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STUDIES IN THE LAKE ONTARIO BASIN USING ERTS-1 AND HIGH ALTITUDE DATA

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ABSTRACT

Studies in the Lake Ontario Basin are designed to provide input for models of river basin discharge and macro-scale features of lake circulation. Lake Studies appear to require high altitude imagery to record the dynamic features of Lake Ontario so that ERTS-1 data may be interpreted. Land area studies require input of soil moisture, land use and soil-sediment-geomorphology measurements some of which appear to be available, on a regional scale from ERTS-1 products.

1. INTRODUCTION

Lake Ontario is the major study area for projects undertaken as part of the International Field Year on the Great Lakes (I.F.Y.G.L.). The Western portion of the Lake Ontario Basin has within it specially designated land and lake study areas which are managed by personnel from government agencies and universities. Remote sensing data over the western portion of Lake Ontario are available from several sources. Correlation of the available remote sensing imagery with ground measurements available through I.F.Y.G.L. studies is undertaken by a team by a team of scientists whose work is co-ordinated through the Centre for Applied Research and Engineering Design (CARED) McMaster University, Hamilton, Ontario. This work is partially supported by funds from U.S.G.S. Contract No. 14-08-001-13169. Remote-sensing data available under this contract are used by Canadian government agencies which have programs in the I.F.Y.G.L and these agencies are associated with the research team co-ordinated by CARED. The individuals participating in the co-ordinated interdisciplinary research project are also involved in many other research activities funded by various agencies. The results of these other activities are, where appropriate, linked to this work in the evaluation of remote sensing imagery for I.F.Y.G.L. purposes.

The western portion of the Lake Ontario Basin (the Lake Ontario Test site see fig. 1) contains both land and lake areas. Studies over the land area are designed to provide input for models of stream basin response so that discharge into major streams or into Lake Ontario can be predicted with greater accuracy. Over the lake the data obtained from lake study programs are evaluated alongside the remote sensing data and the purpose of the studies is to better understand the behaviour of the lake. International agreements on the control and management of Lake Ontario can only be based on the available knowledge and the continued study of the lake is of importance in all aspects so that available knowledge is as complete as possible. Both land and lake studies require a base for measurement of information. Calibration of data from sensors continues as an area of study. Some success with calibration of high altitude data has been achieved and the relationship between this and ERTS-1 data is a continuing investigation. A co-operative project between the University of Guelph and University of Michigan in the investigation of ERTS data for measurement of terrain characteristics, soils and soil moisture is examining this problem using MSS data from ERTS-1 and low altitude flights.

2. LAKE STUDIES REPORTED BY CANADA CENTRE FOR INLAND WATERS (C.C.I.W.)

In evaluating the RB-57 high altitude data, CCIW concentrated upon its potential for identifying and interpreting details of limnological phenomena occurring within inland lake systems. Obvious surficial features (many of which were the subjects of study of other investigators) such as coastal and river mouth plumes and effluents and which were felt to be readily distinguishable from ERTS and/or high altitude aerial imagery were, at least temporarily, ignored in favour of less obvious limnological data that could benefit from a high altitude overview. As is typical of all programs of remote sensing, the RB-57 data were not considered as an independent entity, but were considered in conjunction with other data collected above or below Lake Ontario during the periods of high altitude NASA overflights. These ancillary data included low altitude visible photography performed by CCIW, intermediate altitude visible photography and thermal scans performed by CCIW along with CCRS, and water quality data collected routinely via ship cruises.

Two main areas of limnological interest were explored making direct use of the RB-57 imagery; internal wave observations which have been previously reported (Boyce and Thomson, 1972) and dynamical lake processes which are about to be reported (Bukata, 1973).

1) Surface Indications of Internal Waves

The high altitude imagery clearly indicated a number of wave-like features along the north shore of Lake Ontario (2-10m wide) which are presumed to be convergence lines associated with internal waves in the lake. Figure 2 illustrates a mosaic constructed from the imagery (9 inch color infra-red film, 6 inch lens) and indicates the internal wave configurations in the area of Lake Ontario between Toronto and Oshawa. The most import information to be derived from the imagery was an estimate of the wavelength of the feature and their east-west continuity. Two main groups of waves were evident, the first group exhibiting wavelengths between 1000-1700 metres and the second group exhibiting wavelengths between 400-800 metres.

