

**THE MEAN WATER LEVEL AT POINTE-AU-PERE  
AS USED FOR THE INTERNATIONAL GREAT LAKES DATUM (1955)**

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Canadian Tides and Water Levels

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*This paper was first presented at the Symposium on Coastal Geodesy, 20-24 July 1970, Munich, and is here reproduced by kind permission of the International Union of Geodesy and Geophysics.*

**ABSTRACT**

The use of a number of different vertical control datums in carrying out hydraulic studies, crustal movement investigations and hydrography, in establishing water rights and negotiating water treaties is not only confusing but leads to complications. Because Canada and the United States of America share most of the Great Lakes — St. Lawrence River System, a solution to the problem of an acceptable international vertical control network had to be found.

The datum chosen for the system is the mean water level determined at the gauging station at Pointe-au-Pere at the mouth of the St. Lawrence River. This datum is not the same as those used by the U.S. Coast and Geodetic Survey or the Canadian Geodetic Survey. The datum is also quite distinct from both national levelling networks since dynamic elevations or heights are employed rather than the usual orthometric elevations. Furthermore, it takes into account any crustal movement which had taken place prior to the year of levelling and computation.

As a co-operative venture shared by Canada and the United States, levelling was carried out from Pointe-au-Pere to the lakehead to establish elevations relative to the new datum at each gauging site and at all bench marks along the route.

### THE PROBLEM

The Great Lakes System is shared by the United States and Canada, and the joint use of these waters presents many challenging problems. One particular aspect is the data on water levels and the application of these data in hydrology and hydrography. For many years water level data were collected and information distributed, often with little more than superficial and informal correlation with a common basis or datum. About ten years ago, it was decided to remedy this situation and to introduce a vertical control datum to cover the entire St. Lawrence River and Great Lakes Systems, extending some 2 000 miles into the North American Continent. Set in an European context, the combined systems would reach from Poland to the Atlantic shores of France (figure 1). The datum has now been accepted by the two governments for the measurement of water levels and studies related to the water environment.

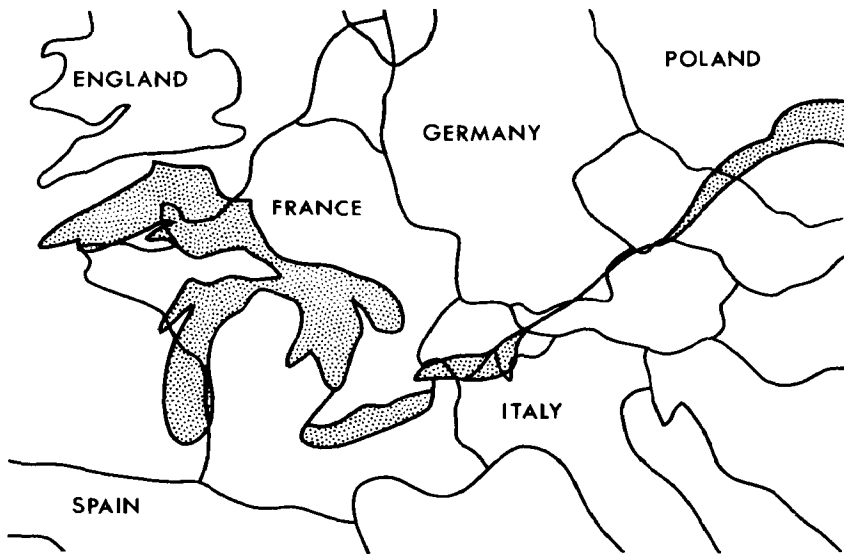


FIG. 1. — The Great Lakes levelling requirements set in an European context.

The Vertical Control Subcommittee of the Co-ordinating Committee on Great Lakes Basic Hydraulic and Hydrological Data was given responsibility for establishing the International Great Lakes Datum. To establish such a datum, several requirements had to be considered.

