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BASIN DESCRIPTION AND INFORMATION PERTINENT TO MASS BALANCE STUDIES OF THE TURKEY LAKES WATERSHED.

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Environmental Contaminants Div.
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Canada Centre for Inland Waters
867 Lakeshore Road. PO Box 5050
Burlington, Ontario, L7R 4A6.

ABSTRACT

The Turkey Lakes Watershed is located in undisturbed terrrain approximately 50 km north of Sault Ste. Marie, Ontario, and 25 km east of the Lake Superior shoreline. The watershed is dominated by Batchawana Mountain thereby exhibiting an overall relief of 300 m. It contains a chain of five lakes surrounded by mixed forest and is predominantly underlain by intermediate to basic metavolcanic rocks and overlain by basal tills of variable thickness (thinnest at the highest altitudes). The overall watershed area is 1050 ha while lake areas and maximum depths range from 5.8 to 52 ha and 4.5 to 37 m respectively. All hydrologic and chemical measurements necessary for the calculation of lake material budgets are being performed and the data are being stored in the computerized NAQUADAT system. Preliminary water budget calculations show that the theoretical water renewal times for the lakes range from approximately 0.2 to 1.6 years.

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INTRODUCTION

Chemical and hydrological monitoring of the Turkey Lakes Watershed was begun in 1980 with the purpose of elucidating the effects of the long range transport of air pollutants (LRTAP) on sensitive aquatic and terrestrial ecosystems. Through study of the interactions of atmospherically deposited strong acids with forest, soil, surface and groundwater systems and their associated biotic communities it will be possible to determine the mechanisms controlling the acidification process. Additional information on acidification rate and the pathways of other contaminants may also be obtained.

The effects of LRTAP on lakes and streams on the Canadian Shield may be investigated by a mass balance approach, that is by measuring the material budgets for small watersheds (see discussion by Likens *et al.*, 1977). This report provides a summary description of the Turkey Lakes Watershed, giving the information required to subsequently calculate mass balances for the five lakes within the basin when sufficient chemical and hydrologic data have been collected. The description includes location and general topography, basin size, sampling stations and data storage, lake morphometry, bedrock and surficial geology, and calculation of a water budget. The geological and water budget information shall be considered preliminary in nature.

I. Study Area

The Turkey Lakes Watershed is located on the Canadian Shield, in Norberg and Wishart Townships approximately 50 km north of Sault Ste. Marie, Ontario, and 25 km east of Coppermine Point on Lake Superior (Figure 1). The overall basin is 10.5 km^2 in size and contains a headwater chain of five lakes (Batchawana Lake (2 distinct basins), Wishart Lake, Little Turkey Lake, and Turkey Lake) which drain into the Batchawana River, and ultimately, Lake Superior. The lakes vary in size from 6 to 52 ha.

The watershed is completely underlain by sparingly soluble silicate bedrock (greenstones and granites) and is overlain by generally thin and discontinuous glacial till.

Except for past logging operations, the watershed is essentially undisturbed. The closest point-source emitter of air pollutants is the steel mill coke ovens which are 50 km south at Sault Ste. Marie. One hundred km to the north is an iron ore sintering plant at Wawa, Ontario. The influence of both of these sources is minimized by the predominantly westerly wind direction.

The general topography of the basin is shown in Figure 2. Batchawana Mountain (elevation 630 m AMSL) is the dominant topographic feature of the area and forms most of the northern boundary of the watershed. Elevation at the lowermost gauging station is approximately 340 m giving an overall basin relief of nearly 300 m. Batchawana Lake lies 497 m AMSL while the lower three lakes fall between 388 and 372 m. Because

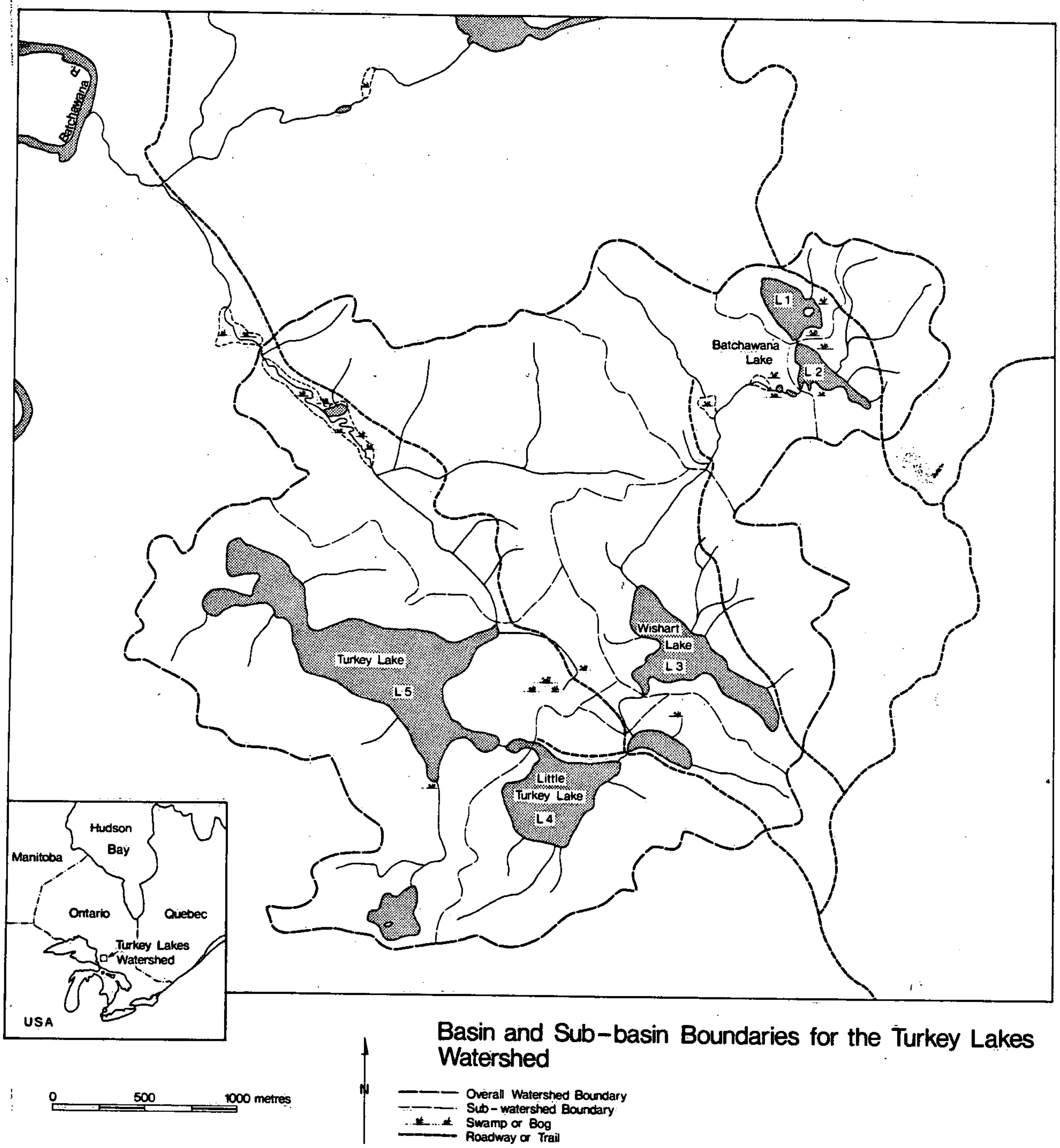
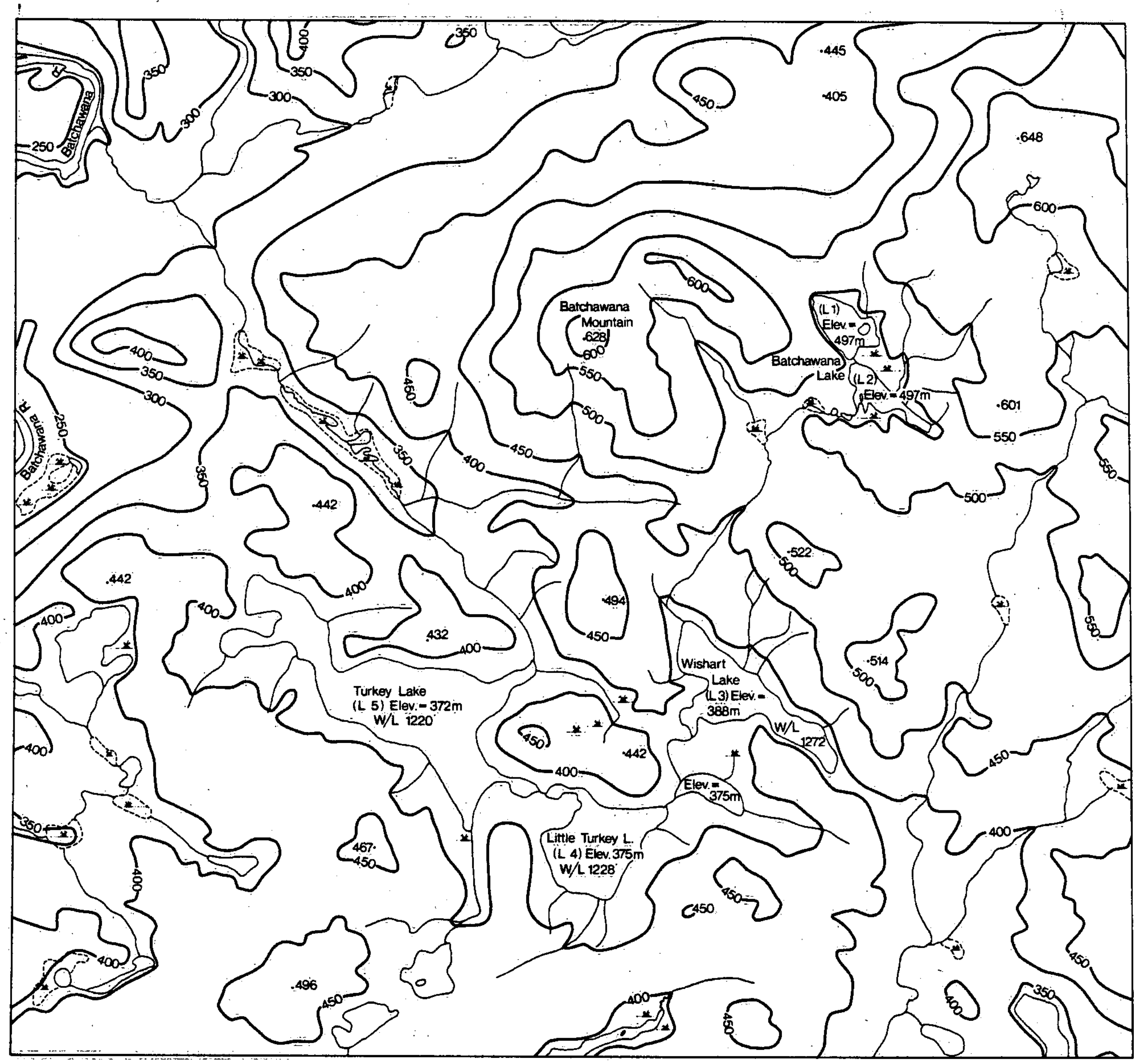

