
60
TOTAL STORAGE IN THOUSANDS OF C.F.S. FOR ONE DAY
0
10
20
30
40
50
60
70
80
90
100
110
TOTAL STORAGE IN THOUSANDS OF ACRE FEET
FILE - 46-a-22

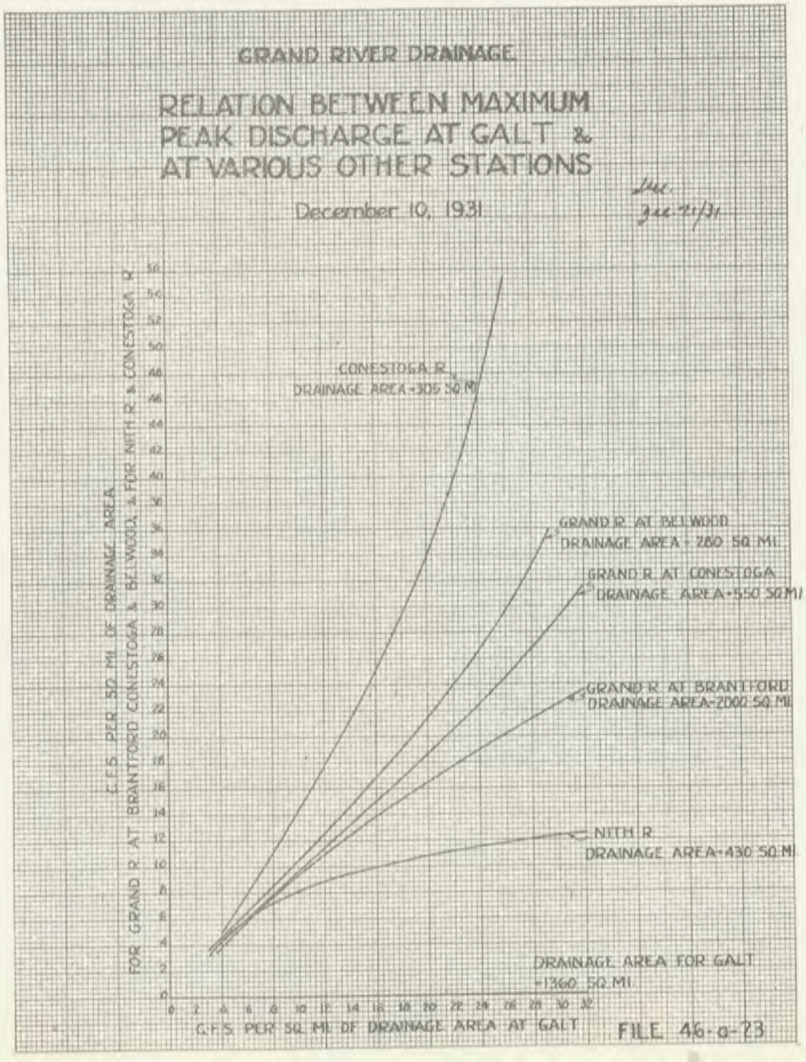
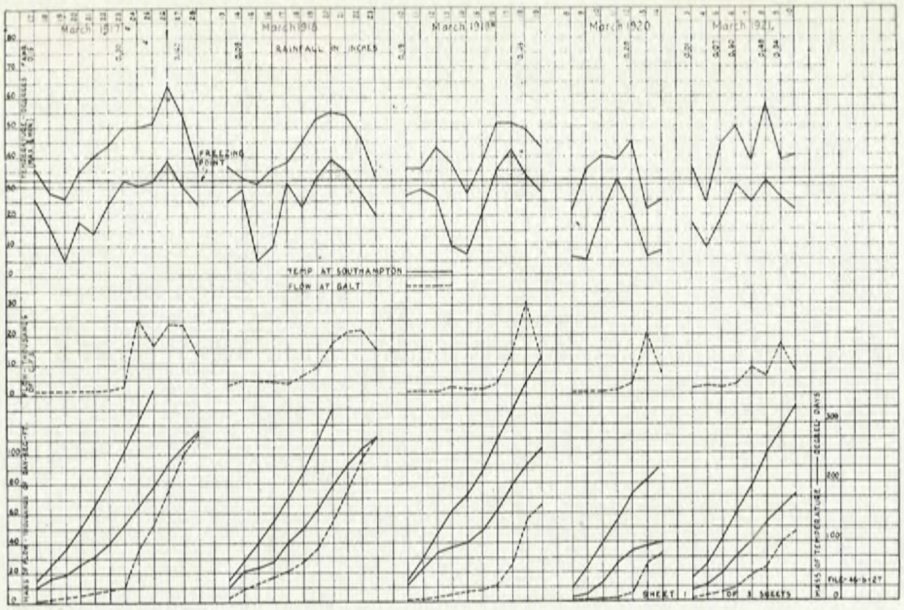
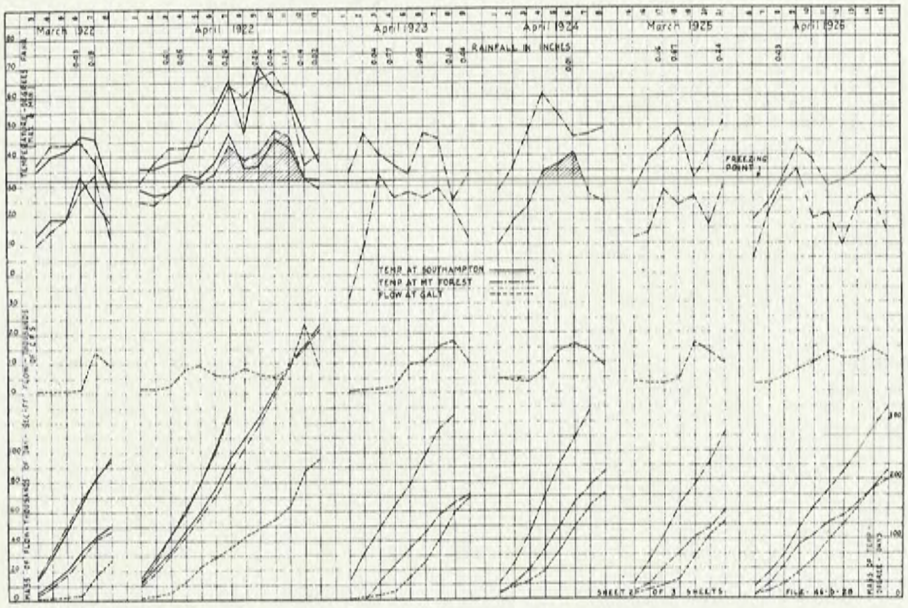

GRAND RIVER DRAINAGE
RELATION BETWEEN MAXIMUM PEAK DISCHARGE AT GALT & AT VARIOUS OTHER STATIONS
December 10, 1931
CONESTOGA R. DRAINAGE AREA - 305 SQ.MI.
GRAND R. AT BELWOOD DRAINAGE AREA - 280 SQ. MI.
GRAND R. AT CONESTOGA DRAINAGE AREA - 550 SQ.MI.
GRAND R. AT BRANTFORD DRAINAGE AREA - 2000 SQ. MI.
NITH R. DRAINAGE AREA - 430 SQ.MI.
DRAINAGE AREA FOR GALT = 1360 SQ. MI.
C.F.S. PER SQ. MI. OF DRAINAGE AREA FOR GRAND R. AT BRANTFORD CONESTOGA & BELWOOD, & FOR NITH R. & CONESTOGA R.
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
52
54
56
C.F.S. PER SQ. MI. OF DRAINAGE AREA AT GALT
FILE 46-a-23

PLATE XIII.