- (a) It must be acceptable to both governments so that most of the existing datums could be abandoned;
- (b) It should compensate for changes in elevation due to the movement of the earth's crust prior to its introduction;
- (c) It must be suitable for hydraulic and hydrographic purposes.

The United States and Canadian Levelling Systems in existence were not acceptable for several reasons. One of them was that orthometric elevations are not a satisfactory solution for large bodies of water such as the Great Lakes, and another that the reference zeros are not located within the Great Lakes — St. Lawrence River System.

Orthometric elevations represent the linear distance above mean sea level, thus a bench mark with an elevation of 200 metres would be exactly 200 metres regardless of where it is located in Canada. On account of this no large body of water would present a surface that is truly level. Water level measurements obtained at both ends of a lake and connected to an existing national levelling network should normally show a permanent northerly downward slope.

### THE SOLUTION

*Dynamic values* were considered for the system because of the following advantages :

- (a) The difference between the dynamic elevation of two points represents the potential head which would exist in a water system joining them;
- (b) Every point on a mean lake level surface has the same dynamic elevation;
- (c) The dynamic elevation of any point as determined from any other point is the same regardless of the route followed in determining the difference in elevation.

The dynamic correction to an orthometric elevation is expressed as :

$$\text{Dynamic Correction} = - D_1h - D_2h^2$$

where  $D_1h$  constitutes the dynamic correction for latitude and is expressed in the same unit as  $h$  which is the average elevation of the instrument between two points, and  $D_2h^2$  is mainly a dynamic correction for elevation.

Values of  $D_1h$  and  $D_2h^2$  can be obtained from published tabulations of the U.S. Coast and Geodetic Survey.

A new *Reference Zero* had to be selected. This required special investigation of the data obtained at several gauging stations. The following points has to be considered :

- (a) The zero, and therefore the gauge, should be situated within the hydraulic system for which the new datum will be used, and the station should have a long period of reliable records;
- (b) The data should show the least difference in the departure of mean sea level if compared with other tidal stations for a period of over five years, and the mean water level computed at such a locality should represent as closely as possible the mean sea level;
- (c) The gauge should be so situated that the tectonic features of the location are similar to those of the rest of the area to be controlled;

(d) The station must be tied into the existing national levelling network, and in addition to maintaining a good levelling and bench mark system within the immediate area of the gauging station, ties to the National Levelling network must be made from time to time;

(e) Meteorological data should be available for the immediate vicinity of the permanent recording station, and the station must be maintained at the same locality continuously for re-evaluation of the datum within a time span of 20 to 30 years.

### GAUGING STATIONS AND INTERPRETATION OF DATA

Permanent gauges which could fulfill the requirements enumerated in the foregoing paragraphs (a) to (e) are located at Quebec City (Lauzon) and Pointe-au-Pere along the south shore of the St. Lawrence River and at Harrington Harbour on the north shore of the Gulf of St. Lawrence (figure 2). Records have been obtained at these stations for many decades. The records may be classed reliable since the accuracy of the data can be established from the available source material which consists of :

(a) the equipment used, and the horizontal and vertical reduction factors applied in measuring the water level (figure 2a);

(b) a knowledge of the ratio of the inlet to the stilling well area (figure 2b);