Batchawana
Batchawana Lake
L 1
L 2
Wishart Lake
L 3
Turkey Lake
L 5
Little Turkey Lake
L 4
Hudson Bay
Manitoba
Ontario
Quebec
Turkey Lakes Watershed
USA
Basin and Sub-basin Boundaries for the Turkey Lakes Watershed
0
500
1000 metres
N
Overall Watershed Boundary
Sub-watershed Boundary
Swamp or Bog
Roadway or Trail

Figure 1.



Topographic Map of the Turkey Lakes Watershed

0 500 1000 metres

N

Contour Interval 50 metres
·496 Elevation (metres AMSL)
Bog or swamp

Figure 2.

precipitation in this area is influenced by the rapid changes in elevation (e.g., orographic effects), it is likely that the upper sub-basin (e.g., for Batchawana Lake) will receive an overall higher annual water input (particularly in winter) than the remaining portions of the watershed.

The degree of relief present in the Turkey Lakes Watershed results in a small, generally sharply defined, sub-basin (Figure 1) for each of the lakes which has implications for both the water budgets of the lakes (discussed later) and rate and type of material being sedimented.

II. Watershed Boundaries and Areas

The overall watershed boundary and the extent of its component sub-watersheds are shown in Figure 1. Location of the boundaries was obtained by assessing the contour pattern on the topographic map prepared by Kenting Earth Sciences Ltd. (scale = 1:12,000 with 20 ft. contour interval). Basin and sub-basin areas were determined by digitizing with a mini-computer controlled digitizer and are presented in Table I.

Note that sub-watershed boundaries are keyed to the position of Water Survey of Canada gauging stations (see Figure 9 in Section V below). In the case of Turkey and Little Turkey Lakes, the WSC gauges (S4 and S3 respectively) are situated at the outflows of the lakes, while for Batchawana and Wishart Lakes the gauges are downstream from the outflows. Use of the stations to measure lake outflow is therefore erroneous, although the error for the Wishart Lake gauge (S2) is trivial. The error which arises when using S1 for Batchawana Lake is nearly 100% however, so that a new gauging station (S0) has been established at the outflow of this lake.

The overall Turkey Lake Watershed drainage area is 1050 ha. Note that this area is considerably smaller than previously quoted values which were presumably obtained from smaller scale topographic maps and probably contained area below S5. The ratio of lake to sub-watershed area is also presented in Table 1. In a general way, the greater the ratio value, the greater the relative importance of direct input of precipitation (e.g., to the lake's surface) to the lake's chemical and hydrological budget.

III. Lake Morphometry

The morphometric character of the lakes within the Turkey Lake Watershed are summarized in Tables II to VI which are accompanied by appropriate bathymetric maps (Figures 3 to 6). The maps were prepared from sounding data previously collected by Technical Operations personnel of the NWRI. Sounding depths were measured using a Raytheon portable sounder along known transects of the lakes, and the data recorded at the appropriate location on optically enlarged versions of the lakes' outlines. Lake outline enlargement was made from a Department of Lands and Forest, Forest Resource Inventory Map (scale 4 in = 1 mile) so that the "working" maps were of the scale 25.7 cm = 1 km. Bathymetric contours were then drawn on the maps and in most cases, they corresponded closely to those on the maps

Table I. Basin and sub-basin areas for the Turkey Lakes Watershed.

Basin[1]	Total Area[2] (ha)	Lake Area (ha)	Ratio[3]	Terrestrial Area[4] (ha)
Batchawana L. (North)	24.0	5.88	0.245	18.1
Batchawana L. (South)	61.7	5.82	0.0943	55.9
Batchawana L. (Whole)	85.6	11.7	0.137	73.9
Basin above S1	185	-	-	173
Wishart Lake[5]	337	19.2	0.0570	306
Little Turkey Lake	491	19.2	0.0391	441
Turkey Lake	803	52.0	0.0648	701
Basin above S5	1050	-	-	948

1 - Basin for a lake includes all terrestrial and aquatic terrain above the outflow of the lake.

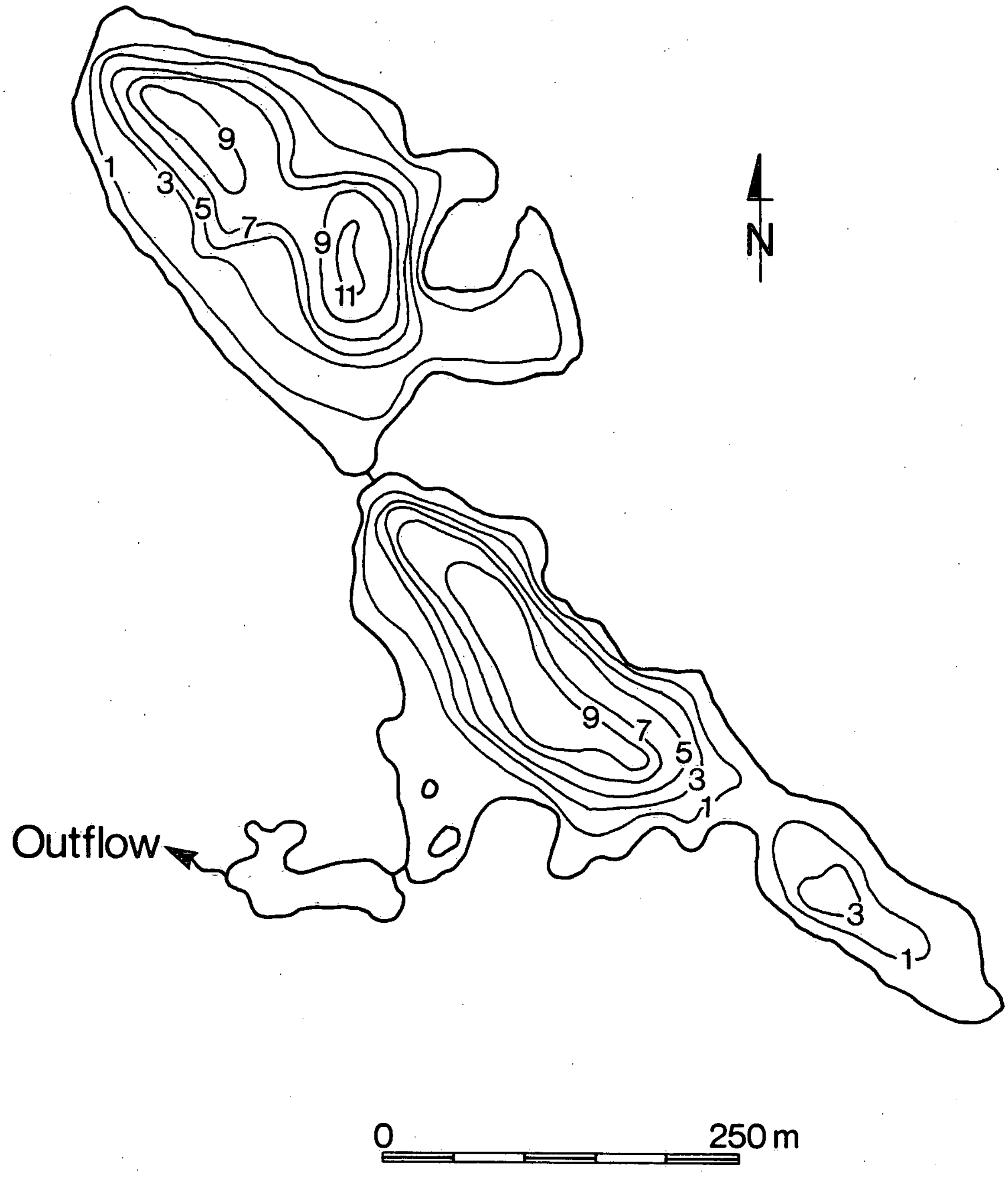
2 - Includes lake area.

3 - Ratio - Lake Area/Total Area.

4 - Terrestrial Area = Total Area - Σ(Lake Areas).

5 - Area above S2 = 344 ha, e.g. 2.1% greater than area above Wishart L. outflow.

BATCHAWANA LAKE BATHYMETRY



Contours in metres, maximum depth, North Basin 11.3 m
South Basin 10.9 m

Figure 3.