March 1917
March 1918
March 1919
March 1920
March 1921
RAINFALL IN INCHES
FREEZING POINT
TEMP AT SOUTHAMPTON
FLOW AT GALT
TEMPERATURE DEGREES FAHR. (MAX & MIN)
FLOW THOUSANDS C.F.S.
MASS OF FLOW THOUSANDS OF DAY-SEC-FT
MASS OF TEMPERATURE — DEGREE DAYS
SHEET 1 OF 3 SHEETS
FILE-46-b-27


March 1922
April 1922
April 1923
April 1924
March 1925
April 1926
RAINFALL IN INCHES
FREEZING POINT
TEMP AT SOUTHAMPTON
TEMP AT MT FOREST
FLOW AT GALT
TEMPERATURE DEGREES FAHR. MAX & MIN
FLOW THOUSANDS OF C.F.S.
MASS OF FLOW THOUSANDS OF DAY-SEC-FT
MASS OF TEMP DEGREE DAYS
SHEET 2 OF 3 SHEETS
FILE-46-b-28

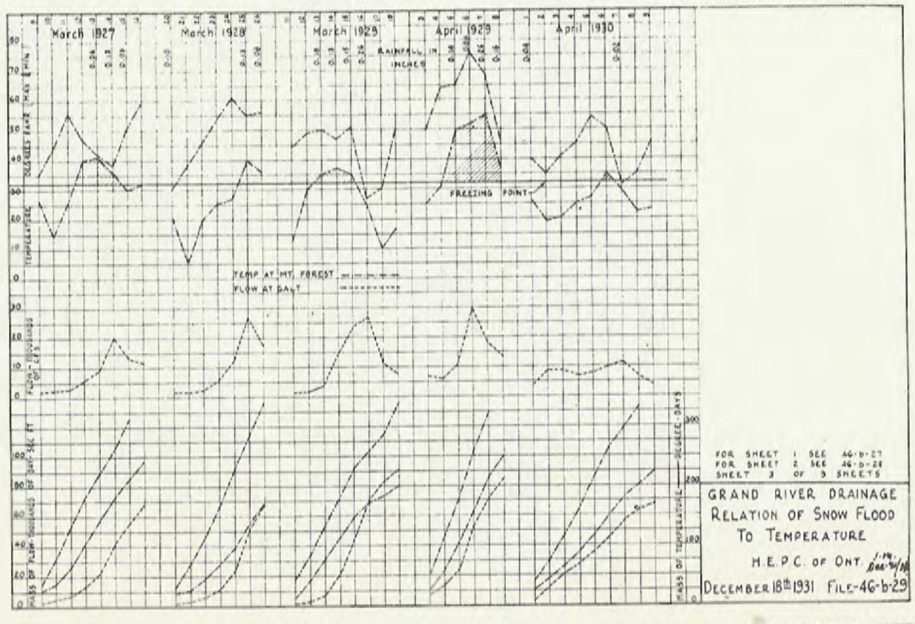
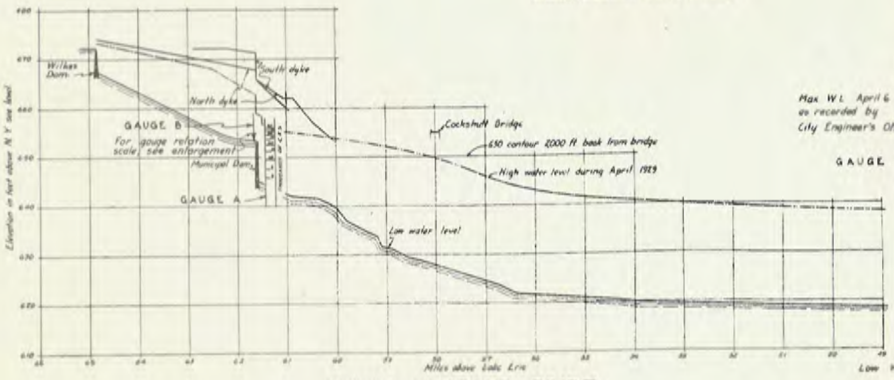

March 1927
March 1928
March 1929
April 1929
April 1930
RAINFALL IN INCHES
FREEZING POINT
TEMP AT MT. FOREST
FLOW AT GALT
TEMPERATURE DEGREES FAHR. MAX & MIN
FLOW THOUSANDS OF C.F.S.
MASS OF FLOW THOUSANDS OF DAY-SEC-FT
MASS OF TEMPERATURE — DEGREE-DAYS
FOR SHEET 1 SEE 46-b-27
FOR SHEET 2 SEE 46-b-28
SHEET 3 OF 3 SHEETS
GRAND RIVER DRAINAGE
RELATION OF SNOW FLOOD
TO TEMPERATURE
H.E.P.C. OF ONT.
DECEMBER 18th 1931 FILE-46-b-29

PLATE XIV.

PLAN

SCALE OF FEET 0 1000 2000 3000 4000



PROFILE OF GRAND RIVER

RELATION BETWEEN FLOW IN C.F.S. AND ELEVATION IN FEET

GRAND RIVER DRAINAGE

GRAND RIVER AT BRANTFORD
PLAN & PROFILE

Scales As shown
Date October 30, 1931

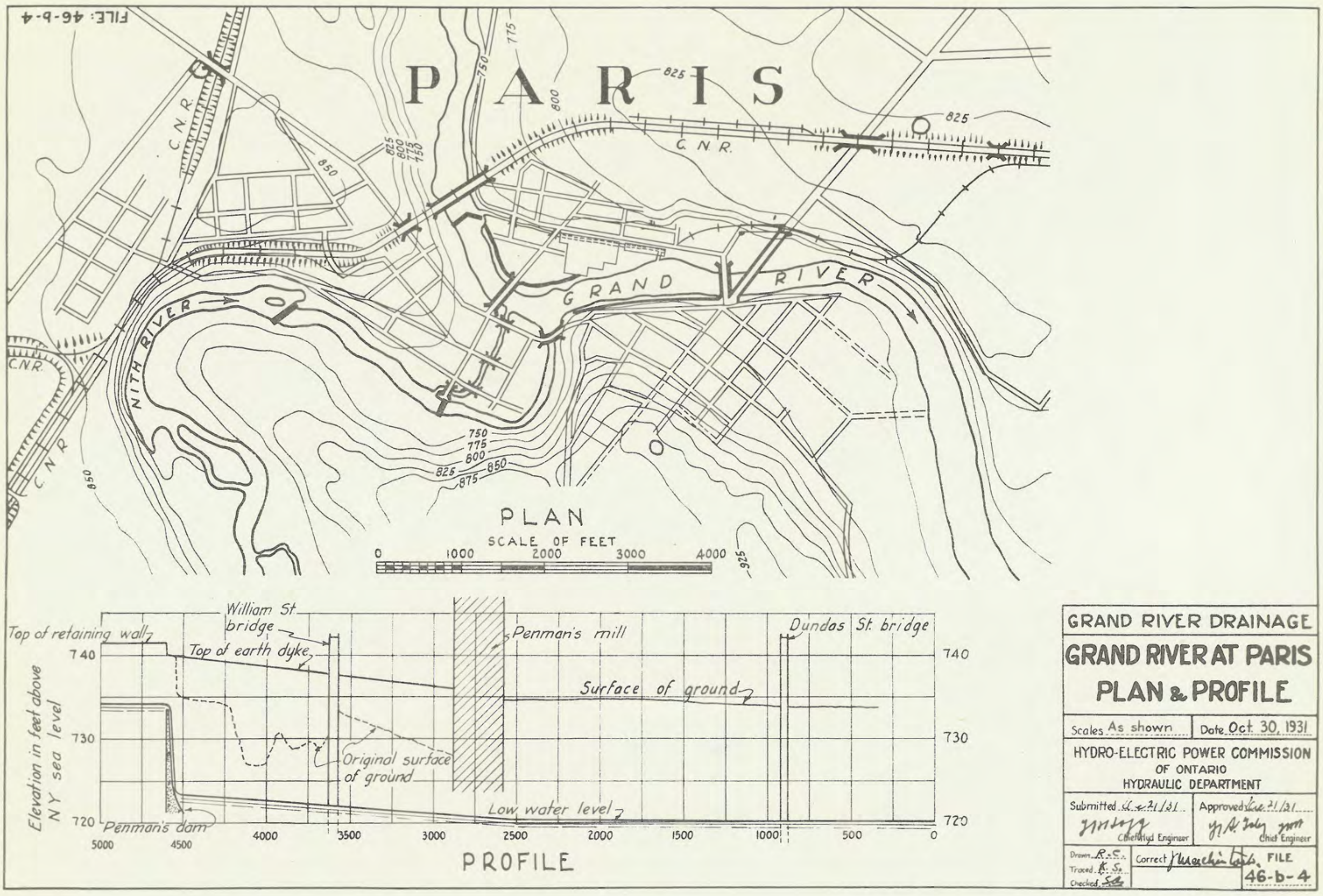
HYDRO-ELECTRIC POWER COMMISSION
OF ONTARIO
HYDRAULIC DEPARTMENT

Submitted Dec 21/31
Chief Hyd Engineer
Approved Dec 11/31
Chief Engineer

Drawn J.R.C.
Traced J.R.C.
Checked R.B.
Correct J. McIntosh
FILE 46-e-3

PLATE XV.

