# SOME OPERATIONAL USES OF SATELLITE RETRANSMISSION IN CANADA

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ABSTRACT

It is now possible through use of the data collection systems carried by satellites such as Landsat and GOES to obtain near real time water resources data from any location in Canada. These data have been used for flow and flood forecasting and to assist in the conduct of hydrometric surveys. Present programs will be continued and, likely, expanded, depending on the availability of suitable satellite systems.

## 1. INTRODUCTION

Shortly after ERTS 1 (now Landsat 1) was launched in 1972, the Water Resources Branch of Environment Canada began using the data collection system carried by the satellite to retransmit water resources data from remote Water Survey of Canada gauging stations to data users in various parts of the country. Nine sites were originally instrumented for satellite data collection, and on the basis of good success, additional equipment was purchased for installation at 19 additional sites in 1975. The sites are shown in Figure 1.

This paper discusses the satellite retransmission systems that are now available and gives examples of operational uses of these systems in Canada. Plans for the near future are also discussed.

## 2. SATELLITE RETRANSMISSION SYSTEMS

Satellite retransmission systems consist of a Data Collection Platform (DCP) which transmits sensor data from a field site to a satellite, a transponder carried by a spacecraft, a receiving antenna and a ground data handling facility. The transmissions from a DCP may be controlled by an internal clock or by interrogation command from a spacecraft. Some of the spacecraft that have data collection systems are discussed below.

### 2.1. LANDSAT

The polar orbiting Landsat spacecraft carry a data collection system in addition to imaging systems. This data collection system is designed to relay 64 bits of data from a DCP to a receiving antenna whenever the satellite is in mutual view of a receiving station and a transmitting DCP. Canadian data are retransmitted during three to eight orbits each day depending on location. (Only Landsat 2 is used for sensor data retransmission). Data can be retransmitted during the southbound passes each morning and northbound passes in the evening.

Canadian data are received by National Aeronautics and Space Administration (NASA) antennas at Goldstone, California or Greenbelt, Maryland then formated and transmitted by NASA land lines to a ground data handling centre at Greenbelt, Maryland. The data are sorted and sent to users by mail in computer printout and punch card format. In addition the data are sent by a dedicated telephone line to the Canada Centre for Remote Sensing (CCRS) at Ottawa after each orbit with a delay of less than an hour.

These data are periodically (normally once daily) entered into the CCRS time sharing computer system. A software data retrieval system sorts the user platforms, reformats the data into engineering units and stores individual user files on disk. Canadian users may then access a data file using either a 110 or 300 baud Teletype or Telex remote terminal.

As the data transmitted over land lines are sometimes degraded, the data received in punch card form are translated into engineering units by computer and the results used to make comparisons with data recorded at the gauging station. Programs have also been written to generate some statistics on data received.

The Landsat DCPs consist of a small electronic unit (about 0.01 $m^3$ volume, 5 kg mass) and an antenna. The electronic units can function in severe temperatures and high humidities. Data inputs consist of eight, 8 bit words in analogue, serial digital or parallel digital form. Later models of DCPs are convertible to use with the GOES system and have data memories up to 720 bits in length.

## 2.2. GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITE (GOES)

Unlike Landsat which is experimental, the GOES spacecraft was developed as an operational system and is the USA's contribution to a worldwide system of similar satellites. The GOES spacecraft perform several tasks including sensor data retransmission. The spacecraft has the ability to handle data from both self timed and interrogatable DCPs. The message length of a GOES DCP is not restricted to 64 bits - messages up to 2000 bits in length can be transmitted.

The GOES system will consist of geostationary satellites at 75° and 135° West longitude and an in-orbit spare mid-way between the two operating satellites. SMS 1 and SMS 2 (the NASA prototypes of the GOES spacecraft) were launched on May 17, 1974 and February 6, 1975 and are in operation at 75° and 115°. GOES A will be launched in October of 1975 and GOES B about one year later. Similar satellites will be operated by the European Space Agency, the Soviet Union and Japan at 0°, 70°E and 140°E respectively by 1978 thus providing global coverage.

The operator of the GOES system is the National Environmental Satellite Service (NESS), National Oceanic and Atmospheric Administration (NOAA), United States Department of Commerce. All data from the satellites are received at Wallops Flight Center, Virginia. Some processing is carried out then the data are sent by landline to Suitland, Maryland for dissemination to users. Canadian data are sent to the Atmospheric Environment Service of Environment Canada at Toronto, Ontario on a 2400 baud dedicated US National Weather Service circuit. From Toronto the data can be distributed by Telex to users. Printouts of retransmitted data are also mailed by NESS to the data users.