Table II. Summary of the morphometry of Batchawana Lake (North Basin)

Lake Area A (ha)	Lake Volume $\bar{V}$ ($m^3 x 10^5$)	Mean Depth $\bar{Z}$ (m)	Maximum Depth Z_m (m)	Shoreline Length L (km)	Development of Shoreline D_L	Development of Volume D_V
5.88	2.27	3.87	11.3	1.31	1.53	1.03

Volume of Lake Layers

Top (m)	Bottom (m)	Volume ($m^3 x 10^5$)
0.0	1.0	0.518
1.0	3.0	0.715
3.0	5.0	0.461
5.0	7.0	0.331
7.0	9.0	0.190
9.0	11.0	0.055
11.0	11.3	0.001

Top* (m)	Bottom* (m)	Volume* ($m^3 x 10^5$)
0.0	1.0	0.518
1.0	2.0	0.403
2.0	3.0	0.312
3.0	4.0	0.250
4.0	5.0	0.211
5.0	6.0	0.179
6.0	7.0	0.153
7.0	8.0	0.116
8.0	9.0	0.074
9.0	10.0	0.040
10.0	11.0	0.015
11.0	11.3	0.001

* Interpolated values

Table III. Summary of the morphometry of Batchawana Lake (South Basin)

Lake Area A (ha)	Lake Volume V ($m^3 x 10^5$)	Mean Depth $\bar{Z}$ (m)	Maximum Depth Z_m (m)	Shoreline Length L (km)	Development of Shoreline D_L	Development of Volume D_V
5.82	1.90	3.27	10.9	1.61	1.88	0.900

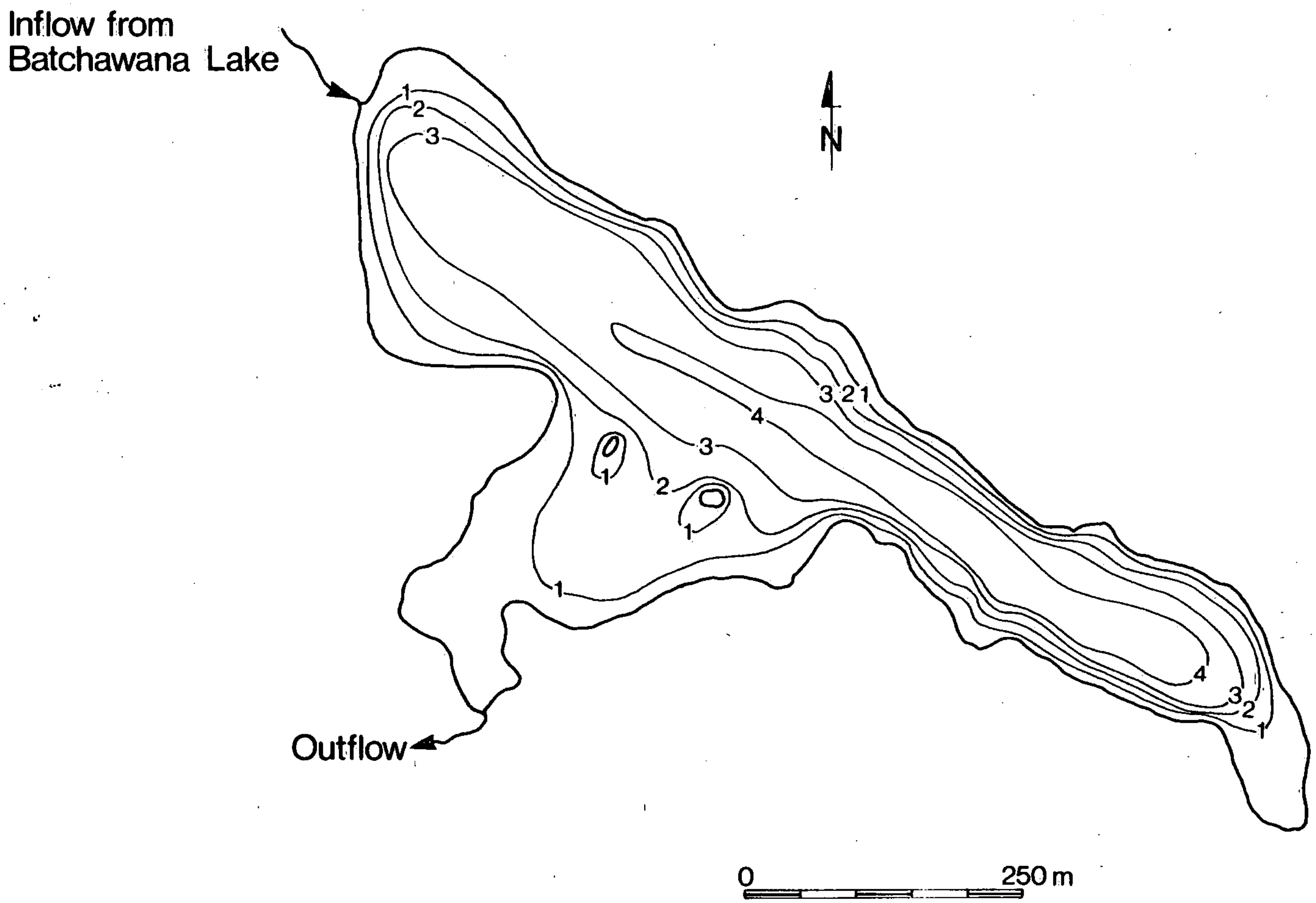
Volume of Lake Layers

Top (m)	Bottom (m)	Volume ($m^3 x 10^5$)
0.0	1.0	0.457
1.0	3.0	0.571
3.0	5.0	0.398
5.0	7.0	0.277
7.0	9.0	0.163
9.0	10.9	0.035

Top* (m)	Bottom* (m)	Volume* ($m^3 x 10^5$)
0.0	1.0	0.457
1.0	2.0	0.313
2.0	3.0	0.258
3.0	4.0	0.215
4.0	5.0	0.183
5.0	6.0	0.153
6.0	7.0	0.125
7.0	8.0	0.096
8.0	9.0	0.067
9.0	10.0	0.031
10.0	10.9	0.004

* Interpolated values

WISHART LAKE BATHYMETRY



Contours in metres, maximum depth 4.5 m

Figure 4.

Table IV. Summary of the morphometry of Wishart Lake

Lake Area A (ha)	Lake Volume V ($m^3 x 10^5$)	Mean Depth $\bar{Z}$ (m)	Maximum Depth Z_m (m)	Shoreline Length L (km)	Development of Shoreline D_L	Development of Volume D_V
19.2	4.21	2.19	4.5	3.14	2.02	1.46

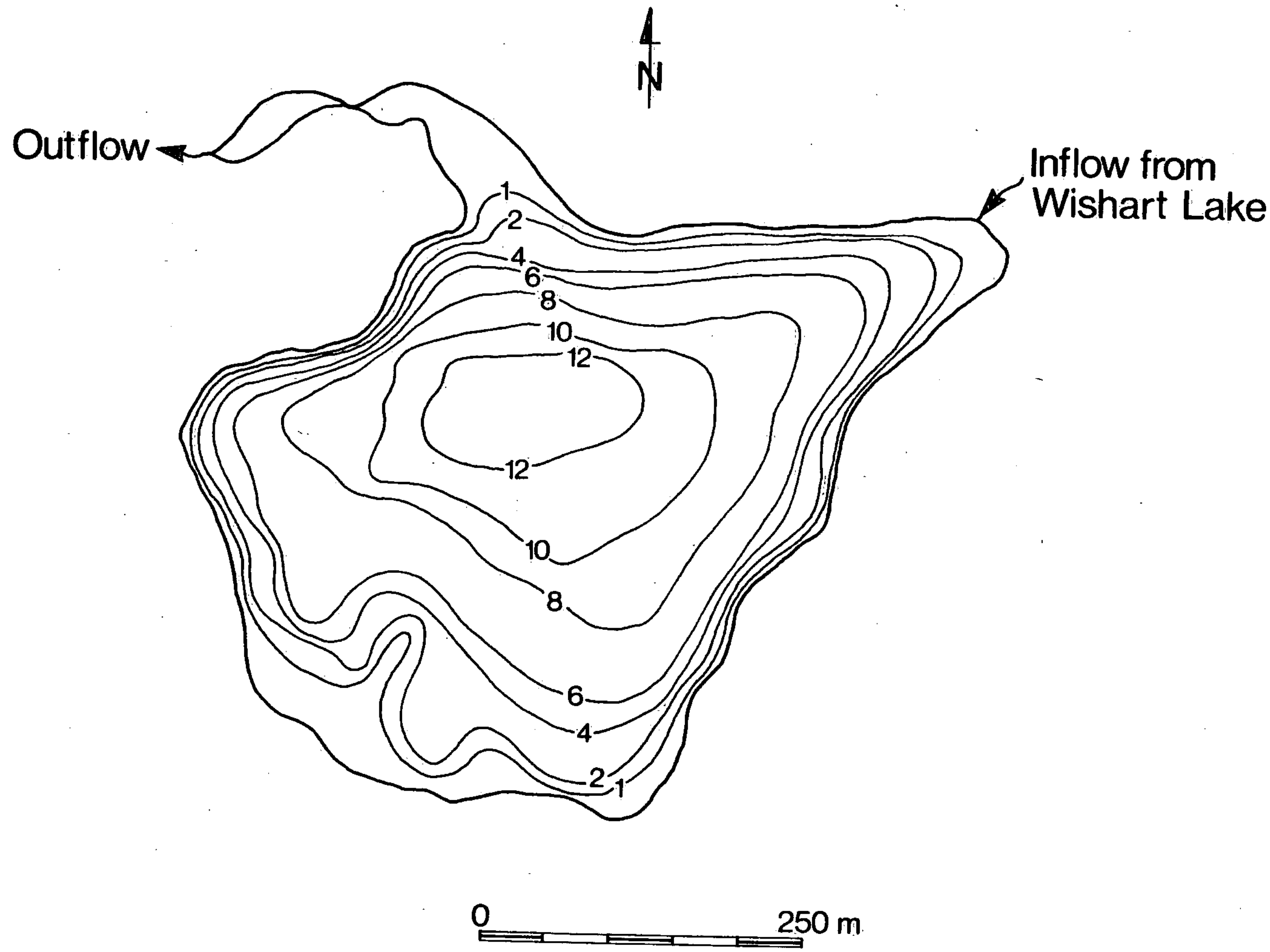
Volume of Lake Layers

Top (m)	Bottom (m)	Volume ($m^3 x 10^5$)
0.0	1.0	1.66
1.0	2.0	1.21
2.0	3.0	0.872
3.0	4.0	0.432
4.0	4.5	0.033

Top* (m)	Bottom* (m)	Volume* ($m^3 x 10^5$)
0.0	0.5	0.893
0.5	1.0	0.764
1.0	1.5	0.653
1.5	2.0	0.559
2.0	2.5	0.474
2.5	3.0	0.398
3.0	3.5	0.282
3.5	4.0	0.150
4.0	4.5	0.033

* Interpolated values

LITTLE TURKEY LAKE BATHYMETRY



Contours in metres, maximum depth 13 m

Figure 5.