PLATE XVI.


FILE: 46-b-4
PARIS
C.N.R.
GRAND RIVER
NITH RIVER
750
775
800
825
850
875
925
PLAN
SCALE OF FEET
0
1000
2000
3000
4000
Top of retaining wall
William St. bridge
Top of earth dyke
Penman's mill
Dundas St. bridge
Surface of ground
Original surface of ground
Low water level
Penman's dam
Elevation in feet above N Y sea level
740
730
720
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
PROFILE
GRAND RIVER DRAINAGE
GRAND RIVER AT PARIS
PLAN & PROFILE
Scales As shown
Date Oct. 30, 1931
HYDRO-ELECTRIC POWER COMMISSION
OF ONTARIO
HYDRAULIC DEPARTMENT
Submitted Dec 21/31
Chief Hyd Engineer
Approved Dec 21/31
Chief Engineer
Drawn R.C.
Traced K. S.
Checked S.C.
Correct
FILE
46-b-4

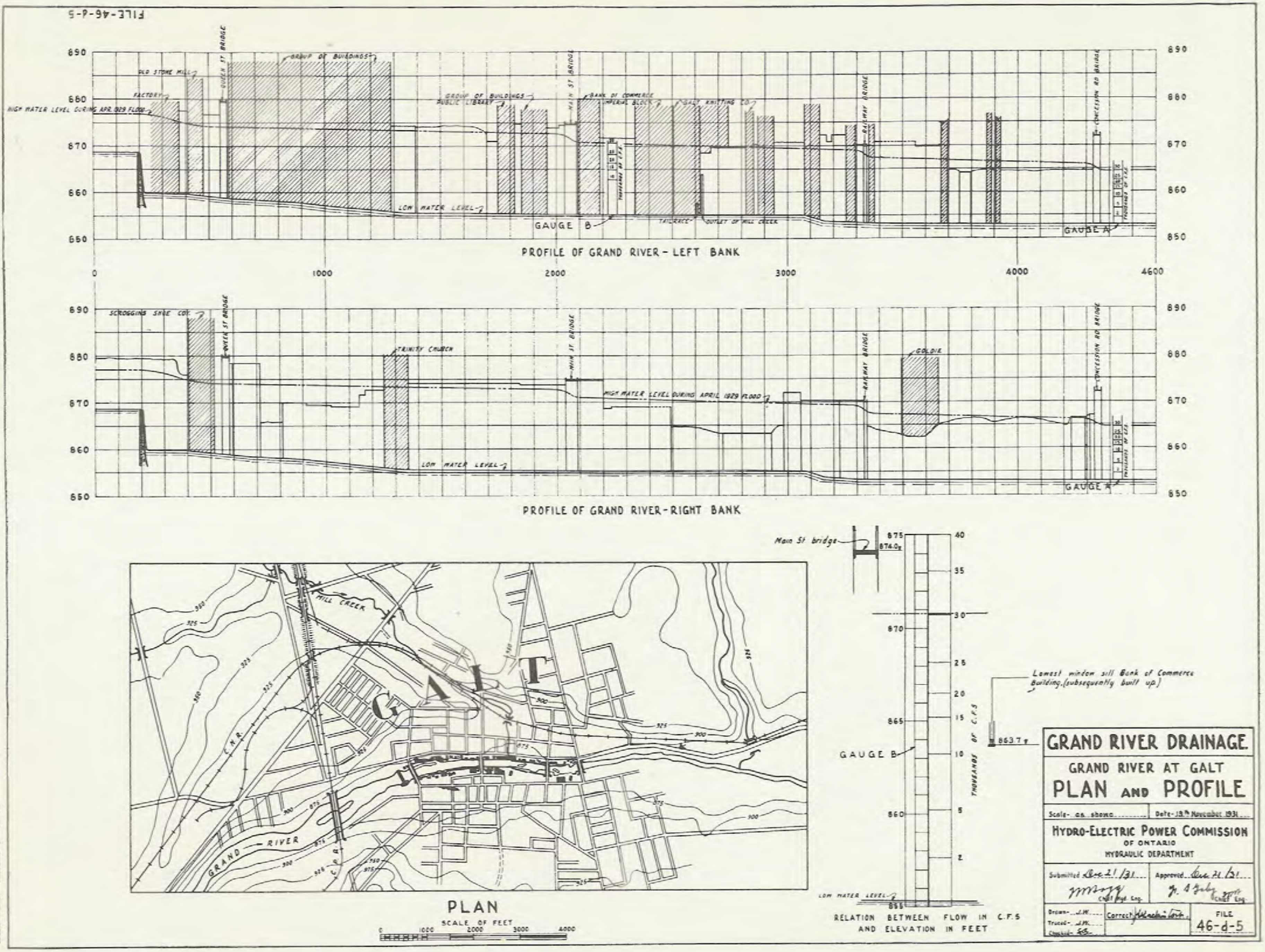

FILE-46-d-5
PROFILE OF GRAND RIVER - LEFT BANK
890
880
870
860
850
0
1000
2000
3000
4000
4600
HIGH WATER LEVEL DURING APR. 1929 FLOOD
FACTORY
OLD STONE MILL
QUEEN ST BRIDGE
GROUP OF BUILDINGS
GROUP OF BUILDINGS
PUBLIC LIBRARY
MAIN ST BRIDGE
BANK OF COMMERCE
IMPERIAL BLOCK
GALT KNITTING CO.
THOUSANDS OF C.F.S.
LOW WATER LEVEL
GAUGE B
TAILRACE
OUTLET OF MILL CREEK
RAILWAY BRIDGE
CONCESSION RD BRIDGE
GAUGE A
PROFILE OF GRAND RIVER - RIGHT BANK
SCROGGINS SHOE CO.
QUEEN ST BRIDGE
TRINITY CHURCH
MAIN ST BRIDGE
HIGH WATER LEVEL DURING APRIL 1929 FLOOD
LOW WATER LEVEL
RAILWAY BRIDGE
GOLDIE
CONCESSION RD BRIDGE
THOUSANDS OF C.F.S.
GAUGE A
PLAN
SCALE OF FEET
0
1000
2000
3000
4000
GALT
MILL CREEK
GRAND RIVER
C.N.R.
C.P.R.
Main St bridge
875
874.0
870
865
860
855
40
35
30
25
20
15
10
5
2
GAUGE B
THOUSANDS OF C.F.S.
LOW WATER LEVEL
863.7
Lowest window sill Bank of Commerce Building. (subsequently built up)
RELATION BETWEEN FLOW IN C.F.S AND ELEVATION IN FEET
GRAND RIVER DRAINAGE.
GRAND RIVER AT GALT
PLAN AND PROFILE
Scale- as shown
Date- 19th November 1931
HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO
HYDRAULIC DEPARTMENT
Submitted Dec 21/31
Chief Hyd. Eng.
Approved Dec 21/31
Chief Eng.
Drawn- J.W.
Traced- J.W.
Checked- E.G.
Correct
FILE 46-d-5

PLATE XVII.