2) A Study of Lake Dynamics

Utilising those portions of the photography which display solar mirror-reflection (sun-glint) it has been shown that high altitude photography which is capable of depicting large water surfaces with good resolution is a powerful tool for evaluating relatively rapid dynamical phenomena. It has been observed that under proper conditions, photography in the visible spectral bands may delineate the dynamic interface between thermally different water masses. Extensive work is currently being performed upon the dynamics of upwelling phenomena and encouraging agreement is being obtained between the calculations of water transport rates as determined from surficial overviews of the lake and the values generally predicted from theoretical studies and ship network determinations.

3. ECOLOGICAL STUDIES OF THE NIAGARA RIVER PLUME AND AREA (reported by G. Harris)

In production ecology studies in the area of the Niagara River plume, L. Ontario, imagery from the ERTS simulation flights has been found to be useful for synoptic views of plume behaviour. In July 1972 production ecology studies were carried out from a moored barge[1] 2.8 km N of Four Mile Point Niagara-on-the-Lake, Ontario. The objective of the study was to examine the relationship between water mixing and production. Simultaneous measurements of chlorophyll (Strickland and Parsons 1968), Turbidity, Production *in situ* (Steemand-Nielsen 1952) and water mixing parameters were made.

On numerous occasions, peculiar chlorophyll and turbidity distributions were noted. Fig. 3 gives one such example. On July 11th the chlorophyll and turbidity distributions were rapidly reversed at 1200 hrs. in the absence of effective wind mixing in the previous few hours. The plot of chlorophyll vs. turbidity (Fig. 3) clearly shows that the water masses at 0m and 5m have reversed positions.

Examination of the imagery from the June RB57 overflight (see Fig. 4) allowed us to interpret these sorts of chlorophyll and turbidity patterns. Ground truth data gathered in June '72 showed a clear high turbidity in the plume area and a low chlorophyll concentration in the plume, presumably caused by cell destruction upriver at the falls. The plume turbidity is clearly associated with industrial effluents from the city of Buffalo as seen in the RB57 imagery from 19 October 1970. On June 7th, 1972 imagery the plumecan be seen to be spreading behind the Niagara bar and flowing out into the lake. On June 5th two sequential sets of imagery were obtained 35 mins. apart which allowed us to interpret dynamic features of the plumes from the Niagara River and the Welland Canal. Overlays of the plume outlines show changes in shape amounting to spreading rates of 600 m to 1100 m in 35 minutes (28-52 cm/sec.). These flow rates are up to 5 times the velocities that are associated with wind mixing effects and it can be seen why they have such effects on sampling in the river plume area.

[1] Used by courtesy of CCIW (an IFYGL project).

The thermal bar is clearly visible on the June 5th imagery marked by a large oil slick. It should be noted that on examination of sun glint areas, the surface of the water reveals many details of the river plume mixing into the lake as well as the thermal bar. Examination of such areas shows promise for further work in this study area. Surface patterns indicate a pulsing effect as the river flows over the shallows of the Niagara Bar into the lake.

Further study of this test site is in progress, but it can be seen that repeated flights over a short time period are of great value when dynamic features of the lake are being studied. Ground truth in such an area is not easy to collect because of these water velocities and only aerial photography can give the complete synoptic picture at one point in time without a large fleet of vessels and prohibitive cost. Water turbidity is very important in controlling plant production, by limiting light distribution underwater; remote sensing techniques would appear to be a promising method for detection of turbidity and suspended solids inputs.

4. STUDIES OVER THE LAND AREA

In the land area of the basin a model of either flood conditions of a stream or a model of continuous flow requires detail of the basin characteristics. Meteorological data are available or can be made available for large areas. The response of a basin can only be predicted if its characteristics can be modelled and the effect of these characteristics is primarily in storage within the basin or loss by evaporation (Dickison and Whiteley 1970, Dickinson and Douglas 1972). Evaporation losses can be estimated from a knowledge of vegetation cover (land-use data) and stored moisture can be estimated from measurements of soil moisture. Other aspects of storage seem to be a function of terrain type and surficial geology (which may be termed geomorphology).