V. Summary of the morphometry of Little Turkey Lake

Lake Area A (ha)	Lake Volume V ($m^3 x 10^5$)	Mean Depth $\bar{Z}$ (m)	Maximum Depth Z_m (m)	Shoreline Length L (km)	Development of Shoreline D_L	Development of Volume D_V
19.2	11.6	6.04	13.0	2.15	1.38	1.39

Volume of Lake Layers

Top (m)	Bottom (m)	Volume ($m^3 x 10^5$)
0.0	1.0	1.79
1.0	2.0	1.58
2.0	4.0	2.75
4.0	6.0	2.31
6.0	8.0	1.69
8.0	10.0	0.973
10.0	12.0	0.450
12.0	13.0	0.041

Top* (m)	Bottom* (m)	Volume* ($m^3 x 10^5$)
0.0	1.0	1.79
1.0	2.0	1.58
2.0	3.0	1.44
3.0	4.0	1.31
4.0	5.0	1.20
5.0	6.0	1.11
6.0	7.0	0.952
7.0	8.0	0.739
8.0	9.0	0.560
9.0	10.0	0.413
10.0	11.0	0.281
11.0	12.0	0.169
12.0	13.0	0.041

* Interpolated values.

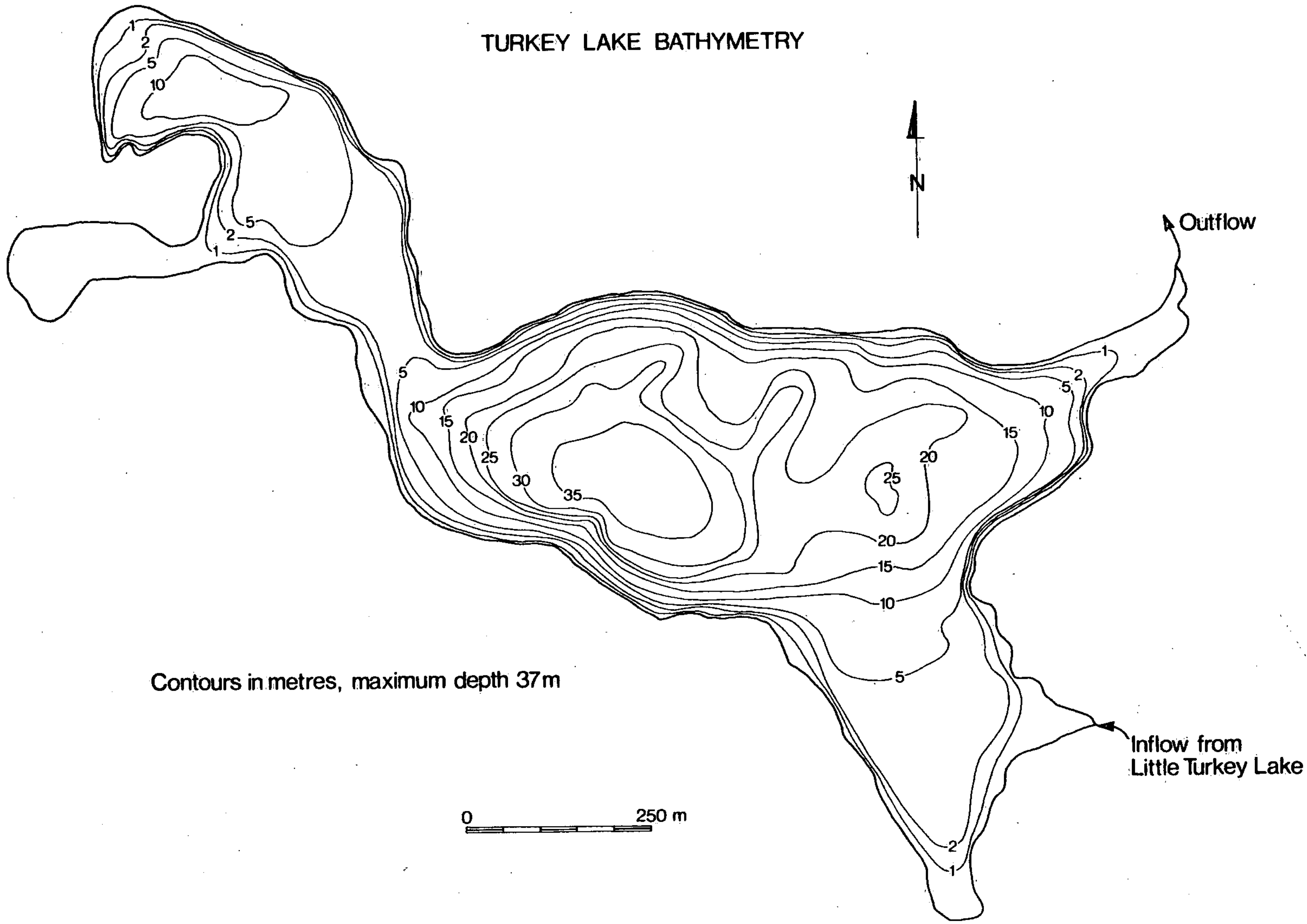

TURKEY LAKE BATHYMETRY
N
Outflow
Inflow from
Little Turkey Lake
Contours in metres, maximum depth 37 m
0
250 m
1
2
5
10
15
20
25
30
35

Figure 6.

Table VI. Summary of the morphometry of Turkey Lake

Lake Area A (ha)	Lake Volume V ($m^3 x 10^5$)	Mean Depth $\bar{Z}$ (m)	Maximum Depth Z_m (m)	Shoreline Length L (km)	Development of Shoreline D_L	Development of Volume D_V
52.0	63.4	12.2	37.0	5.91	2.31	0.989

Volume of Lake Layers

Top (m)	Bottom (m)	Volume ($m^3 x 10^5$)
0.0	1.0	4.88
1.0	2.0	4.40
2.0	5.0	11.20
5.0	10.0	14.10
10.0	15.0	10.80
15.0	20.0	7.99
20.0	25.0	5.06
25.0	30.0	3.11
30.0	35.0	1.74
35.0	37.0	0.145

Top* (m)	Bottom* (m)	Volume* ($m^3 x 10^5$)
0.0	1.0	4.88
1.0	2.0	4.40
2.0	3.0	4.06
3.0	4.0	3.71
4.0	5.0	3.39
5.0	6.0	3.14
6.0	7.0	2.97
7.0	8.0	2.81
8.0	9.0	2.65
9.0	10.0	2.49
10.0	11.0	2.37
11.0	12.0	2.26
12.0	13.0	2.16
13.0	14.0	2.07
14.0	15.0	1.97
15.0	16.0	1.86
16.0	17.0	1.72
17.0	18.0	1.59
18.0	19.0	1.47
19.0	20.0	1.35
20.0	21.0	1.23
21.0	22.0	1.12
22.0	23.0	1.01
23.0	24.0	0.902
24.0	25.0	0.803
25.0	26.0	0.728
26.0	27.0	0.673
27.0	28.0	0.620
28.0	29.0	0.569
29.0	30.0	0.521
30.0	31.0	0.465
31.0	32.0	0.402
32.0	33.0	0.344
33.0	34.0	0.290
34.0	35.0	0.241
35.0	36.0	0.127
36.0	37.0	0.018

* Interpolated values.

previously completed by Technical Operations. The variations which do exist between them generally arose from differences in interpretation of the data. Shoreline length and contour areas were determined using a mini-computer controlled digitizer.

The descriptive parameters outlined in the map and table for each lake are as defined by Hutchinson (1957) and include the following:

1) Lake Area (A) - lake surface area in ha.
2) Lake Volume (V) - total lake volume in $m^3 \times 10^5$ calculated by summing the individual stratum volumes determined as noted below.
3) Mean Depth ($\bar{z}$) - calculated as V/A and reported in meters.
4) Maximum Depth (z_m) - the maximum depth in meters determined while echo-sounding the lake.
5) Shoreline Length (L) - total shoreline length in km.
6) Development of Shoreline (D_L) - a dimensionless parameter which is the ratio of the shoreline length to the length of the circumference of a circle of equal area to that of the lake.

$$D_L = L/2\,(\pi A)^{\frac{1}{2}} \qquad (1)$$

This quantity cannot be less than one and may be considered a measure of the potential effect of the littoral zone on the lake as a whole.

7) Development of Volume (D_V) - a dimensionless parameter which is the ratio of the volume of the lake to that of a cone of basal area A and height z_m.

$$D_V = 3\bar{z}/z \qquad (2)$$

This quantity is an expression of the form of the lake basin.