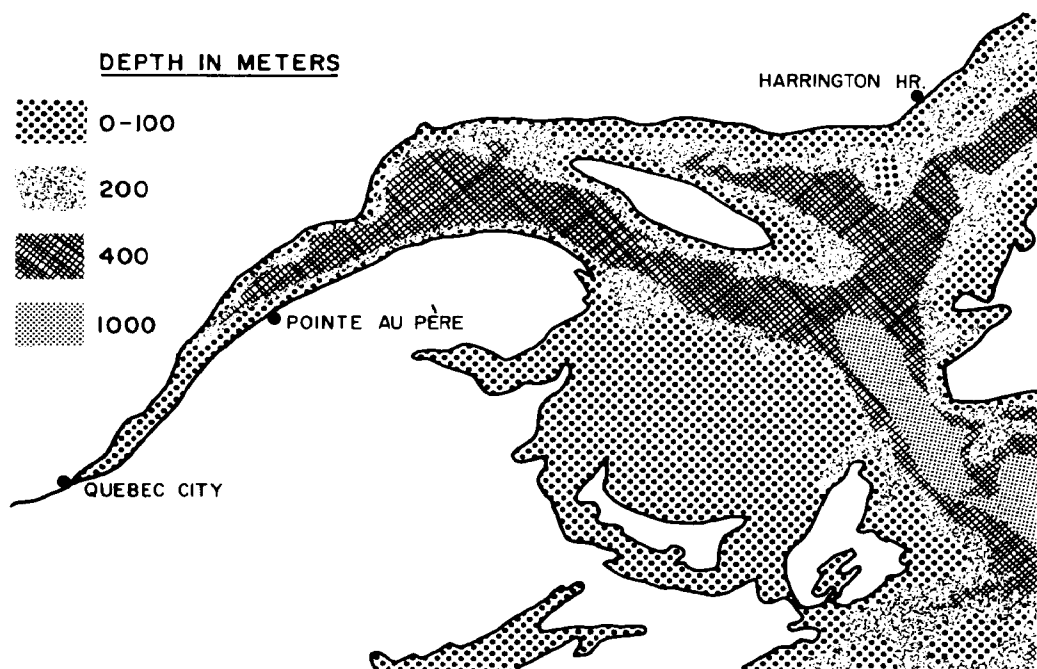


Fig. 2. — Location of permanent gauges along the St. Lawrence River.

- (c) the vertical stability of the station within the immediate area;  
 (d) the change of location and of the equipment within the area for which the water level data apply.

The tidal characteristics (figure 3) at Quebec City and Pointe-au-Pere are semi-diurnal, thus there are two complete tidal oscillations daily. The two daily high water elevations are similar, and this applies also to the two daily low water elevations. The two high waters of the day follow the upper and lower transit of the moon by nearly the same interval. The mean tide range at Quebec City is 13.3 feet while at Pointe-au-Pere a mean range of 10.0 feet has been computed. The tidal characteristics at Harrington Harbour are of the mixed type, but mainly semi-diurnal. Two complete tidal oscillations occur daily with inequalities both in heights and in the time taken to reach the greatest values when the declination of the moon has passed its maximum. The mean range at this station is only 7.6 feet.

Mean values computed from high and low water observations and from the hourly water levels for a period of one year at each station expressed as :

$$X = \frac{1}{n} (x_1 + x_2 + \dots + x_n)$$

reveal a difference of about one to two feet at Quebec City while at the other two stations less than 1/10 of a foot can be detected. Thus, the effect of the discharge of the St. Lawrence River, meteorological disturbances and seabed topography on the water level data for Quebec City is greater than for Pointe-au-Pere or for Harrington Harbour. For this reason, the Quebec City station could not be considered suitable for the establishment of a levelling zero.

By inspection of figure 4, representing monthly and yearly mean values, and figure 5, showing the differences of these values between stations 142-141 and 142-143, a very small rise of the water surface in reference to the land can be seen to have taken place at Quebec City (141) and at Pointe-au-Pere (142), while at Harrington Harbour (143) the opposite occurred. The values obtained from least square computation confirm these trends and the following rise/fall per year has been obtained.

			Standard Error
Quebec City	Rise in feet per year	0.0010	0.0017
Pointe-au-Pere	Rise in feet per year	0.0007	0.0004
Harrington Harbour	Fall in feet per year	0.0036	0.0011

The long-period frequencies Ssa, Mm and Msf are also more pronounced at Quebec City than at the stations at Pointe-au-Pere and Harrington Harbour (figure 6). The period for the power spectral analysis used to compute and prepare figure 6 consists of one year of hourly water-level data.