Vegetation cover and land-use studies over regional zones appear to be possible using ERTS imagery (see University of Michigan studies). Over small area test basins RB-57 data have been used for land-use data and the resulting correlation between image density and soil moisture status permits estimation of soil moisture values. This result has been achieved through correction of high altitude imagery (Collins 1972, MacDowall et al 1972) and a knowledge of soil types. Work by Protz and his associates (Cihlar and Protz, 1972a, 1972b, 1973, Crosson and Protz 1972, 1973a, 1973b) has shown that the characteristics of soils which can be detected by sensors are not necessarily those which are represented on published maps. This work also indicates that major soil differences can be detected. Interactions of slope type, slope class and soil properties are important, so too are interactions between parent material and soil type and all have an effect on moisture status.

For modelling of hydrologic response of river basins the knowledge of both soil type and terrain units is important. From RB-57 data the important parameters for small basins can be measured. Examination of ERTS data to date reveals that physiographic maps and soil associations maps do not appear to be directly compatable with ERTS-1 interpretation. Thus, for regional interpretation of hydrologic parameters from ERTS we must determine the precise nature of the properties which ERTS-1 detects. It appears that useful physiographic information can be obtained from ERTS data (Bruce and Howarth 1972) and at the 1:250,000 scale ERTS provides a more accurate record of wetlands than existing maps. ERTS also permits measurement across the image so that determination of required information within the whole region appears possible.

5. CONCLUSIONS

ERTS-1 data provide a definition of the macro-scopic features within the Lake Ontario Test-site. Definition of lake features including river plumes and effluent upwelling is possible. The significance of other detail within the lake is difficult to determine because many features of the lake are dynamic features and detailed ground truth data cannot be gathered in the available time interval. High altitude (RB-57) data appear to offer the essential step in the correlation of lake behavior with ERTS data by providing keys to the time nature of the major patures.

Over the land area ERTS-1 data offer regional scale information which could yield input for models of river basin response and thus provide important data for lake level control. Maps of land-use, vegetation type soil regions and physiographic regions would provide important information and the preparation of such maps is being investigated. It is clear that ERTS-1 data offer many advantages over regional area mosaics for this purpose and the detail availabe is far greater than shown on existing maps. The ERTS-1 data also apply to the present-day situation. At the present time it appears that ERTS-1 offers hope of improving predictions of discharge from river systems. Conversely ERTS-1 also provides a basis on which to plan instrumentation and control of river systems.

ACKNOWLEDGEMENTS

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LAKE ONTARIO EXTENDED TEST SITE