FILE 46-C-7

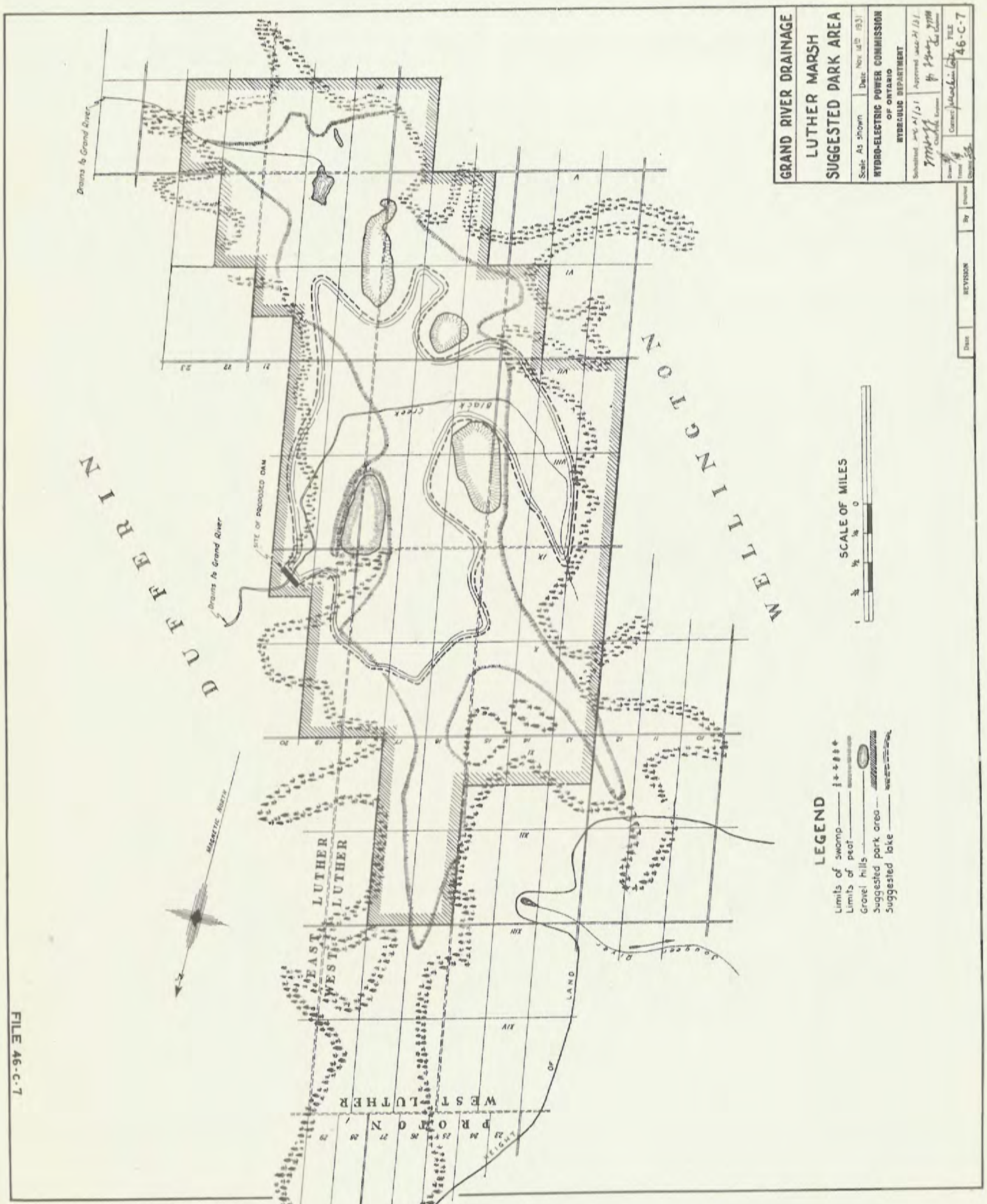
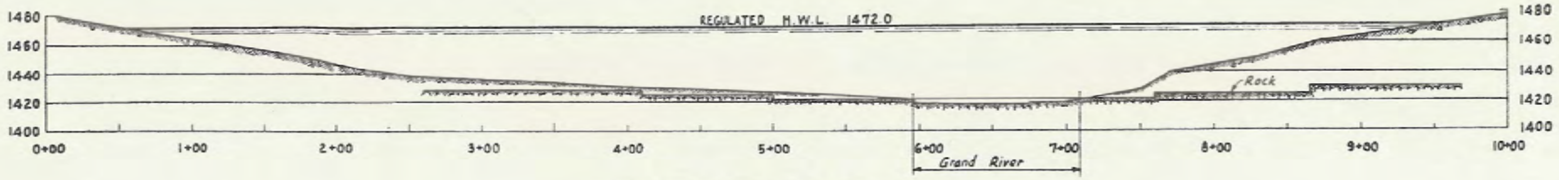


PLATE XVIII.

FILE - 46-c-30

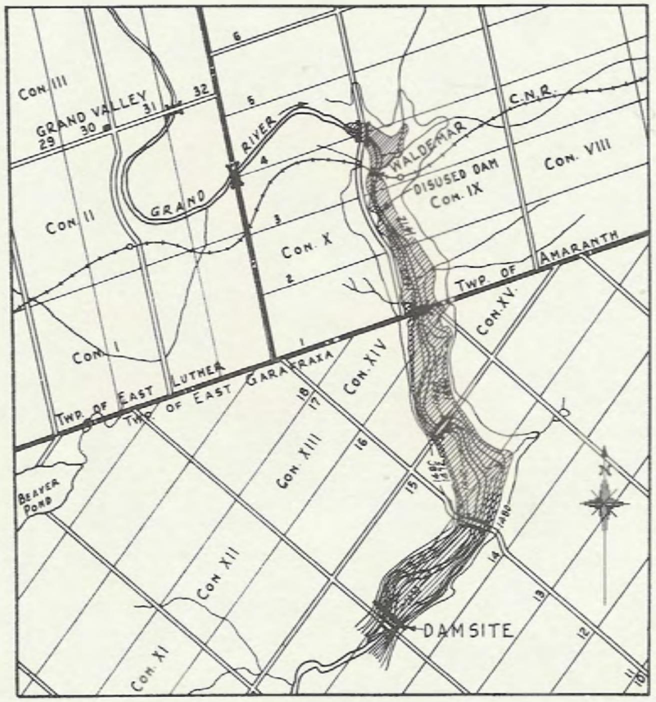


CROSS SECTION OF DAM SITE

LOOKING UPSTREAM

SCALE OF FEET

20 0 20 40 60 80 100



LOCATION PLAN

SCALE OF MILES

1 3/4 1/2 1/4 0

Date	REVISION	By	Checked

GRAND RIVER DRAINAGE

PROPOSED WALDEMAR STORAGE

Scales - As shown | Date - 13th Jan. 1932

HYDRO-ELECTRIC POWER COMMISSION
OF ONTARIO
HYDRAULIC DEPARTMENT

Submitted Jan 14/32 | Approved Jan 14/32

Drawn J.W.
Traced J.W.
Checked
Correct
FILE 46-c-30

PLATE XIX.

FILE-46-C-17

CROSS SECTION OF DAM SITE
LOOKING UPSTREAM
SCALE OF FEET
100 0 20 40 60 80 100

LOCATION PLAN
SCALE OF MILES
1 ¾ ½ ¼ 0 1

Date	REVISION	By	Checked

GRAND RIVER DRAINAGE
PROPOSED ELORA STORAGE

Scales - As shown | Date - 31st Nov. 1931

HYDRO-ELECTRIC POWER COMMISSION
OF ONTARIO
HYDRAULIC DEPARTMENT

Submitted Dec 4/31
Chief Engineer

Approved Dec 21/31
Chief Engineer

Drawn J.W.
Traced J.W.
Checked
Correct
FILE
46-c-17

PLATE XX.