According to figure 7, Harrington Harbour, from a geological point of view, would be the best location because the area to be controlled by the new zero and datum is mostly of Kenoran and Grenvillian orogen.

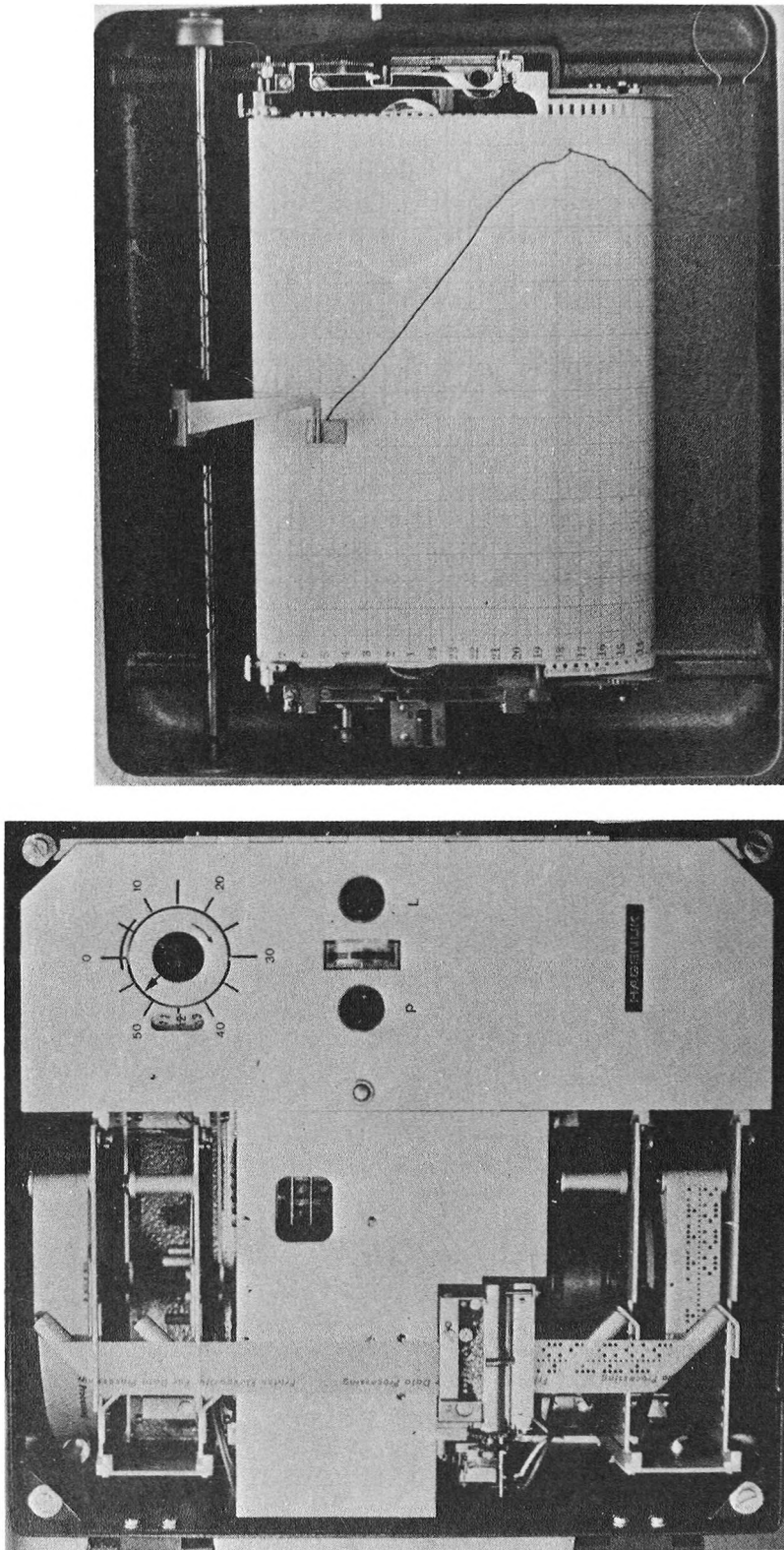


Fig. 2 (a). — Analogue and digital gauging equipment.