8) Stratum Volume - the volume of the lake stratum in $m^3 \times 10^5$ defined by a selected upper and lower contour depth and calculated as follows:

$$V_{m-n} = 1/3 \; (A_m + A_n + (A_m A_n)^{\frac{1}{2}}) \cdot (m-n) \qquad (3)$$

where A_m = surface area of the lower contour

A_n = surface area of the upper contour

m = the lower contour depth, and

n = the upper contour depth

In addition to the stratum volume for the lake layers defined by the map contours, interpolated layer volumes between successive one meter deep layers are also provided (0.5 m successive layers for Wishart Lake). This information is useful for volume-weighting lake samples or existing lake data to obtain the best estimates of whole-lake or thermal layer (epilimnion, metalimnion, hypolimnion) composition.

The lakes in the Turkey Lake Watershed are morphometrically similar to other Shield lakes under study at the Experimental Lakes Area (northwest Ontario) and at Muskoka-Haliburton (south-central Ontario), Table VII.

IV. Basin Bedrock and Surficial Geology

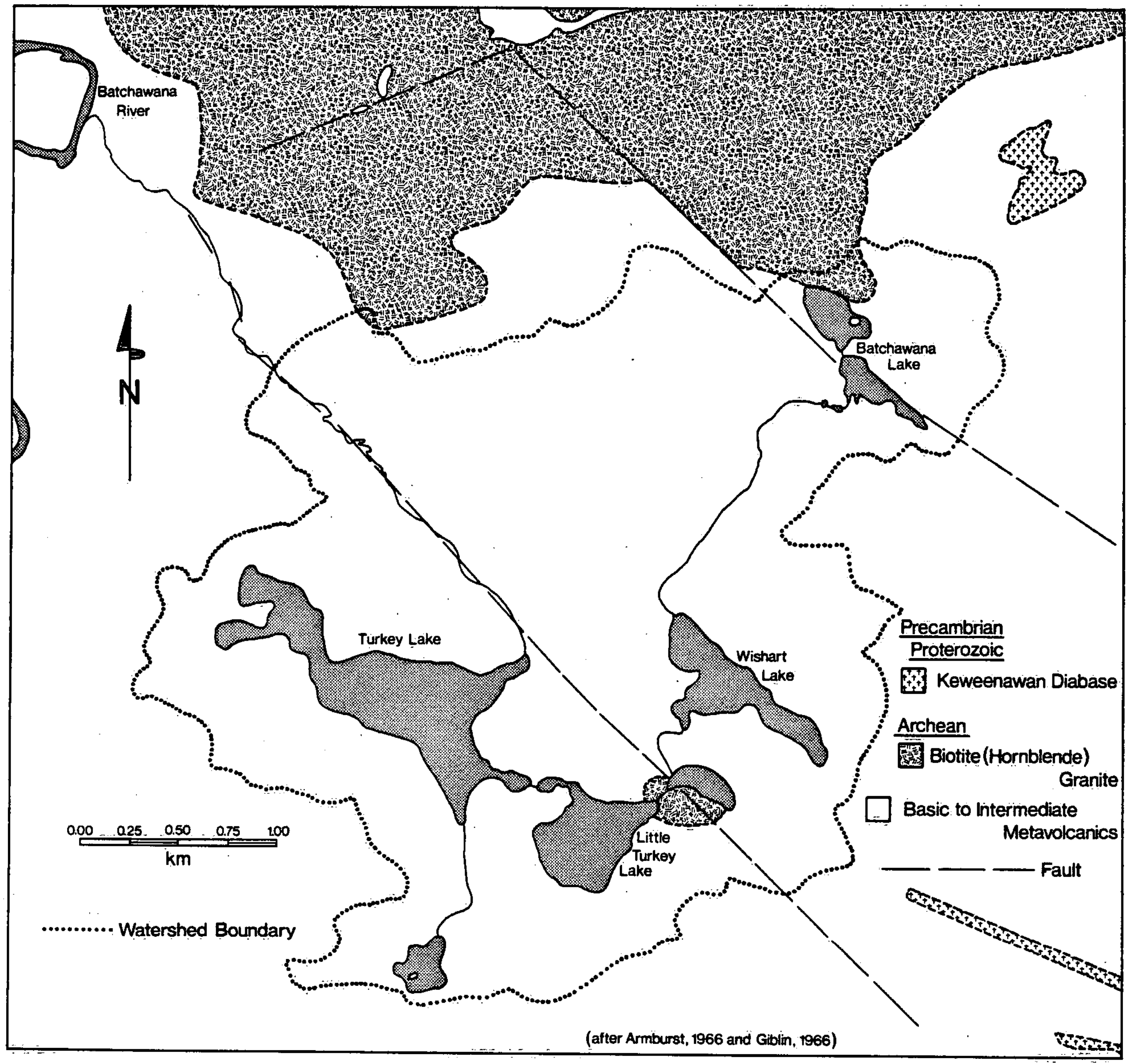
The watershed is underlain by Precambrian silicate rocks of the Canadian Shield, the predominant rock type being basic to intermediate metavolcanic (Figure 7). These Archean rocks are described by Giblin (1966) and Armburst (1966) as being very fine-grained, massive to slightly schistose, grey-green to dark green or black and having a composition

Table VII. Sumary of lake morphometry for Shield lakes under study in the Turkey Lake Watershed, Experimental Lakes Area[1], and Muskoka-Haliburton[2].

Morphometry Parameter	Turkey Lakes (n=5)	ELA[1] (n=17)	Muskoka-Haliburton[2] (n=15)
Lake Area (ha)	5.82 -52.0	1.67 -56.1	16.3 -124
Lake Volume ($m^3 x 10^5$)	1.90 -63.4	1.04 -78.6	11.8 -164
Mean Depth (m)	2.2 -12.2	1.5 -15.1	4.8 -14.2
Maximum Depth (m)	4.5 -37	2.5 -32.7	12-40
Shoreline Length (km)	1.31 - 5.91	0.523- 4.90	1.83- 8.24
Development of Shoreline	1.38 - 2.31	1.14 - 1.97	1.26- 2.29
Development of Volume	0.900- 1.46	0.90 - 1.78	0.93- 1.44

[1] - from Brunskill G.J. and D.W. Schindler (1971).

[2] - from MOE, 1978.



BEDROCK GEOLOGY OF THE TURKEY LAKES WATERSHED

Figure 7.

ranging from andesite to basalt. Interlayered with the fine-grained rocks are medium-to-coarse-grained basic rocks which Armburst (1966) speculated may represent the centres of volcanic flows or possibly diabase sills/dikes or gabbroic rocks that have undergone metamorphism. The Archean metavolcanics may contain economic deposits of base metals (Giblin 1966). Although no significant occurrence of such mineralization has been reported within the basin, sulphide grains can be observed in highly weathered, metavolcanic rock at the outlet of Batchawana Lake.

Archean granite intrudes the metavolcanic rocks and within the study basin it is concentrated at the north end of Batchawana Lake and at the inlet of Little Turkey Lake. The granite is pink in colour, medium- to coarse-grained with biotite or hornblende as the mafic minerals. Small pockets of granite containing quartz veinlets can also be seen along the channels of streams entering the lakes and Norberg Creek.

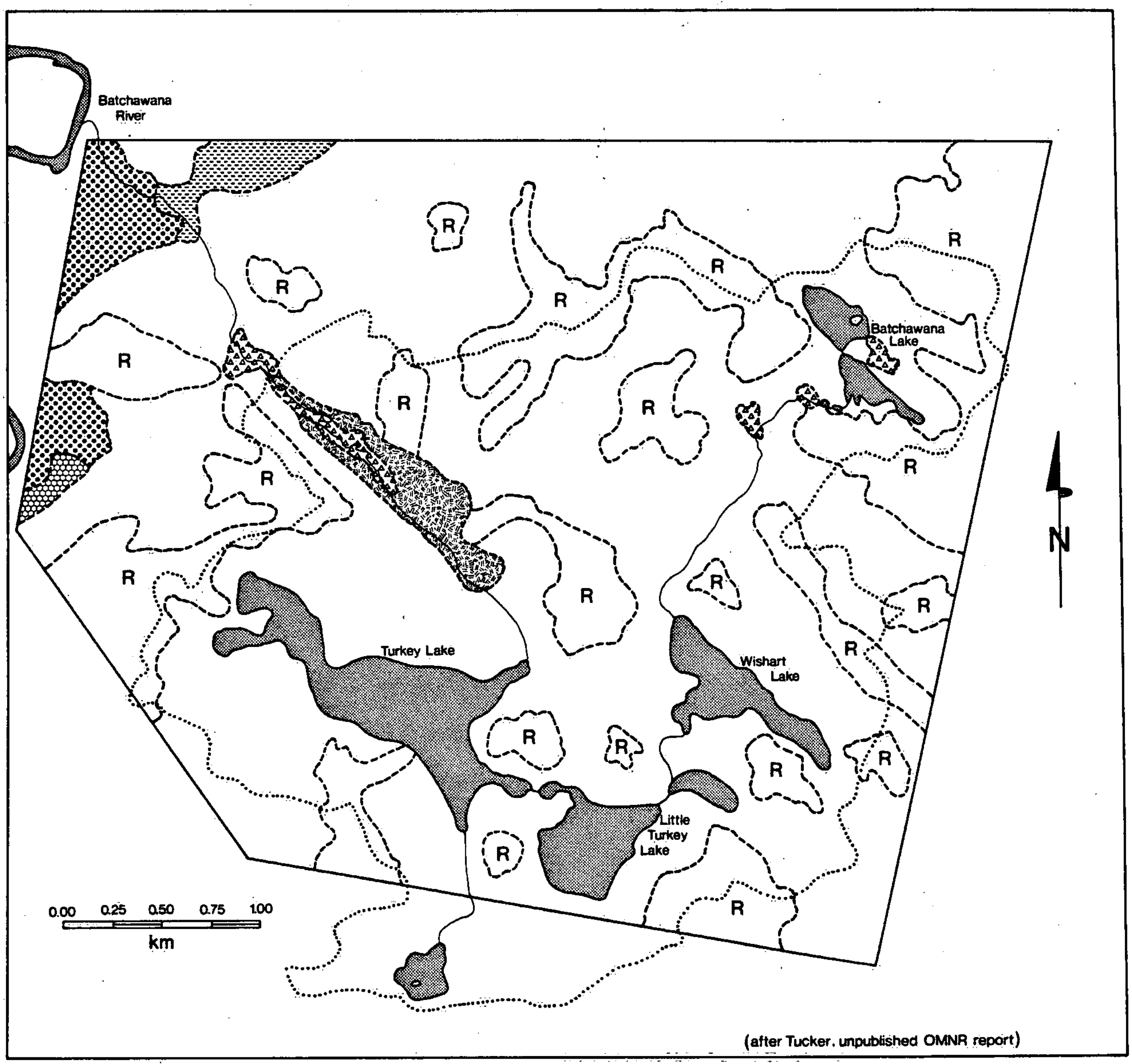
Diabase is also found in the area and although not shown in Figure 7, numerous small diabase dikes cut the Archean metavolcanics and granites within the study basin. As a result of its relatively greater resistance to weathering, the diabase stands out in the watershed as hills or ridges. The general insolubility of all the bedrock types in the area is reflected in the dilute nature of the surface waters.