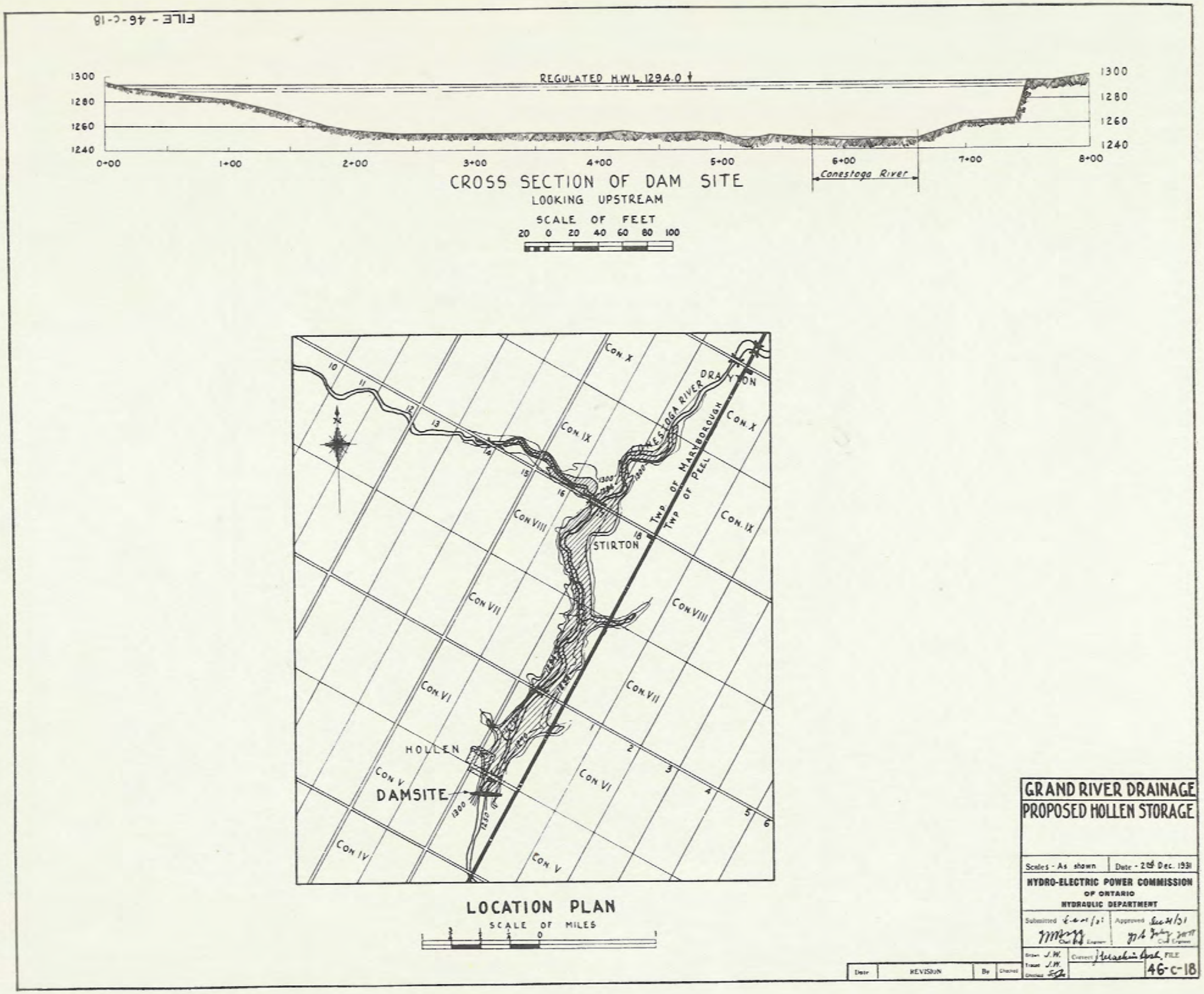

FILE - 46-C-18
REGULATED H.W.L. 1294.0 ±
1300
1280
1260
1240
0+00
1+00
2+00
3+00
4+00
5+00
6+00
7+00
8+00
Conestoga River
CROSS SECTION OF DAM SITE
LOOKING UPSTREAM
SCALE OF FEET
20 0 20 40 60 80 100
CON X
CON IX
CON VIII
CON VII
CON VI
CON V
CON IV
CONESTOGA RIVER
DRAYTON
TWP OF MARYBOROUGH
TWP OF PEEL
STIRTON
HOLLEN
DAMSITE
10
11
12
13
14
15
16
18
1
2
3
4
5
6
1300
1290
LOCATION PLAN
SCALE OF MILES
GRAND RIVER DRAINAGE
PROPOSED HOLLEN STORAGE
Scales - As shown
Date - 2nd Dec. 1931
HYDRO-ELECTRIC POWER COMMISSION
OF ONTARIO
HYDRAULIC DEPARTMENT
Submitted
Chief Hyd. Engineer
Approved Dec 21/31
Chief Engineer
Drawn J.W.
Traced J.W.
Checked
Correct
FILE
46-C-18
Date
REVISION
By
Checked

PLATE XXI.

APPENDIX A

Grand River Drainage Flood Particulars

GRAND RIVER DRAINAGE

FLOOD PARTICULARS

River	Year	Period of Flood	Discharge in C.F.S. Max	Discharge in C.F.S. Mean	Discharge in C.F.S. per Square Mile Max	Discharge in C.F.S. per Square Mile Mean	Drainage Area (Sq. Miles)	Inches on Drainage Area	Flood Ratio
Grand at Belwood	1914	Mar. 25 - Apr. 6	2,360	1,060	8.43	3.79	280	1.83	2.23
	1915	Apr. 4 - Apr. 17	1,949	1,022	6.96	3.65	280	1.90	1.91
	1916	Mar 26 - Apr. 29	3,850	1,540	13.70	5.50	280	7.37	2.49
	1917	Mar. 21 - Apr. 11	5,150	1,830	18.40	6.54	280	5.35	2.81
	1918	Mar. 16 - Apr. 7	4,290	1,680	15.32	5.98	280	5.11	2.56
	1919	Mar. 15 - Mar. 31	5,310	1,660	18.97	5.92	280	3.75	3.20
	1920	Mar. 10 - Apr. 6	3,860	1,580	13.78	5.64	280	5.88	2.44
	1921	Mar 2 - Apr. 4	4,130	1,350	14.80	4.82	280	6.10	3.07
	1921	Apr. 18 - May 4	1,800	750	6.50	2.68	280	1.70	2.43
	1922	Mar. 4 - Mar. 20	4,900	1,730	17.50	6.18	280	3.90	2.73
	1922	Apr. 2 - Apr. 25	3,400	1,370	12.14	4.92	280	4.40	2.47
	1923	Apr. 1 - Apr. 11	4,270	1,910	15.27	6.83	280	2.79	2.24
		Maximum	5,310	1,910	18.97	6.83		7.37	3.20
		Minimum	1 800	750	6.50	2.68		1.70	1.91
		Mean	3,772	1,457	13.47	5.20		4.18	2.59
Irvine River	1914	Mar. 25 - Apr. 6	650	347	9.70	5.18	67	2.51	1.87
	1915	Apr. 4 - Apr. 17	701	288	10.47	4.30	67	2.24	2.43
	1916	Mar. 26 - Apr. 29	920	370	13.70	5.50	67	7.37	2.49
	1917	Mar. 21 - Apr. 11	1,250	440	18.40	6.54	67	5.35	2.81
		Maximum	1.250	440	18.40	6.54		7.37	2.81
		Minimum	650	288	9.70	4.30		2.24	1.87
		Mean	880	361	13.14	5.40		4.37	2.43

River	Year	Period of Flood	Discharge in C.F.S. Max	Discharge in C.F.S. Mean	Discharge in C.F.S. per Square Mile Max	Discharge in C.F.S. per Square Mile Mean	Drainage Area (Sq. Miles)	Inches on Drainage Area	Flood Ratio
Grand at Conestoga	1914	Mar. 25 - Apr. 6	4,800	2,210	8.72	4.01	550	1.94	2.17
	1915	Apr. 4 - Apr. 17	4,200	2,073	7.63	3.76	550	1.96	2.03
	1916	Mar. 26 - Apr. 29	7,550	3,020	13.72	5.49	550	7.35	2.50
	1917	Mar. 21 - Apr. 11	10,160	3,600	18.40	6.54	550	5.35	2.81
	1918	Mar. 16 - Apr. 7	8,430	3,290	15.32	5.98	550	5.11	2.56
	1919	Mar. 15 - Mar. 31	10,430	3,250	18.97	5.92	550	3.75	3.20
	1920	Mar. 10 - Apr. 6	5,790	2,590	10.50	4.72	550	4.93	2.22
	1921	Mar. 2 - Apr. 4	7,730	2,160	14.08	3.93	550	4.97	3.58
	1921	Apr. 18 - May 4	3,110	1,410	8.37	2.56	550	1.62	3.27
	1922	Mar. 4 - Mar. 20	6,400	2,640	11.62	4.81	550	3.04	2.42
	1922	Apr. 2 - Apr. 25	7,120	2,700	12.95	4.92	550	4.40	2.63
	1923	Apr. 1 - Apr. 11	8.320	3,760	15.27	6.83	550	2.79	2.24
		Maximum	10,430	3,760	18.97	6.83		7.35	3.58
		Minimum	3,110	1,410	8.37	2.56		1.62	2.03
		Mean	7,003	2,725	12.72	4.96		3.94	2.56
Conestoga River	1914	Mar. 25 - Apr. 6	4,130	2,350	13.52	7.70	305	3.72	1.76
	1915	Apr. 4 - Apr. 17	3,120	774	10.22	2.53	305	1.32	4.04
	1916	Mar. 26 - Apr. 29	6,870	666	22.50	2.18	305	8.27	3.64
	1917	Mar. 21 - Apr. 11	7,720	1,650	25.30	5.41	305	4.43	4.67
	1918	Mar. 16 - Apr. 7	7,340	1,920	24.00	6.30	305	5.39	3.81
	1919	Mar. 15 - Mar. 31	12,000	2,125	39.40	6.96	305	4.40	5.65
	1920	Mar. 10 - Apr. 6	6,280	1,390	20.60	4.56	305	4.75	4.51
	1921	Mar. 2 - Apr. 4	5,140	950	16.84	3.11	305	3.94	5.41
	1921	Apr. 18 - May 4	2,430	450	7.96	1.48	305	0.94	5.37
	1922	Mar. 4 - Mar. 20	3,960	1,290	13.00	4.23	305	2.67	3.07
	1922	Apr. 2 - Apr. 25	11,180	1,420	36.60	4.65	305	4.16	7.85
	1923	Apr. 1 - Apr. 11	4,450	1,290	14.60	4.23	305	1.73	3.45
		Maximum	12,000	2,350	39.40	7.70		8.27	7.85
		Minimum	2,430	450	7.96	1.48		0.94	1.76
		Mean	6,220	1,277	20.40	4.18		3.81	4.88