## 2.3. OTHER SATELLITES

Tiros N, which is scheduled for launch in 1978, will carry a data collection and localization system designed by the French Centre National d'Etudes Spatiales. This polar orbiting satellite is, like SMS 1 and SMS 2, a NASA prototype of a future operational system. The Tiros N system will handle up to 6000 platforms and, in addition to retransmitting sensor data, will determine the location of the DCP by computing the Doppler shift of the incoming message. This feature makes the system attractive for use in tracking drifting buoys, meteorological balloons, or ice floes.

The Canadian Department of Communications is now in the project definition phase of a study for a geostationary, low capacity, UHF communications satellite that would have a sensor data retransmission capability. The main purpose of the satellite would be to provide communications services (voice, data, facsimile) in support of field operations in northern Canada. It's possible that the first satellite in such a system would be launched in 1979.

# 3. OPERATIONAL USES OF SATELLITE RETRANSMISSION

In Canada, the data retransmitted by Landsat have been used by many agencies in preparation of flow forecasts, flood forecasts and in conducting hydrometric operations.

## 3.1. MACKENZIE RIVER FLOW FORECAST

The Mackenzie River (Figure 2) flows north, draining a 1.8 x $10^6$ $km^2$ portion of western Canada - an area as large as that of Great Britain, France, Germany, Spain, Portugal and Italy combined. The 1600 km reach from Great Slave Lake to the mouth of the river is navigable during the short ice-free period in the summer. During this time about 400 000 tonnes of cargo are shipped by barge from Hay River to resupply 18 small communities along the waterway and to support oil and gas exploration and development.

The navigation channel is so shallow that, under low water conditions, barge loadings must be reduced to 75% of capacity. Because of this, the Water Survey of Canada at Calgary makes predictions of Mackenzie River flows and produces a water level bulletin that is broadcast daily on marine radio. The barge operators can then adjust loadings so that as much cargo as possible may be carried without danger of running aground.

Until recent years, preparation of an accurate forecast was difficult as water level data were available only from a few locations on the main stem of the river. This information was obtained by local observers and relayed to Calgary, in some cases using uncertain radio telephone links. In addition very little information concerning tributary inflow was available on a daily basis. Tributary inflow accounts for at least 40% of the flow in the Mackenzie and this inflow can vary widely because of storms that move south from the arctic coast along the Mackenzie mountains to the west of the river. Preparation of the forecast is essentially a flow routing procedure and is described in Holinshead, 1974 and in Davies, 1975..

In 1972, two Landsat DCPs were installed on the main stream of the Mackenzie at critical points thus ensuring that several daily readings of water level would be available for the forecast. Also in 1972, the Regina office, Water Survey of Canada, installed a DCP on Lake Athabasca. Data from this site are not used in the Mackenzie forecast but are used by navigational and environmental interests on Lake Athabasca. The principle purpose of the data is to monitor water levels in the Peace-Athabasca Delta. Fluctuations in water level affect migratory birds, fish, and wildlife in the Delta thus affecting the lives of the native people in the area. Water levels are now partially controlled by weir on the Rivière des Rochers - one of the principle water courses in the Delta.

During 1975, four more DCPs were installed on major tributaries of the Mackenzie so that tributary inflow could be determined more accurately on the basis of real time data. Table I lists the present location of all the DCPs in the Mackenzie River basin. The sites are plotted in Figure 2.

TABLE I. DATA COLLECTION PLATFORMS IN MACKENZIE RIVER BASIN

| Gauging Station | Latitude | Longitude |
|---|---|---|
| Lake Athabasca at Crackingstone Point | 59° 23' | 108° 53' |
| Mackenzie River near Wrigley | 63° 16' | 123° 36' |
| Mackenzie River at Sans Sault Rapids | 65° 46' | 128° 45' |
| Mountain River below Cambrian Creek | 65° 14' | 128° 34' |
| Root River near the Mouth | 62° 29' | 123° 26' |
| Liard River at Fort Liard | 60° 15' | 123° 29' |
| South Nahanni River above Virginia Falls | 61° 38' | 125° 48' |

No rigorous benefit-cost study of the value of the forecast service has been conducted. However the $31 000 capital cost of DCPs and associated equipment plus the $50 000 annual operating cost of the forecast network seems minor in comparison to the multi-million dollar investment in transportation equipment and the value of the cargo shipped each year. The annual cost of channel dredging alone is in the order of $1 000 000 a year.