The most pronounced structural feature in the study area is the set of faults cutting through the bedrock. Three directions of faulting can be observed; faults striking northwesterly are most common although northeasterly- and northerly-trending faults are quite numerous. Only the major faults have been shown in Figure 7. The faults are significant to the basin hydrology in that they control drainage patterns. This is illustrated by the course of the stream discharging Turkey Lake and by the smaller streams which flow from a northern or northeastern direction throughout the watershed.

Figure 8 depicts the distribution of surficial deposits in the study area. The surficial geology has been interpreted from air photographs by C.M. Tucker (OMNR unpublished report) with subsequent ground level verification. Glacial drift covers the basin predominantly as a ground moraine consisting of thin and discontinuous till. The till has a silty, sandy matrix and is buff-light brown in colour below the soil horizon. Clasts are sub-angular to angular and consist of mafic to intermediate metavolcanics with some acidic intrusives. The till is deepest in valleys and bedrock depressions and is considerably thinner in the Batchawana Lake basin where bedrock is frequently exposed. The preliminary survey by Tucker identified minor concentrations of ice-contact deposits in the valley downstream of Turkey Lake. Tucker further reported that Norberg Creek cuts through a raised glacio-lacustrine delta in the vicinity of the lowest gauging stations S5. Here the major stream has developed a flood plain characterized by an organic cover overlying grey, silty alluvium.

V. Data Accumulation and Storage

In order to measure the mass balance of a lake or terrestrial watershed, the hydrological and chemical inputs and outputs must be measured or estimated. For a lake, important inputs include precipitation (both wet and dryfall), terrestrial basin output via streams



Organic Cover. Thin But Continuous; Alluvium, Variable Texture; Silt to Pebble, Gravel; Glaciolacustrine Deltaic Deposits. Stratified Silt, Sand and Gravel; Glaciofluvial Deposits. Discontinuous Silt, Sand and Gravel Overlying Bedrock; Ice-Contact Silt, Sand and Gravel Intermixed With Englacial, Sandy Till; Till. Silty Sand, Buff-Brown. Variable in Thickness But Generally Close to Bedrock; R Rock With Very Thin, Discontinuous Colluvium and Till. ········ Watershed Boundary

SURFICIAL GEOLOGY OF THE TURKEY LAKES WATERSHED

Figure 8.

or groundwater, and solar energy. In the Turkey Lakes Watershed, continuous measurements of wet precipitation fall and streamflow will be combined with weekly or bi-weekly measures of composition to give wet precipitation and stream inputs to the lakes. Estimates of dry precipitation will be made by either applying a deposition factor (or "deposition velocity") to measured air concentrations or by consideration of the difference between measured wet precipitation and "bulk" deposition. "Bulk" deposition is simply that which falls into a continuously open collector. No direct measures of groundwater inputs are being made at this time; however, if after initial evaluation, groundwater appears to be an important component of lake inputs, then estimates will be prepared from information now being collected by NHRI. Similarly, although it is possible that regeneration of materials from the sediments may be a significant input to the lake, this is not under investigation at present. Solar inputs to the lakes is important as it influences lake temperature (and therefore water loss by evaporation) and primary production. Net solar radiation along with other meteorological parameters (wind speed and direction, air temperature, relative humidity, etc.) are being measured continuously at the field site.

Important outputs from the lakes include outflow, evaporation, sedimentation, and perhaps groundwater seepage. At present, only outflow is being measured. No methods have yet been selected for estimating the remaining outputs.

The hydrological and chemical data required to calculate the mass balances are collected by several branches of DOE, see Table VIII. The locations of sampling sites of all kinds are shown in Figures 9 and 10. A systematic method of station identification was adopted, thus all streams

Table VIII. Routine hydrological and aquatic chemical data collected at the Turkey Lakes Watershed on a year-round basis.

Parameter	Collection Agency[1]	Sampling Schedule
Stream Flow	WSC (6 stations) CFS (14 stations)[2]	- continuous monitoring; data to be reduced to mean daily discharge values
Stream Composition	ECD CFS	- biweekly - on precipitation event basis
Lake Composition (incl. thermal structure)	ECD	- biweekly
Groundwater Composition	NHRI	- variable
Precipitation depth	ECD	- continuous monitoring; data to be reduced to daily precipitation depth
Precipitation Composition	AES WQB ECD CFS	- daily wet only - monthly wet only - weekly bulk - bulk on a precipitation event basis
Air Composition	AES	- daily

1 - WSC - Water Survey of Canada, Guelph, Ontario
- CFS - Canadian Forestry Service, Sault Ste. Marie, Ontario
- ECD - Environmental Contaminants Division, National Water Research Institute, Burlington, Ontario
- NHRI - National Hydrology Research Institute, Ottawa, Ontario
- AES - Atmospheric Environmentl Service, Downsview, Ontario
- WQB - Water Quality Branch, National Water Research Institute, Burlington, Ontario

2 - 10 streams monitored throughout the year, remainder during ice free season only; instantaneous discharge is measured on six additional streams which do not have flow control structures.

entering the study lakes (Figure 9) have been assigned a sampling site and number although they are not necessarily being monitored at this time. Stream station identification has been keyed to the WSC flow monitoring stations and NWRI sampling sites, numbered S0 through S5. Hence a stream flowing into another stream or lake above S4 and below S3 has been arbitrarily assigned S4a, S4b, etc. Stream station numbers used by CFS are also indicated on Figure 9. The prinicpal lake sampling station is situated at the deepest spot in the lake; however, those lakes with two distinct basins have been assigned a secondary station for the smaller basin. Beaver ponds have also been assigned sampling stations and numbers.

The precipitation, groundwater, and forestry related sampling sites have been indicated on Figure 10. The primary precipitation sampling station (M3; precipitation depth, wet and bulk composition, air composition, basic meteorology) is located on a small hill near the field base camp; however, in order to assess the variation in precipitation fall due to orographic factors, precipitation depth (but not composition) is also measured at M1, M2 and M4. Bulk deposition and precipitation depth is monitored at the CFS precipitation sites (P1 and P2). Snow pack monitoring is conducted at eleven sites (Sn 1, 2, etc.) throughout the watershed.

The chemical data collected by ECD, AES and WQB (see Table VIII) are being stored in the computerized National Water Quality Data (NAQUADAT) system. It is expected that other data pertinent to the mass balance studies (collected and made available by CFS) will also be stored in NAQUADAT. The NAQUADAT staion codes corresponding to the sampling stations in Figures 9 and 10 are given in Table IX. Note that although stations codes have been assigned to all the sampling sites, the data storage system