River	Year	Period of Flood	Discharge in C.F.S. Max	Discharge in C.F.S. Mean	Discharge in C.F.S. per Square Mile Max	Discharge in C.F.S. per Square Mile Mean	Drainage Area (Sq. Miles)	Inches on Drainage Area	Flood Ratio
Speed River	1914	Mar. 25 - Apr. 6	1,420	803	5.68	3.21	250	1.55	1.76
	1915	Apr. 4 - Apr. 17	790	407	3.16	1.63	250	0.85	1.94
	1916	Mar. 26 - Apr. 29	2,620	1,014	10.48	4.05	250	5.43	2.59
	1917	Mar. 21 - Apr. 11	3,030	1,460	12.10	5.84	250	4.79	2.07
	1918	Mar. 16 - Apr. 7	2,940	1,370	11.76	5.48	250	4.69	2.14
	1919	Mar. 15 - Mar. 31	3,790	1,190	15.16	4.76	250	3.01	3.18
	1920	Mar. 10 - Apr. 6	2,390	760	9.55	3.03	250	3.16	3.15
	1921	Mar. 2 - Apr. 4	2,060	590	8.24	2.37	250	3.00	3.47
	1921	Apr. 18 - May 4	1,450	590	6.16	2.37	250	1.49	2.61
	1922	Mar. 4 - Mar. 20	1,810	8.90	7.22	3.56	250	2.25	2.03
	1922	Apr. 2 - Apr. 25	2,750	1,120	11.00	4.49	250	4.01	2.45
	1923	Apr. 1 - Apr. 11	2,290	1,230	9.16	4.91	250	2.01	1.86
		Maximum	3,790	1,460	15.16	5.84		5.43	3.47
		Minimum	790	407	3.16	1.63		0.85	1.76
		Mean	2,278	952	9.10	3.81		3.02	2.39
Grand at Galt	1914	Mar. 25 - Apr. 6	11,700	6,130	8.60	4.51	1,360	2.17	1.91
	1915	Apr. 4 - Apr. 17	8,920	3,670	6.56	2.69	1,360	1.40	2.44
	1916	Mar. 26 - Apr. 29	19,700	5,715	14.50	4.20	1,360	5.63	3.47
	1917	Mar. 21 - Apr. 11	24,000	8,100	18.66	5.95	1,360	4.88	3.13
	1918	Mar. 16 - Apr. 7	21,700	7,980	15.96	5.87	1,360	5.02	2.72
	1919	Mar. 15 - Mar. 31	30,090	7,780	22.12	5.71	1,360	3.61	3.70
	1920	Mar. 10 - Apr. 6	16,900	5,510	14.81	4.05	1,360	4.22	3.66
	1921	Mar. 2 - Apr. 4	17,030	4,300	12.52	3.15	1,360	3.98	3.98
	1921	Apr. 18 - May 4	8,560	3,050	6.29	2.24	1,360	1.42	2.81
	1922	Mar. 4 - Mar. 20	14,010	5,730	10.30	4.21	1,360	2.66	2.44
	1922	Apr. 2 - Apr. 25	23,850	6,380	17.53	4.69	1,360	4.19	3.74
	1923	Apr. 1 - Apr. 11	17,400	7,530	12.79	5.53	1,360	2.26	2.31
	1924	Mar. 21 - Apr. 19	16,120	5,577	11.85	4.10	1,360	4.58	3.37
	1925	Mar. 9 - Apr. 6	16,660	5,130	12.25	3.77	1,360	4.07	3.91
	1926	Mar. 22 - Apr. 29	14,520	7,060	10.69	5.20	1,360	7.35	2.44
	1927	Mar. 7 - Apr. 13	20,610	4,960	15.20	3.65	1,360	5.16	5.08
	1928	Mar. 13 - Apr. 19	26,750	5,920	19.70	4.35	1,360	5.99	5.34
	1929	Mar. 11 - Mar. 19	29,720	8,160	21.80	6.00	1,360	8.95	6.03
	1930	Mar. 10 - Apr. 19	11,350	3,840	8.40	2.82	1,360	4.31	3.66
		Maximum	30,090	8,160	22.12	6.00		8.95	6.03
		Minimum	8,560	3,050	6.29	2.24		1.40	1.91
		Mean	18,400	5,920	13.52	4.35		4.30	3.38

River	Year	Period of Flood	Discharge in C.F.S.		Discharge in C.F.S. per Square Mile		Drainage Area (Sq. Miles)	Inches on Drainage Area	Flood Ratio
			Max	Mean	Max	Mean			
Nith River	1914	Mar. 25 - Apr. 6	4,080	1,728	11.19	4.73	365	2.28	2.36
	1915	Apr. 4 - Apr. 17	1,903	979	5.22	2.68	365	1.40	1.95
	1916	Mar. 26 - Apr. 29	3,940	1,069	10.80	3.20	365	4.29	3.38
	1917	Mar. 21 - Apr. 11	3,900	1,820	10.69	4.99	365	4.09	2.14
	1920	Mar. 10 - Apr. 6	4,170	1,600	9.70	3.72	430	3.88	2.61
	1921	Mar. 2 - Apr. 4	3,970	1,440	9.23	3.35	430	4.24	2.75
	1921	Apr. 18 - May 4	3,560	980	8.28	2.27	430	1.44	3.65
	1922	Mar. 4 - Mar. 20	4,630	1,600	10.76	3.72	430	2.35	2.89
	1922	Apr. 2 - Apr. 25	4 280	1,460	9.95	3.40	430	3.04	2.93
	1923	Apr. 1 - Apr. 11	3,000	1,820	5.68	4.23	430	1.73	1.34
		Maximum	4,630	1,820	10.76	4.23		4.29	3.65
		Minimum	1,903	979	5.22	2.68		1.40	1.34
		Mean	3,743	1,450	9.15	3.63		2.87	2.52
Whiteman's Creek	1914	Mar. 25 - Apr. 6	875	482	5.68	3.13	154	1.51	1.81
	1915	Apr. 4 - Apr. 17	263	182	1.71	1.18	154	0.62	1.45
	1916	Mar. 26 - Apr. 29	1,660	488	10.80	3.19	154	4.28	3.38
		Maximum	1,660	488	10.80	3.19		4.28	3.38
		Minimum	263	182	1.71	1.18		0.62	1.45
		Mean	933	384	6.05	2.49		2.14	2.43
Grand at Brantford	1914	Mar. 25 - Apr. 6	17,183	8,628	8.59	4.31	2,000	2.08	1.99
	1915	Apr. 4 - Apr. 17	11,290	5,488	5.57	2.74	2,000	1.43	2.03
	1916	Mar. 26 - Apr. 29	26,600	7,659	11.50	3.83	2,000	5.14	3.00
	1917	Mar. 21 - Apr. 11	30,800	11,360	15.40	5.68	2,000	4.65	2.71
	1918	Mar. 16 - Apr. 7	29,000	11,500	14.50	5.75	2,000	4.92	2.56
	1919	Mar. 15 - Mar. 31	37,360	10,160	18.68	5.08	2,000	3.21	3.67
	1920	Mar. 10 - Apr. 6	23,110	7,890	11.55	3.95	2,000	4.12	2.93
	1921	Mar. 2 - Apr. 4	22,940	6,440	11.47	3.22	2,000	4.07	3.56
	1921	Apr. 18 - May 4	13,860	4,510	6.93	2.26	2,000	1.43	3.06
	1922	Mar. 9 - Mar. 20	20,900	8,110	10.45	4.05	2,000	2.56	2.58
	1922	Apr. 2 - Apr. 25	30,230	8 550	15.12	4.28	2,000	3.83	3.53
	1923	Apr. 1 - Apr. 11	21,590	10,240	10.79	5.12	2,000	2.09	2.30
		Maximum	37,360	11,500	18.68	5.75		5.14	3.67
		Minimum	11,290	4,510	5.57	2.26		1.43	1.99
		Mean	23,740	8,378	11.87	4.19		3.30	2.83