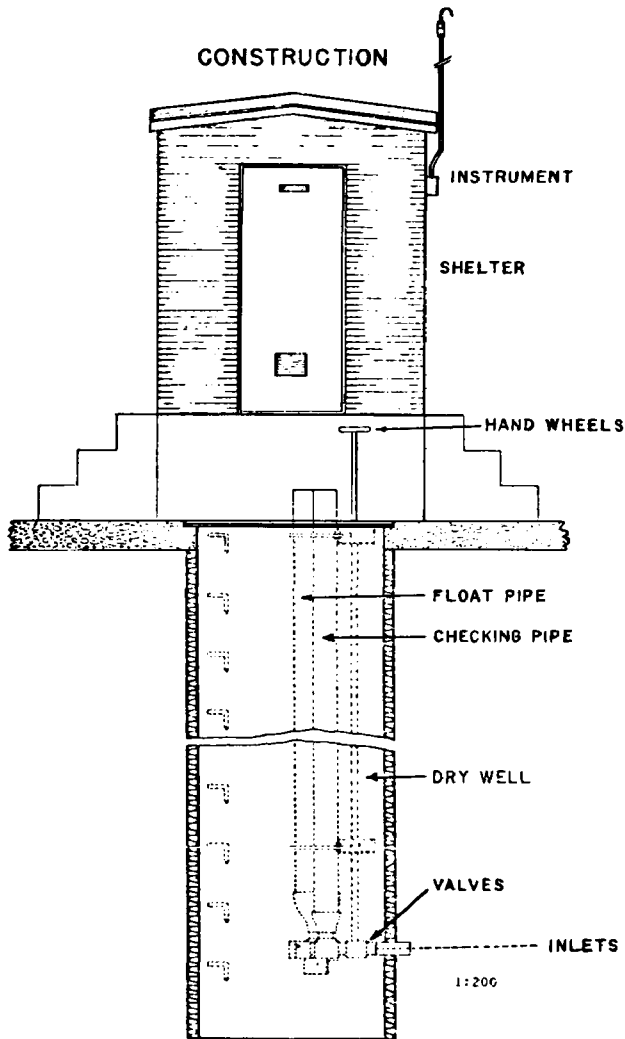


FIG. 2 (b). — A typical gauge station.

The stations at Pointe-au-Pere and Quebec City are situated in an area of taconic orogen and furthermore lie south of an ancient fault line (Logan's Line). The fact that these two stations are separated from the area to be controlled by a significant geological feature could affect the stability of the station in reference to this area.

Only Pointe-au-Pere and Quebec City, however, were connected to the present National Levelling Network of the Geodetic Survey of Canada and this ruled out Harrington Harbour as a possible choice for the establishment of the zero.

Meteorological data is available in the vicinity of the Pointe-au-Pere gauging station. The station itself will be operated for an indefinite period as a tidal station to reassess in future years the International Great Lakes Datum (1955).