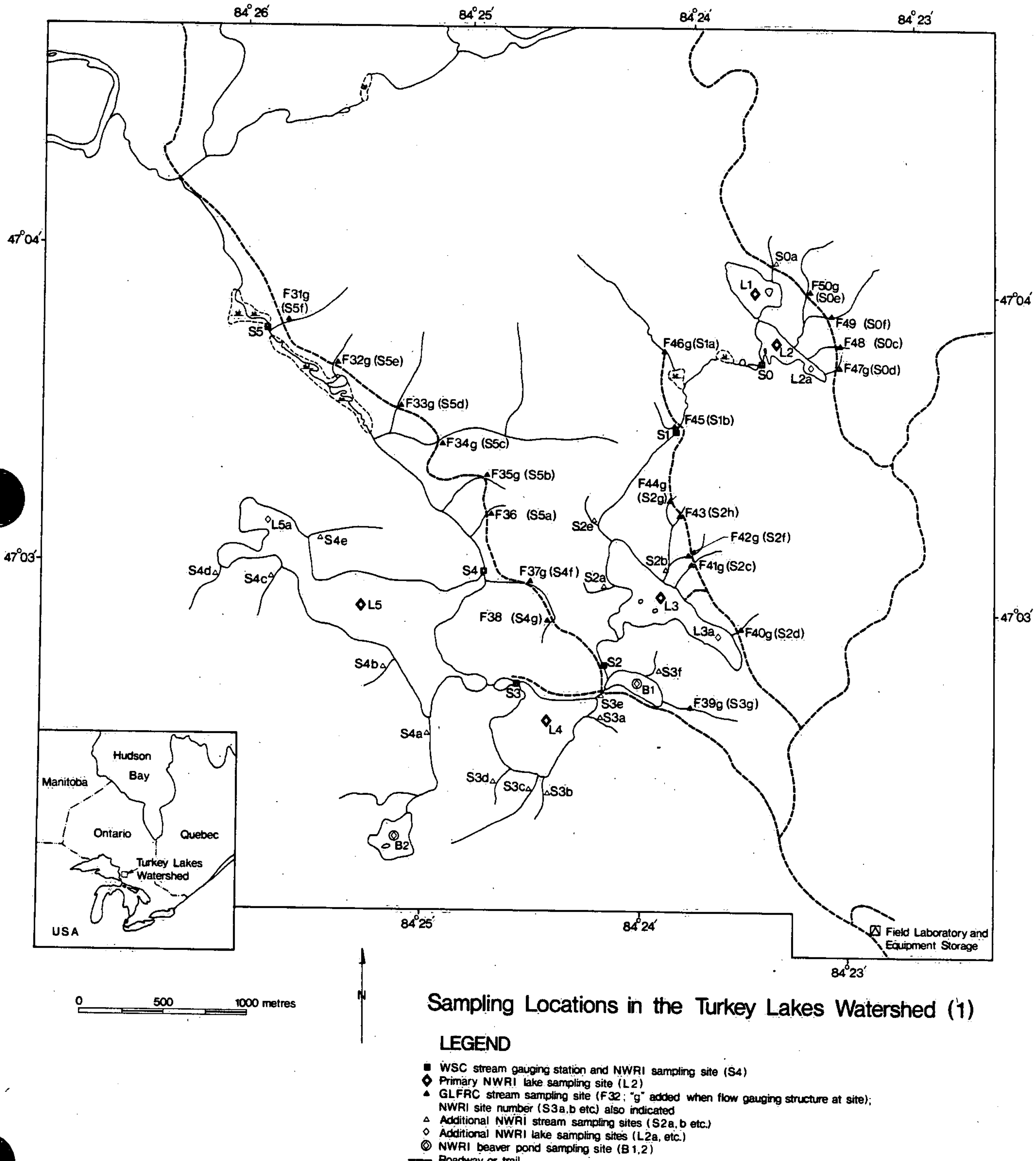


Figure 9: Stream and lake sampling stations.

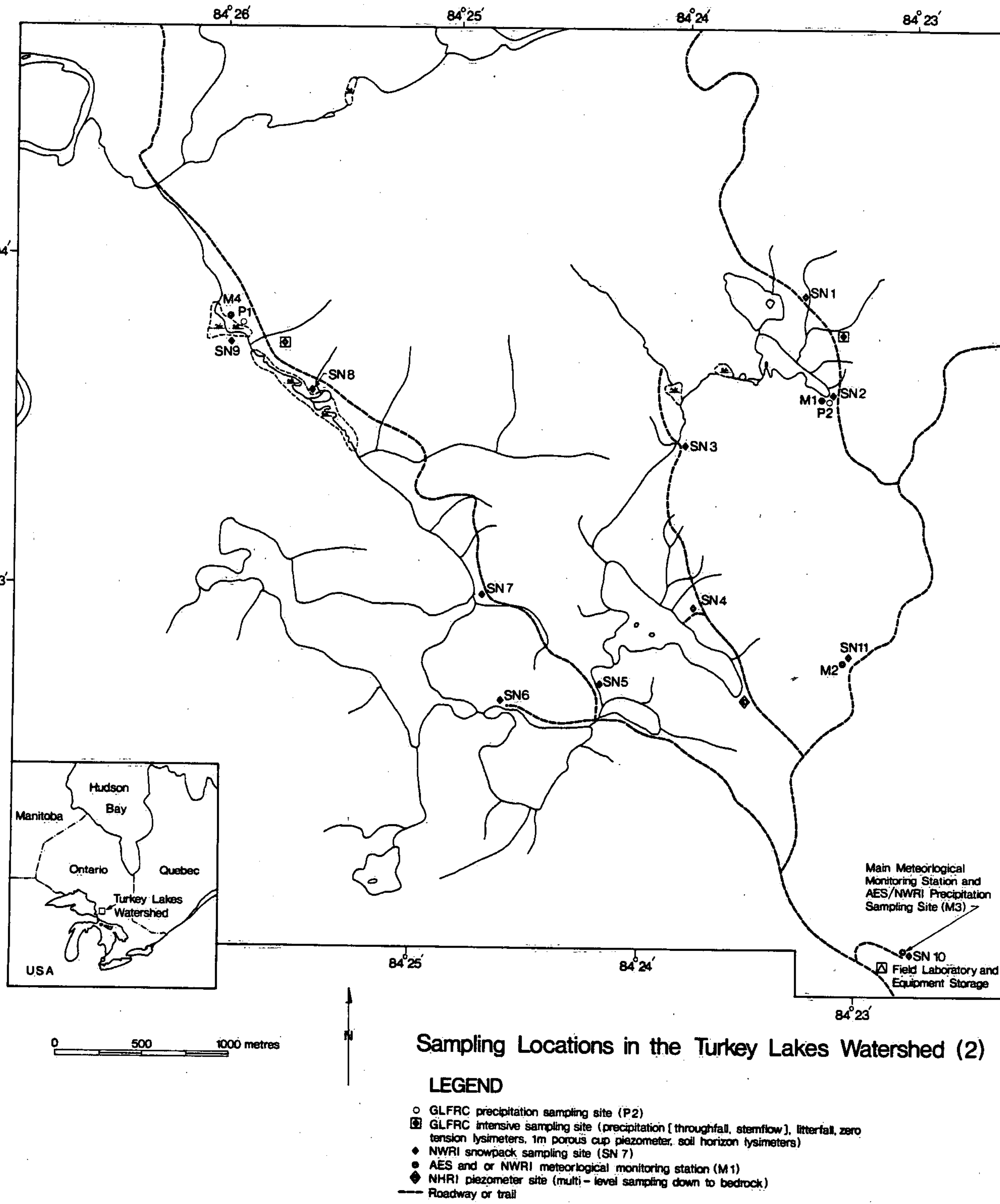


Figure 10: Precipitation, snowpack, groundwater, and GLFRC intensive sampling locations.

(as of November 1981) only recognizes those indicated by a single asterisk in Table IX. Station descriptions for those locations as stored in NAQUADAT are shown in Table X. As data from the other stations becomes available for entry into NAQUADAT, station definition will be required using appropriate station update routines. Contact Dean S. Jeffries (Environmental Contaminants Division, NWRI, Burlington, Ontario; Telephone 416-637-4252.) before any attempt is made to alter the NAQUADAT, Turkey Lakes Watershed, data base. The data stored in NAQUADAT is available to any approved user on a batch or interactive terminal basis and can be manipulated or displayed in various ways using existing programs.

VI. Preliminary Water Budget Calculation

Theoretically, the total possible water reaching a lake in a year is the sum of: precipitation directly on the lake's surface and that part of its terrestrial basin draining directly into the lake (P), the inflow from other lakes above it (I), and groundwater imported from outside the basin (G). The "net" sum of water reaching the lake is the above minus lake evaporation (E) and terrestrial watershed evapotranspiration (E_t). This net sum, divided by lake volume (V) is an estimate of the theoretical annual water renewal coefficient (e.g., the fraction of lake volume lost to outflow in a year). The reciprocal of this coefficient (τ, the number of years necessary to completely replace the lake volume assuming a mixed water mass) has been called the "theoretical water renewal time" (Brunskill and Schindler, 1971).

Table IX. NAOUADAT station identification codes for sampling location and types in the Turkey Lakes Watershed.

Stream Station	Station Identification Number			CFS Station
S0*	↑	↑	0101000	
S0a			0102000	
S0b			0103000	
S0c	00	ON02BF	0104000	F48
S0d			0105000	F47
S0e			0106000	F50
S0f	↓	↓	0107000	F49
S1*	↑	↑	0111000	
S1a	00	ON02BF	0112000	F46
S1b	↓	↓	0113000	F45
S2*	↑	↑	0121000	
S2a			0122000	
S2b			0123000	
S2c			0124000	F41
S2d	00	ON02BF	0125000	F40
S2e			0126000	
S2f			0127000	F42
S2g			0128000	F44
S2h	↓	↓	0129000	F43
S3*	↑	↑	0131000	
S3a			0132000	
S3b			0133000	
S3c			0134000	
S3d	00	ON02BF	0135000	
S3e			0136000	
S3f			0137000	
S3g	↓	↓	0138000	F39
S4*	↑	↑	0141000	
S4a			0142000	
S4b			0143000	
S4c			0144000	
S4d	00	ON02BF	0145000	
S4e			0146000	
S4f			0147000	F37
S4g	↓	↓	0148000	F38
S5*	↑	↑	0151000	
S5a			0152000	F36
S5b			0153000	F35
S5c	00	ON02BF	0154000	F34
S5d			0155000	F33
S5e			0156000	F32
S5f	↓	↓	0157000	F31

Lake Station	Station Identification Number		
L1*	↑	↑	0111000
L2*			0121000
L2a			0122000
L3*	01	ON02BF	0131000
L3a			0132000
L4*			0141000
L5*			0151000
L5a	↓	↓	0152000
Beaver Pond Station			
B1	04	ON02BF	0191000
B2	04	ON02BF	0192000
Precipitation Station			
P1	35	ON02BF	0111000
P2	35	ON02BF	0112000
M3**	↑	↑	0001000
	33	ON02BF	0702000
	↓	↓	0113000
Snow Core Station			
SN1	↑	↑	0121000
SN2			0122000
SN3			0123000
SN4			0124000
SN5			0125000
SN6	31	ON02BF	0126000
SN7			0127000
SN8			0128000
SN9			0129000
SN10			0130000
SN11	↓	↓	0131000

* - Station currently recognized by NAQUADAT (November 1981)