GRAND RIVER DRAINAGE
FLOOD PARTICULARS

River	Year	Period of Flood	Discharge in C.F.S.		Discharge in C.F.S. per Square Mile		Drainage Area (Sq. Miles)	Inches on Drainage Area	Flood Ratio
			Max	Mean	Max	Mean			
Grand at Belwood	1914	Mar. 25 - Apr. 6	2,360	1,060	8.43	3.79	280	1.83	2.23
Irvine River			650	347	9.70	5.19	67	2.51	1.87
Grand at Conestoga			4,800	2,210	8.72	4.02	550	1.94	2.17
Conestoga River			4,130	2,350	13.52	7.70	305	3.72	1.76
Speed River			1,420	803	5.68	3.21	250	1.55	1.76
Grand at Galt			11,700	6,130	8.60	4.50	1,360	2.17	1.91
Nith River			4,080	1,728	11.19	4.73	365	2.28	2.36
Whiteman's Creek			875	482	5.68	3.13	154	1.51	1.81
Grand at Brantford			17,183	8,628	8.59	4.31	2,000	2.08	1.99
Grand at Belwood	1915	Apr. 4 - Apr. 17	1,949	1,022	6.96	3.65	280	1.90	1.91
Irvine River			701	288	10.47	4.30	67	2.24	2.43
Grand at Conestoga			4,200	2,073	7.63	3.76	550	1.96	2.03
Conestoga River			3,120	774	10.22	2.53	305	1.32	4.04
Speed River			790	407	3.16	1.63	250	0.85	1.94
Grand at Galt			8,920	3,670	6.56	2.69	1,360	1.40	2.44
Nith River			1,903	979	5.22	2.68	365	1.40	1.95
Whiteman's Creek			263	1,820	1.71	1.18	154	0.62	1.45
Grand at Brantford			11,290	5,488	5.57	2.74	2,000	1.43	2.03
Grand at Belwood	1916	Mar. 26 - Apr. 29	3,850	1,540	13.70	5.50	280	7.37	2.49
Irvine River			920	370	13.70	5.50	67	7.37	2.49
Grand at Conestoga			7.550	3,020	13.72	5.49	550	7.35	2.50
Conestoga River			6,870	666	22.50	6.17	305	8.27	3.64
Speed River			2,620	1,014	10.48	4.05	250	5.43	2.59
Grand at Galt			19,700	5,715	14.50	4.20	1,360	5.63	3.47
Nith River			3,940	1,069	10.80	3.20	365	4.29	3.38
Whiteman's Creek			1,660	488	10.80	3.19	154	4.28	3.38
Grand at Brantford			26,600	7,659	11.50	3.83	2,000	5.14	3.00

River	Year	Period of Flood	Discharge in C.F.S. Max	Discharge in C.F.S. Mean	Discharge in C.F.S. per Square Mile Max	Discharge in C.F.S. per Square Mile Mean	Drainage Area (Sq. Miles)	Inches on Drainage Area	Flood Ratio
Grand at Belwood	1917	Mar. 21 - Apr. 11	5,150	1,830	18.40	6.54	280	5.35	2.81
Irvine River			1,250	440	18.40	6.54	67	5.35	2.81
Grand at Conestoga			10,160	3,600	18.40	6.54	550	5.35	2.81
Conestoga River			7,720	1,650	25.30	5.41	305	4.43	4.67
Speed River			3,030	1,460	12.10	5.84	250	4.79	2.07
Grand at Galt			24,000	8,100	18.66	5.95	1,360	4.88	3.13
Nith River			3,900	1,820	10.69	4.99	365	4.09	2.14
Grand at Brantford			30,800	11,360	15.40	5.68	2,000	4.65	2.71
Grand at Belwood	1918	Mar. 16 - Apr. 7	4,290	1,680	15.32	5.98	280	5.11	2.56
Grand at Conestoga			8,430	3,290	15.32	5.98	550	5.11	2.56
Conestoga River			7,340	1,920	24.00	6.30	305	5.39	3.81
Speed River			2,940	1,370	11.76	5.48	250	4.69	2.14
Grand at Galt			21,700	7,980	15.96	5.87	1,360	5.02	2.72
Grand at Brantford			29,000	11,500	14.50	5.75	2,000	4.92	2.56
Grand at Belwood	1919	Mar. 15 - Mar. 31	5,310	1,660	18.97	5.92	280	3.75	3.20
Grand at Conestoga			10.430	3,250	18.97	5.92	550	3.75	3.20
Conestoga River			12,000	2,125	39.40	6.96	305	4.40	5.65
Speed River			3,790	1,190	15.16	4.76	250	3.01	3.18
Grand at Galt			30,090	7,780	22.12	5.71	1,360	3.61	3.70
Grand at Brantford			37,360	10,160	18.68	5.08	2,000	3.21	3.67

River	Year	Period of Flood	Discharge in C.F.S.		Discharge in C.F.S. per Square Mile		Drainage Area (Sq. Miles)	Inches on Drainage Area	Flood Ratio
			Max	Mean	Max	Mean			
Grand at Belwood	1920	Mar. 10 - Apr. 6	3,860	1,580	13.78	5.64	280	5.88	2.44
Grand at Conestoga			5,790	2,590	10.50	4.72	550	4.93	2.22
Conestoga River			6,280	1,390	20.60	4.56	305	4.75	4.51
Speed River			2,390	760	9.55	3.03	250	3.16	3.15
Grand at Galt			16,900	5,510	14.81	4.05	1,360	4.22	3.66
Nith River			4,170	1,600	9.70	3.72	430	3.88	2.61
Grand at Brantford			23,110	7,890	11.55	3.95	2,000	4.12	2.93
Grand at Belwood	1921	Mar. 2 - Apr. 4	4,130	1,350	14.80	4.82	280	6.10	3.07
Grand at Conestoga			7,730	2,160	14.08	3.93	550	4.97	3.58
Conestoga River			5,140	950	16.84	3.11	305	3.94	5.41
Speed River			2,060	590	8.24	2.37	250	3.00	3.47
Grand at Galt			17,030	4,300	12.52	3.15	1,360	3.98	3.98
Nith River			3,970	1,440	9.23	3.35	430	4.24	2.75
Grand at Brantford			22,940	6,440	11.47	3.22	2,000	4.07	3.56
Grand at Belwood	1921	Apr. 18 - May 4	1,800	750	6.50	2.68	280	1.70	2.43
Grand at Conestoga			3,110	1,410	8.37	2.56	550	1.62	3.27
Conestoga River			2,430	450	7.96	1.48	305	0.94	5.37
Speed River			1,450	590	6.16	2.36	250	1.49	2.61
Grand at Galt			8,560	3,050	6.29	2.24	1,360	1.42	2.81
Nith River			3,560	980	8.28	2.27	430	1.44	3.65
Grand at Brantford			13,860	4,510	6.93	2.26	2,000	1.43	3.06