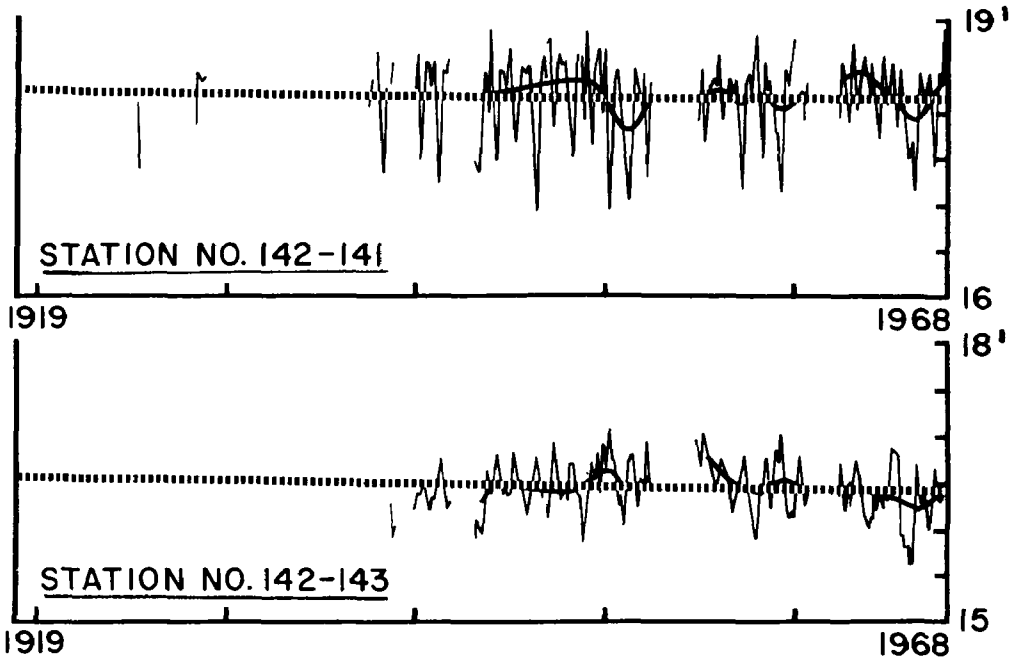


FIG. 5. — Plot of monthly mean differences of Pointe-au-Pere minus Quebec City and Pointe-au-Pere minus Harrington Harbour.

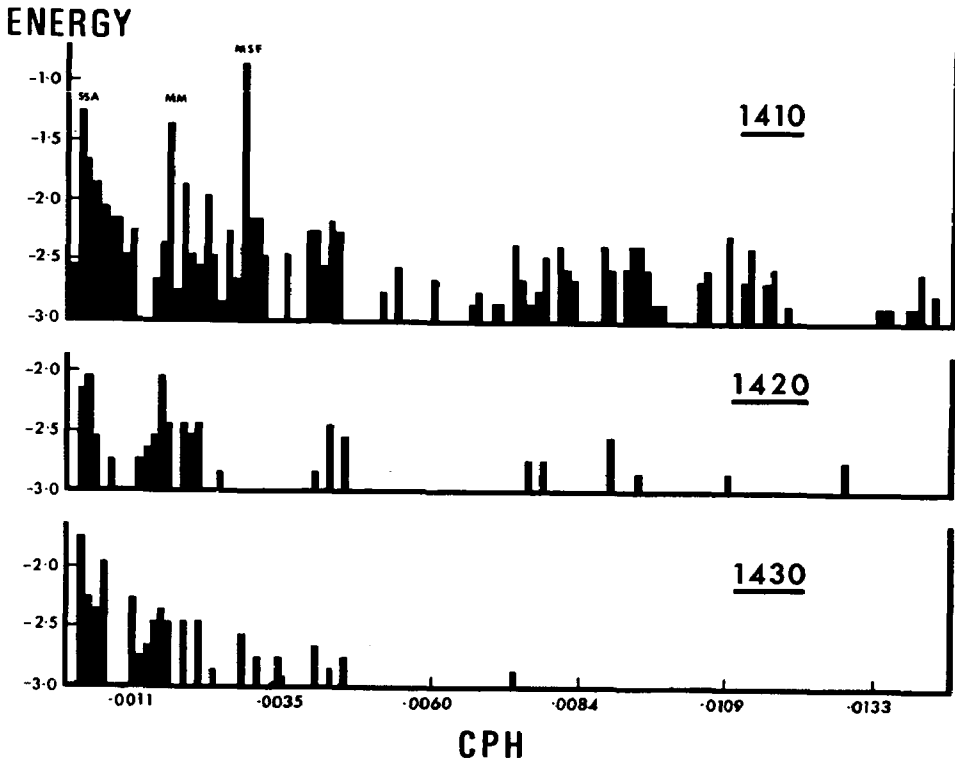


FIG. 6. — Power spectra analysis for Quebec City, Pointe-au-Pere and Harrington Harbour.