** - 001 = AES wet only;
702 = WOB wet only;
113 = ECD bulk sampler

Table X : Turkey Lakes Watershed NAQUADAT Station Descriptions*

Stream Stations

STATION NUMBER - 000N02BF0101000
REFERENCE STN NUMBER - 010N02BF0111000
DIST FROM REF STAT (KM) - .40
WSC STATION NUMBER -
REGION - ONTARIO
BASINS - 02BF
LATITUDE - 047/03/46
LONGITUDE - 084/23/33
AVG. DEPTH -
WATER TYPE - SURFACE (STREAM-CHANNEL)

NARRATIVE
TURKEY LAKES WATERSHED PROJECT
STREAM STATION - S0
OUTFLOW OF BATCHAWANA LAKE (S BASIN)
ALGOMA ONTARIO

STATION NUMBER - 000N02BF0111000
REFERENCE STN NUMBER - 010N02BF0111000
DIST FROM REF STAT (KM) - 1.30
WSC STATION NUMBER -
REGION - ONTARIO
BASINS - 02BF
LATITUDE - 047/03/34
LONGITUDE - 084/23/57
AVG. DEPTH -
WATER TYPE - SURFACE (STREAM-CHANNEL)

NARRATIVE
TURKEY LAKES WATERSHED PROJECT
STREAM STATION - S1
NORBERG CREEK HALF-WAY BETWEEN
BATCHAWANA AND WISHART LAKES
ALGOMA ONTARIO

STATION NUMBER - 000N02BF0121000
REFERENCE STN NUMBER - 010N02BF0111000
DIST FROM REF STAT (KM) - 3.30
WSC STATION NUMBER -
REGION - ONTARIO
BASINS - 02BF
LATITUDE - 047/02/47
LONGITUDE - 084/24/12
AVG. DEPTH -
WATER TYPE - SURFACE (STREAM-CHANNEL)

NARRATIVE
TURKEY LAKES WATERSHED PROJECT
STREAM STATION - S2
OUTFLOW OF WISHART LAKE
ALGOMA ONTARIO

STATION NUMBER - 000N02BF0131000
REFERENCE STN NUMBER - 010N02BF0111000
DIST FROM REF STAT (KM) - 4.10
WSC STATION NUMBER -
REGION - ONTARIO
BASINS - 02BF
LATITUDE - 047/02/43
LONGITUDE - 084/24/38
AVG. DEPTH -
WATER TYPE - SURFACE (STREAM-CHANNEL)

NARRATIVE
TURKEY LAKES WATERSHED PROJECT
STREAM STATION - S3
OUTFLOW OF LITTLE TURKEY LAKE
ALGOMA ONTARIO

STATION NUMBER - 000N02BF0141000
REFERENCE STN NUMBER - 010N02BF0111000
DIST FROM REF STAT (KM) - 5.50
WSC STATION NUMBER -
REGION - ONTARIO
BASINS - 02BF
LATITUDE - 047/03/02
LONGITUDE - 084/24/47
AVG. DEPTH -
WATER TYPE - SURFACE (STREAM-CHANNEL)

NARRATIVE
TURKEY LAKES WATERSHED PROJECT
STREAM STATION - S4
OUTFLOW OF TURKEY LAKE
ALGOMA ONTARIO

STATION NUMBER - 000N02BF0151000
REFERENCE STN NUMBER - 010N02BF0111000
DIST FROM REF STAT (KM) - 7.80
WSC STATION NUMBER -
REGION - ONTARIO
BASINS - 02BF
LATITUDE - 047/03/47
LONGITUDE - 084/25/51
AVG. DEPTH -
WATER TYPE - SURFACE (STREAM-CHANNEL)

NARRATIVE
TURKEY LAKES WATERSHED PROJECT
STREAM STATION - S5
NORBERG CREEK HALF-WAY BETWEEN TURKEY
LAKE AND BATCHAWANA RIVER
ALGOMA ONTARIO

Lake Stations

STATION NUMBER - 010N02BF0111000
REFERENCE STN NUMBER -
DIST FROM REF STAT (KM) -
WSC STATION NUMBER -
REGION - ONTARIO
BASINS - 02BF
LATITUDE - 047/04/00
LONGITUDE - 084/23/35
AVG. DEPTH -
WATER TYPE - SURFACE (LAKE)

NARRATIVE
TURKEY LAKES WATERSHED PROJECT
LAKE STATION - L1
BATCHAWANA LAKE (N BASIN) - MAIN
SAMPLING STN AT DEEPEST POINT
ALGOMA ONTARIO

STATION NUMBER - 010N02BF0121000
REFERENCE STN NUMBER -
DIST FROM REF STAT (KM) -
WSC STATION NUMBER -
REGION - ONTARIO
BASINS - 02BF
LATITUDE - 047/03/51
LONGITUDE - 084/23/30
AVG. DEPTH -
WATER TYPE - SURFACE (LAKE)

NARRATIVE
TURKEY LAKES WATERSHED PROJECT
LAKE STATION - L2
BATCHAWANA LAKE (S BASIN) - MAIN
SAMPLING STN AT DEEPEST POINT
ALGOMA ONTARIO

STATION NUMBER - 010N02BF0131000
REFERENCE STN NUMBER -
DIST FROM REF STAT (KM) -
WSC STATION NUMBER -
REGION - ONTARIO
BASINS - 023F
LATITUDE - 047/03/01
LONGITUDE - 084/23/60
AVG. DEPTH -
WATER TYPE - SURFACE (LAKE)

NARRATIVE
TURKEY LAKES WATERSHED PROJECT
LAKE STATION - L3
WISHART LAKE - MAIN SAMPLING STN AT
DEEPEST POINT
ALGOMA ONTARIO

STATION NUMBER - 010N02BF0141000
REFERENCE STN NUMBER -
DIST FROM REF STAT (KM) -
WSC STATION NUMBER -
REGION - ONTARIO
BASINS - 02BF
LATITUDE - 047/02/35
LONGITUDE - 084/24/29
AVG. DEPTH -
WATER TYPE - SURFACE (LAKE)

NARRATIVE
TURKEY LAKES WATERSHED PROJECT
LAKE STATION - L4
LITTLE TURKEY LAKE - MAIN SAMPLING
STN AT DEEPEST POINT
ALGOMA ONTARIO

STATION NUMBER - 010N02BF0151000
REFERENCE STN NUMBER -
DIST FROM REF STAT (KM) -
WSC STATION NUMBER -
REGION - ONTARIO
BASINS - 02BF
LATITUDE - 047/02/56
LONGITUDE - 084/25/21
AVG. DEPTH -
WATER TYPE - SURFACE (LAKE)

NARRATIVE
TURKEY LAKES WATERSHED PROJECT
LAKE STATION - L5
TURKEY LAKE - MAIN SAMPLING STN AT
DEEPEST POINT
ALGOMA ONTARIO

* as of November, 1981; note that the reference station for stream stations is L1.

An "order of magnitude" estimate of τ for each of the five lakes in the Turkey Lakes Watershed has been calculated and is given in Table XI. As measured hydrological data becomes available, more precise τ values will be calculated by simply dividing V by annual outflow. The τ values in Table XI have been calculated by using estimated values for P, E, and E_t and assuming that G = 0. Long-term annual precipitation estimates are available from six meteorlogical monitoring stations east of Lake Superior between Sault Ste. Marie and Wawa. These range from 814 mm yr^{-1} (Chapleau) to 1123 mm yr^{-1} (Montreal Falls). The influence of elevation on precipitation fall is evident with Sault Ste. Marie airport (elevation 192 m AMSL) recording 935 mm yr^{-1} while Montreal Falls (elevation 408 m AMSL) showing 1123 mm yr^{-1}. Since most of the lakes are approximately at the same elevation as Montreal Falls, we have used 1120 mm yr^{-1} for P. Values for E and E_t (550 and 500 mm yr^{-1} respectively) have been interpolated from the Hydrological Atlas of Canada (1978).

Table XI gives the terrestrial drainage area (A_d) for each lake <u>excluding</u> that associated with lakes above it in the chain, the lake surface area (A), lake volume (V), A multiplied by P minus E (A[P-E]), A_d multiplied by P minus E_t ($A_d[P-E_t]$), the average annual outflow volume of water ($OF_{lake} = I_{lake\ above} + A[P-E] + A_d[P-E_t]$) where $I_{lake\ above}$ equals the outflow volume calculated for the lake immediately above it in the chain, and τ ($=V/OF_{lake}$). Note that stream evaporation between lakes is considered zero, that no distinction has been made between the terrestrial watershed and ponds or bogs within the watershed, and finally, that the OF_{lake} for each successively lower lake is more

Table XI. Data for computation of the theoretical water renewal time (τ) for the lakes in the Turkey Lakes Watershed. Symbols are explained in the text.

Lake	A_d (ha)	A (ha)	V ($m^3 \cdot 10^3$)	A[P-E] ($m^3 yr^{-1} \cdot 10^3$)	$A_d[P-E_t]$ ($m^3 yr^{-1} \cdot 10^3$)	OF_{lake} ($m^3 yr^{-1} \cdot 10^3$)	τ (yr)
Batchawana (North)	18.1	5.88	227	33.5	112	146	1.6
Batchawana (South)	55.9	5.82	190	33.2	347	526	0.4
Wishart	232	19.2	421	109	1440	2070	0.2
Little Turkey	135	19.2	1160	109	837	3020	0.4
Turkey	260	52.0	6340	296	1610	4930	1.3

uncertain since it contains an increasingly larger and uncertain $I_{lake\ above}$ estimate.

Both the magnitudes and range of values for τ are small (0.2-1.6 yrs). The chemistry of the lakewater may therefore be expected to reflect the presently occurring geochemical interactions between acidic deposition and basin materials. Moreoever, the short water replenishment time suggest that these lakes may be particularly sensitive to short term acidification during periods of high flow and low pH such as spring melt.

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