NO. 239

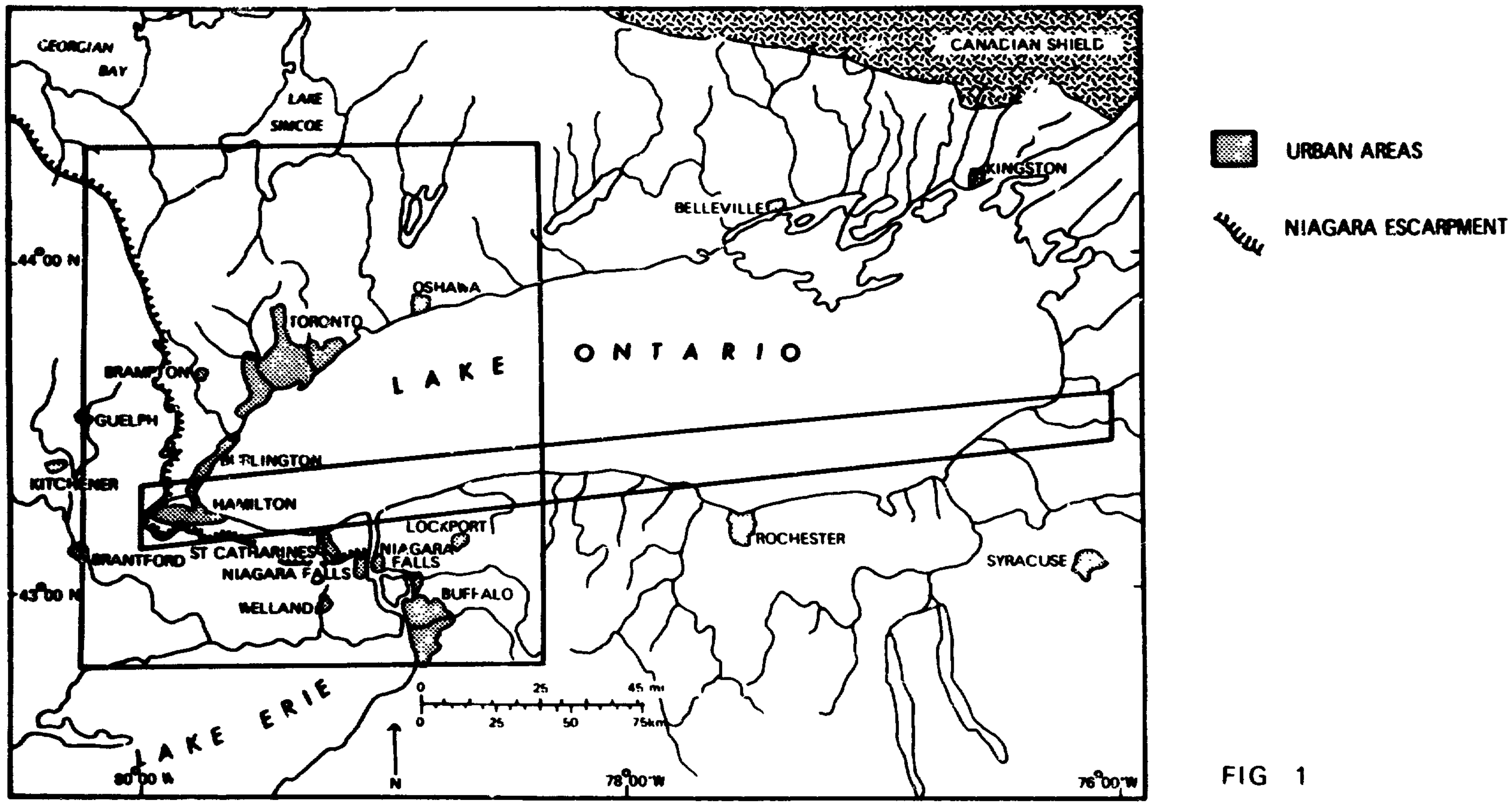