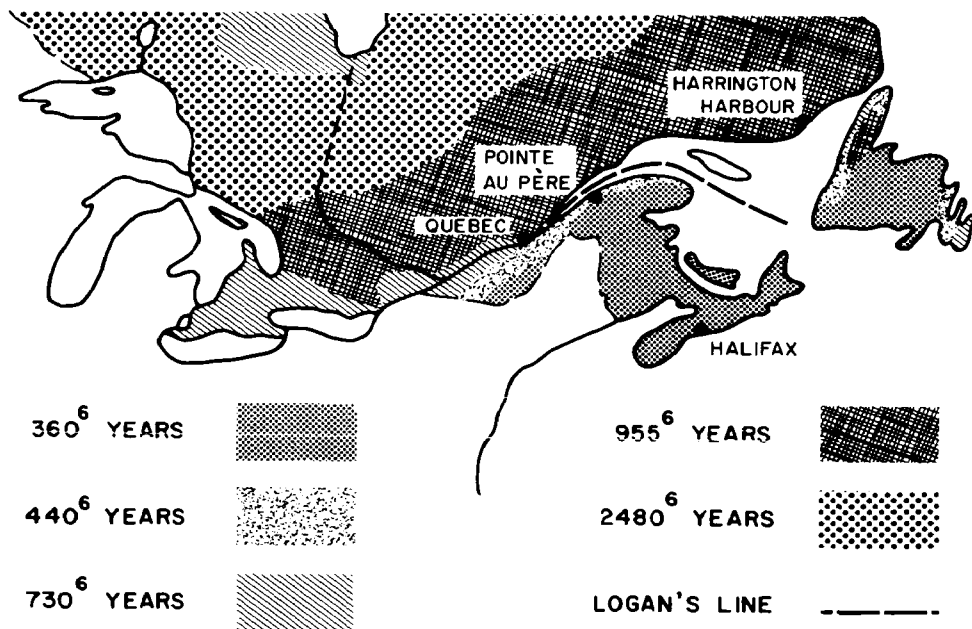


FIG. 7. — Tectonic features of the area to be controlled.

### THE DATUM

Taking into consideration all the aforementioned factors, Pointe-au-Pere was selected as the reference gauge for the establishment of the International Great Lakes Datum 1955. Figure 4 shows the monthly and yearly mean water elevations at Pointe-au-Pere for the years of record. Each yearly mean is the sum of the hourly readings taken during the year, divided by the number of hours of record for that year. The period between 1941 and 1956 was used in the final determination to minimize any possible level changes at Pointe-au-Pere, and because better gauging equipment, improved methods, and more rigid control were used during that period.

The datum was established as 7.486 feet above the zero of the gauge and was referenced to a bench mark located in bedrock near the gauging station. Instrument levelling was carried out from Pointe-au-Pere along the St. Lawrence River route to Thunder Bay. Lake surfaces were used to transfer elevations across the Great Lakes (figure 8). The methods of levelling and water level transfer are not covered in this article since a special investigation to compare instrument levelling with hydrostatic levelling around and across large lakes is planned.