River	Year	Period of Flood	Discharge in C.F.S. Max	Discharge in C.F.S. Mean	Discharge in C.F.S. per Square Mile Max	Discharge in C.F.S. per Square Mile Mean	Drainage Area (Sq. Miles)	Inches on Drainage Area	Flood Ratio
Grand at Belwood	1922	Mar. 4 - Mar. 20	4,900	1,730	17.50	6.18	280	3.90	2.73
Grand at Conestoga			6,400	2,640	11.62	4.81	550	3.04	2.42
Conestoga River			3,960	1,290	13.00	4.23	305	2.67	3.07
Speed River			1,810	890	7.22	3.56	250	2.25	2.03
Grand at Galt			14,010	5,730	10.30	4.21	1,360	2.66	2.44
Nith River			4,630	1,600	10.76	3.72	430	2.35	2.89
Grand at Brantford			20,900	8,110	10.45	4.05	2,000	2.56	2.58
Grand at Belwood	1922	Apr. 2 - Apr. 25	3,400	1,370	12.14	4.92	280	4.40	2.47
Grand at Conestoga			7,120	2,700	12.95	4.92	550	4.40	2.63
Conestoga River			11,180	1,420	36.60	4.65	305	4.16	7.85
Speed River			2,750	1,120	11.00	4.49	250	4.01	2.45
Grand at Galt			23,850	6,380	17.53	4.69	1,360	4.19	3.74
Nith River			4.280	1,460	9.95	3.40	430	3.04	2.93
Grand at Brantford			30,230	8,550	15.12	4.28	2,000	3.83	3.53
Grand at Belwood	1923	Apr. 1 - Apr. 11	4,270	1,910	15.27	6.83	280	2.79	2.24
Grand at Conestoga			8,320	3,760	15.27	6.83	550	2.79	2.24
Conestoga River			4,450	1,290	14.60	4.23	305	1.73	3.45
Speed River			2,290	1,230	9.16	4.91	250	2.01	1.86
Grand at Galt			17,400	7,530	12.79	5.53	1,360	2.26	2.31
Nith River			3,000	1,820	5.68	4.23	430	1.73	1.34
Grand at Brantford			21,590	10,240	10.79	5.12	2,000	2.09	2.30

APPENDIX B

Roads in the Grand Valley

BY

Roger M. Lee

Roads in the Grand Valley

The first arteries of traffic in any new country are the lakes and rivers by which the early settler more easily prospects the land and while these may be somewhat obscured by fast rail and highway routes, they are still of first importance.

The Grand River aided very materially in the early development of the lower part of the valley. Boats ran from Lake Erie up as far as Brantford while farther northward settlers were attracted by the accessibility of its water supply for domestic use and for the operation of grist mills and other industries, which sprang up along its banks.

The great majority of the roads, however, in the Counties of Haldimand, Brant, Waterloo, Wellington and Dufferin, which are the counties of the Grand Valley, were laid out in the township surveys from 1796 and 1854. Most of these surveys were completed under instructions from the Governor but the Townships of North and South Dumfries, which had been granted in block to the Hon. Wm. Dickson, were laid out by a surveyor employed by him. The original deed which is in possession of the ancestors of the late Wm. Dickson, was signed by Joseph Brant and a considerable number of his fellow Indians. The Township of Oakland in the County of Brant, which is the smallest township in any of these counties, was the first to be laid out while the Township of Burford followed two years later.

Certain main diagonal roads were in use, however, prior to or during the early part of this sub-division period and radiated in a fan-like manner from the leading lake points, of which Dundas at the head of the lake was one of the most important. These included the Dundas to Lake Huron Road, the Brock Road which ran northerly to Guelph, the Hamilton to London Road, the road from Burlington to Niagara and others. The Governors Road, conceived by Governor Simcoe as a road for military purposes, was laid out westerly from York in a long straight unbroken line till it reach the Grand River. Many of these roads were first cut out as narrow trails and wet or low-lying portions, which were many, were corduroyed. Certain of them, however, were planked but it was soon found that the planks rotted or were quickly worn away and they were replaced by stone and gravel. The Hamilton to London plank road was constructed of three inch by sixteen foot pine plank of first quality. The planks were laid on three by six inch pine runners which were two and one-half feet apart and ran parallel to the line of traffic. The surface planks were spiked down to the runners by hand made spikes, some of which are still to be found when re-construction work is undertaken. The Dundas to Lake Huron Road was constructed of stone or gravel as a plentiful supply of these materials were available at various points along its route. The population of the Township of Waterloo in 1850 was second only to the population of the Township of York.

While it was necessary for the development of the country that these roads be built by the Government, there were no funds available for their maintenance and they were consequently turned over to toll road companies who maintained them and charged for their use certain tolls. The first of these was the Dundas to Lake Huron Toll Roal Co. which was chartered in 1829. In the course of the following forty or fifty years toll roads became numerous and were reasonably well operated. In some cases they were constructed by private companies for the development of their own lands. Two of the last to disappear were the Cockshutt toll road leading south of the City of Brantford and the Brantford to Paris toll road leading northerly therefrom. During this period stage coaches ran over the more important lines connecting settlements. Farm produce was drawn over them and in the autumn, roads leading to the lake ports were much used. Taverns were established throughout their length at convenient distances and at some of the main intersections four taverns served the travelling public. The lake ports at this season of the year were active places of trade but many of them then important, now remain in name only. In some cases the main road improvements were undertaken by County Councils as was instanced by certain early development in the County of Wellington.

With the coming of the railways long distance farm haulage ceased and the stage coach routes disappeared. By the end of the last century the public demanded a freer use of the roads and the removal of toll roads was hastened by legislation whereby the Province contributed one-third the purchase price providing they were included in a scheme of a County Road System.

The commencement of road construction as we know it today was brought about by the introduction of the motor car about the beginning of this century. Under this influence long distance highway travel has assumed immense proportions and a system of Provincial Highways laid out in 1921 with a length of 1,800 miles has been largely completed and additions are being made yearly to it.

To understand thoroughly the operation of the highway system as it is carried on today and the assistance by Federal and Provincial Governments and the place taken by the rural and urban municipalities, it might be well to review the legislation affecting highways since its inception.

The Ontario Good Roads Association was formed in 1894 and in 1901 the Highway Improvement Act allowed for a grant of one-third contribution by the Province towards the construction of county roads. The Department of Public Highways was created in 1915 by the passing of the Ontario Highway Act, the regulations of which cover the administration of these highways at the present time. The Federal Government in 1919 passed legislation giving aid to the various Provinces in the construction of main highways.

In the central and upper counties of the Grand Valley there are approximately 200 miles of King's Highways. These are financed to the extent of 20 per cent. by the counties and 80 per cent. by the Province except in certain areas adjoining the cities, whereon this latter percentage is decreased by the contribution of 20 per cent. by the cities.

Roads in the rural districts may be divided into three groups, viz., King's highways, county roads and township roads. The Department of Highways designate certain through roads as King's highways and construct and maintain them dividing the cost as above outlined.

The councils of the various counties designate by by-law certain of the remaining roads and assume them as county roads. These are secondary in importance to King's highways and the Department of Highways assists in financing these to an extent of 50 per cent. of the total cost of both construction and maintenance.

The remaining mileage of roads which constitute the greatest mileage, are constructed and maintained by the various townships, who receive a grant of 40 per cent. of the total cost from the Department of Highways.

The total mileage of these various roads in the County of Brant, which may be a fair example is as follows: King's highways 58 miles, county roads 90 miles, township roads 480 miles.

The great bulk of highway traffic has been east and west along Highways 2 and 3 and parallel roads but branching from these the motorist in increasing numbers is travelling northward to the attractive resorts of Northern Ontario. The north and south traffic routes in the Grand Valley particularly in the southern portion, were not permanently surfaced to any extent until a very few years ago and only during the present year are pavements being completed to link up completely its towns and cities. There are still unpaved highways extending southward and eastward in the lower part of the valley and were these completed the result would be an increase in traffic and in business generally to the central and upper sections.

The highways of today are primarily commercial traffic ways which are being constructed with a view to economical transportation and the safety of fast moving traffic. Curves are being constructed to give clear vision and safe alignment while grades are being eliminated at no small cost. It is possible to visualize a time when the routes of additional roadways will be chosen by reason of their scenic advantages. This may mean the construction of roadways whose curves and grades furnish a scenic route rather than a commercial roadway. The natural location for such roadways, still undeveloped, are found along the banks of the Grand River and the adjoining heights of land.

(Signed) ROGER M. LEE.