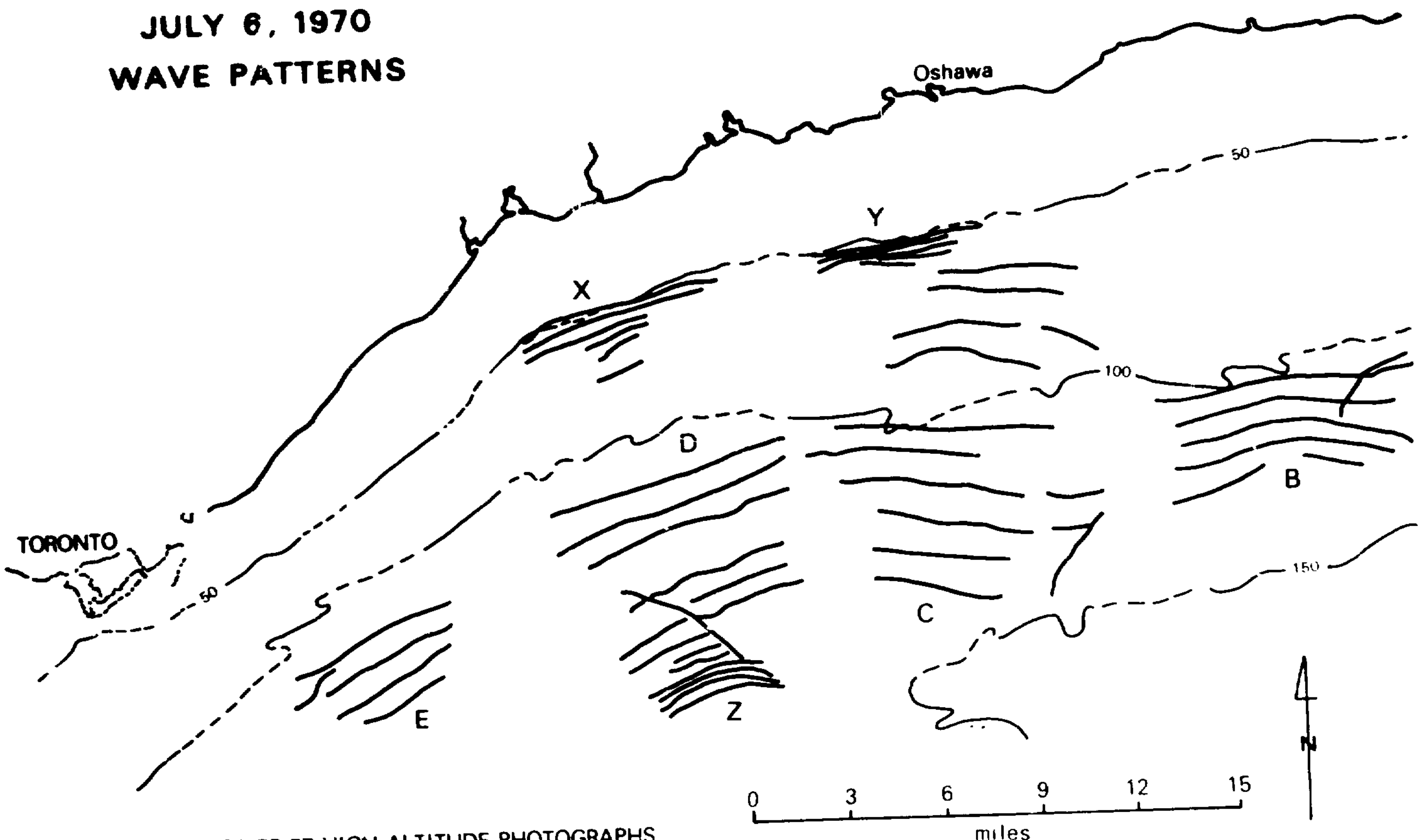