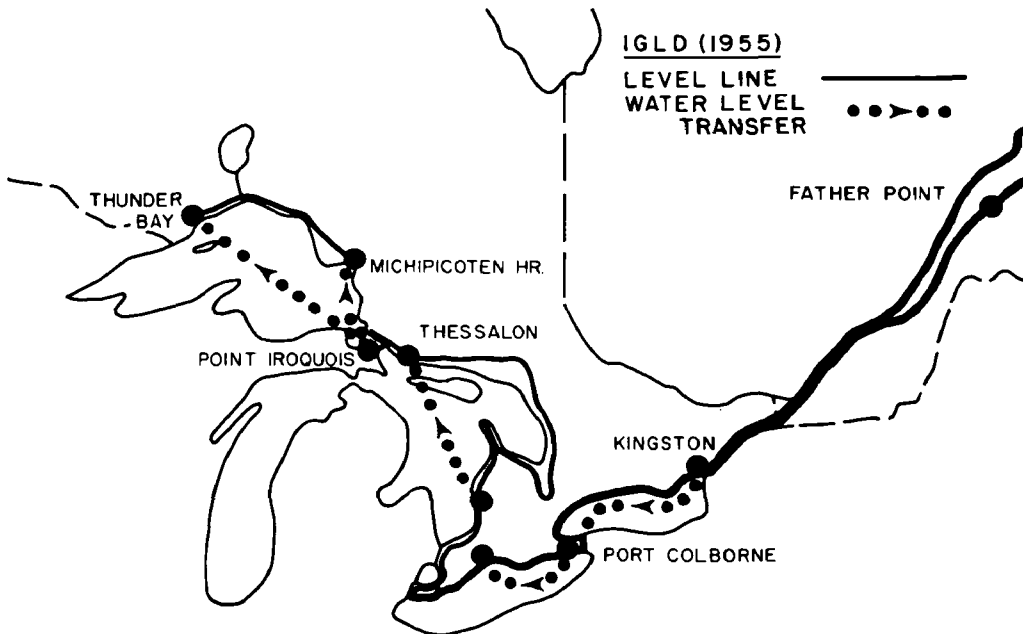


FIG. 8. — The level routes followed.

### FUTURE PLANS

It is well known that the surface of any body of water is tilted or warped by the influence of the current, the wind differentials of barometric pressure, tides and temperature gradients. Therefore, as a prerequisite to expanding the significance of the water level readings at permanent gauge sites, certain meteorological data must be made available. As these data have not been quantitatively evaluated or correlated with continuous water level recordings within the area of our study, a joint Canada-United States program to reassess the International Great Lakes Datum 1955, particularly with respect to the method of water level transfer, has been initiated. At selected gauging stations, the following parameters will be recorded at hourly intervals over a period of one year :

<u>Parameter</u>	<u>Accuracy</u>	<u>Elevation</u>
Wind direction	$\pm 2^\circ$	10 metres above chart datum
Wind velocity	$\pm 0.2$ metre per second	10 metres above chart datum
Barometric pressure	$\pm 0.5$ millibar	At land surface elevation
Air temperature	$\pm 0.5^\circ$ centigrade	At land surface elevation

In addition, the same instrument levelling procedures and the routes used for the establishment of the 1955 datum will be followed.

The factors that will be used to decide whether a new or revised datum for the Great Lakes — St. Lawrence River System should be introduced in the near future will be the extent of any permanent lake surface tilt due to meteorological or hydrological causes, the rates of crustal movement along levelling routes and possible changes in the water level at Pointe-au-Pere.

#### REFERENCES

- The Co-ordinating Committee on Great Lakes Basic Hydraulic and Hydrological Data, 1961 — Establishment of International Great Lakes Datum (1955).
- DOHLER, G. : Tides in Canadian Waters.
- DOHLER, G. (1961) : The Adoption of the International Great Lakes Datum (1955).
- DOHLER, G. and KU (1970) : The Presentation and Assessment of Tides and Water Level Records for Geophysical Investigations, *Canadian Journal of Earth Sciences* (In Press).
- Geological Survey of Canada (1968) : Tectonic map of Canada.
- MACLEAN, W. (1962) : Postglacial uplift in the Great Lakes Region, University of Michigan.
- ROPES, G.E. (1965) : Vertical control on the Great Lakes, *Journal of the Surveying and Mapping Division*, American Society of Civil Engineers.