FIG 1

LAKE ONTARIO
JULY 6, 1970
WAVE PATTERNS



TAKEN FROM NASA RB 57 HIGH ALTITUDE PHOTOGRAPHS
CONTOURS IN METRES

FIG 2

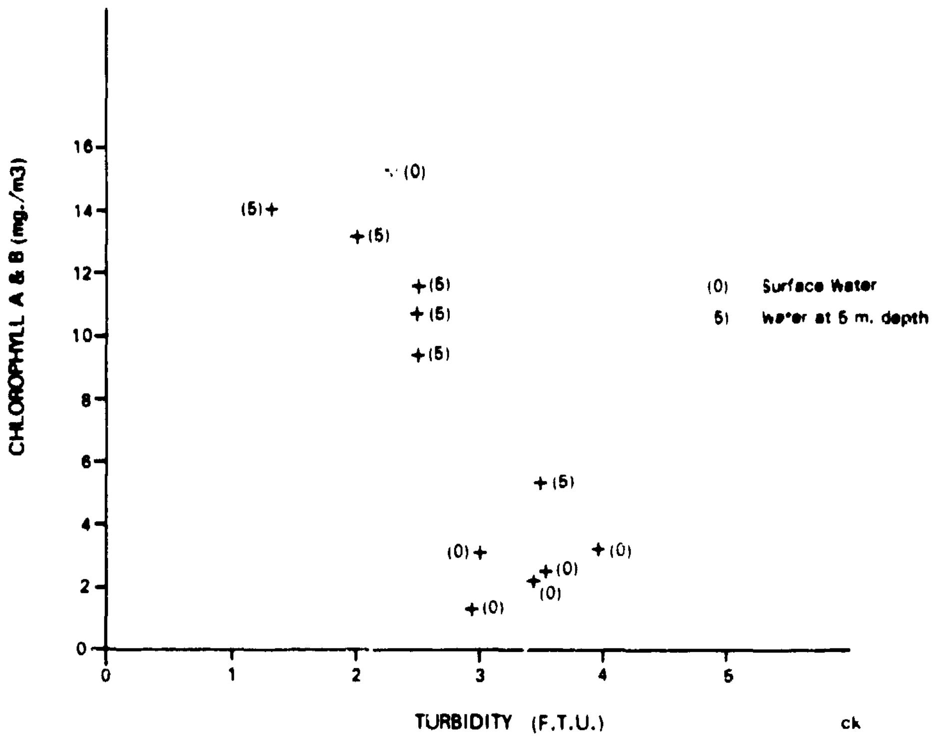


FIG 3 LAKE ONTARIO CHLOROPHYLL DATA

		CHLOROPHYLL A & B (Milligrams per cubic metre) JULY 11th, 1972.					
TIME IN HOURS E.S.T.		0900	1000	1200	1400	1600	1800
DEPTH IN METRES	0	3.05	1.35	15.4	2.2	2.3	3.2
	5	13.9	13.09	5.54	10.8	11.6	9.4
	10	9.78	7.16	5.02	5.06	3.18	4.76

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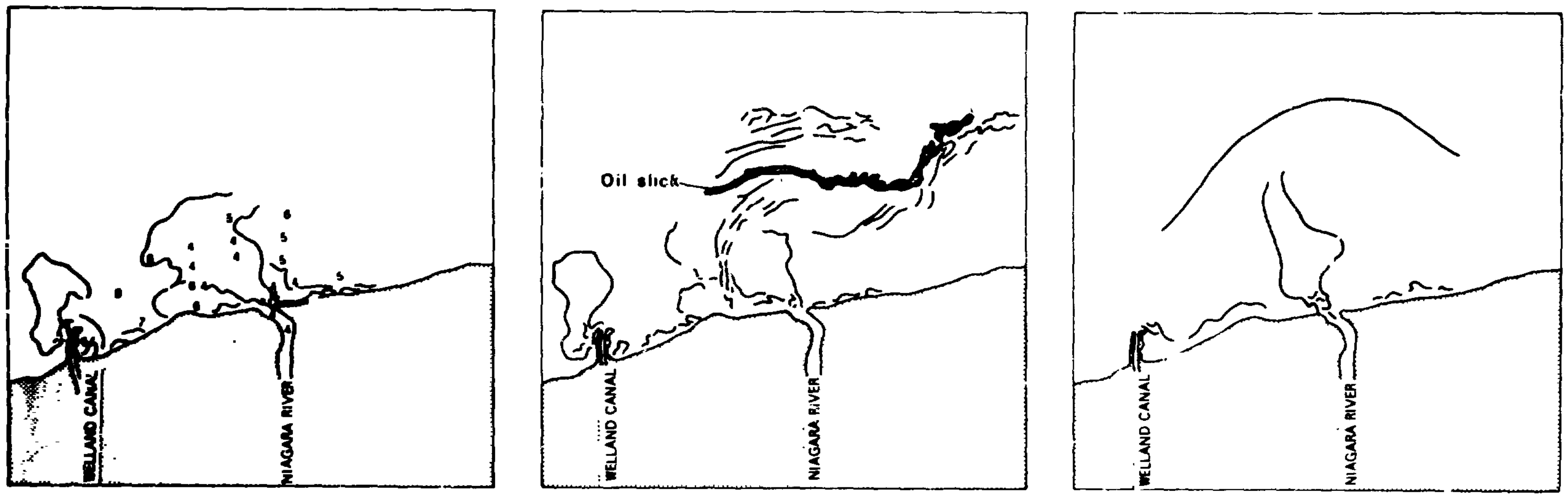
FIG 4

LAKE ONTARIO TEST SITE

Niagara Plume (Short Term Dynamics)



NIAGARA PLUME
JUNE 5TH
SO 397
1400 HOURS

NIAGARA PLUME
JUNE 5TH
SO 397
1435 HOURS

NIAGARA PLUME
JUNE 7TH
SO 397
1550 HOURS

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NASA RB - 57 DATA