## 3.2. SAINT JOHN AND FRASER RIVER FLOOD FORECAST

The Saint John River is an international river forming part of the boundary between New Brunswick in Canada and Maine in the United States. The 55 000 km$^2$ basin is subject to heavy snowfalls during the winter. Therefore, every spring the lower Saint John Valley could be subject to flooding if snow melt is rapid and if there is precipitation during the melt period.

Three DCPs are installed in the basin - two on the St. John River in Maine are operated by the United States Army Corps of Engineers and one on the St. Francis River (Site 27, Figure 1) in New Brunswick by the Halifax office of the Water Survey of Canada. The stage-discharge relation for the St. Francis River site is not subject to backwater effects from ice therefore the retransmitted water level data can be used to compute accurate discharges. These figures are then used as an index of tributary inflow in a SSARR (Streamflow Synthesis and Reservoir Regulation) forecasting model for the lower Saint John River.

The St. Francis River data are also used by the United States Geological Survey, Water Resources Division to assist inflow computations for the International Gauging Station on the St. John River at Fort Kent, Maine, a typical station in their reporting network and by the United States Army Corps of Engineers for their water management activities in the upper St. John basin in the state of Maine.

The Fraser River drains 215 000 km$^2$ in British Columbia, flowing into the Pacific Ocean at Vancouver, Canada's third largest city. Like the St. John basin, the snow accumulation in the Fraser watershed is sufficient to cause spring flooding if unfavorable climatic conditions prevail during the melt period. One flood, in 1948, caused $300 000 000 damage.

Two DCPs are operated on tributaries of the Fraser by the Vancouver office of the Water Survey of Canada to provide an index of tributary inflow into the river. One DCP is in the headwaters on the McGregor River (Site 2, Figure 1) while the other is in the lower canyon area on the Nahatlatch River (Site 1, Figure 1). Precipitation and air temperature data are transmitted from the Nahatlatch site as well as water level data. Access to both of these sites is difficult and costly, therefore, prior to installation of the DCPs, it was not possible to make a good estimate of the tributary inflow to the Fraser.

### 3.3. HYDROMETRIC OPERATIONS

In addition to the water management uses of satellite retransmitted data, there are ways in which the data may be used by operators of hydrometric data gathering networks. Incoming data can be examined to ensure that water level and other sensors are operating normally. Also diagnostic data such as battery voltages or recorder status can be transmitted. If malfunctions are noted, repair parts can be carried in on the next visit to the site.

The data can also be used in trip planning; visits to a site may be postponed if the instrumentation is operating normally and the water level is such that no discharge measurement is necessary. Alternatively, special trips can be scheduled if river conditions warrant it. The result of data retransmission, then, is either decreased operating costs or better quality data, or both.

Another promising application to hydrometric data collection is that of using a DCP equipped with a memory to store then transmit water level data thus eliminating the need for on-site recording of data. Memories having a 720 bit capacity have been used to produce daily water level record based on 96 observations a day.

## 4. PLANS FOR THE NEAR FUTURE

The Water Survey of Canada DCPs will continue to be used with Landsat 2 to provide real time data for operational purposes. It's likely that, as more experience is gained with the GOES system, some of the Landsat sites will be converted to GOES operation. This will apply particularly to those sites used for flood forecasting as it's possible to obtain data more frequently using GOES.

The Canada Centre for Remote Sensing has completed a study of the reception of Landsat and GOES data collection system data at the Prince Albert Satellite Station. Implementation of the system is particularly attractive for the Landsat data as this would enable data to be received on more orbits of the satellite as Prince Albert is much closer to the transmitting DCPs.

One Canadian manufacturer is now making a small number of GOES DCPs under contract to Environment Canada. No large purchases of additional DCPs are planned at present, however, quantity purchases will be made after the decisions with respect to the Canadian UHF system are known.

## 5. CONCLUSIONS

Satellites that carry data collection systems such as Landsat and GOES have been used to relay water resources data from remote areas in Canada with good success. The data have been used for flow forecasting, flood forecasting and for hydrometric operations. The systems have proved to be reliable and cost effective.

Future activities include continuation of existing programs with possible direct reception of data in Canada and more input from Canadian manufacturers. Expansion of networks in Canada likely will not take place until decisions are made with respect to satellites.

## 6. REFERENCES

Davies, K. 1975. Report of the 1975 Conference on Improvements to the Athabasca-Mackenzie Waterway and Western Arctic, Appendix "J".

Holinshead, P. 1974. Mackenzie River Forecast. Proceedings, 1974 Calgary District Conference, Water Survey of Canada, Calgary, Alberta.

FIGURE 1

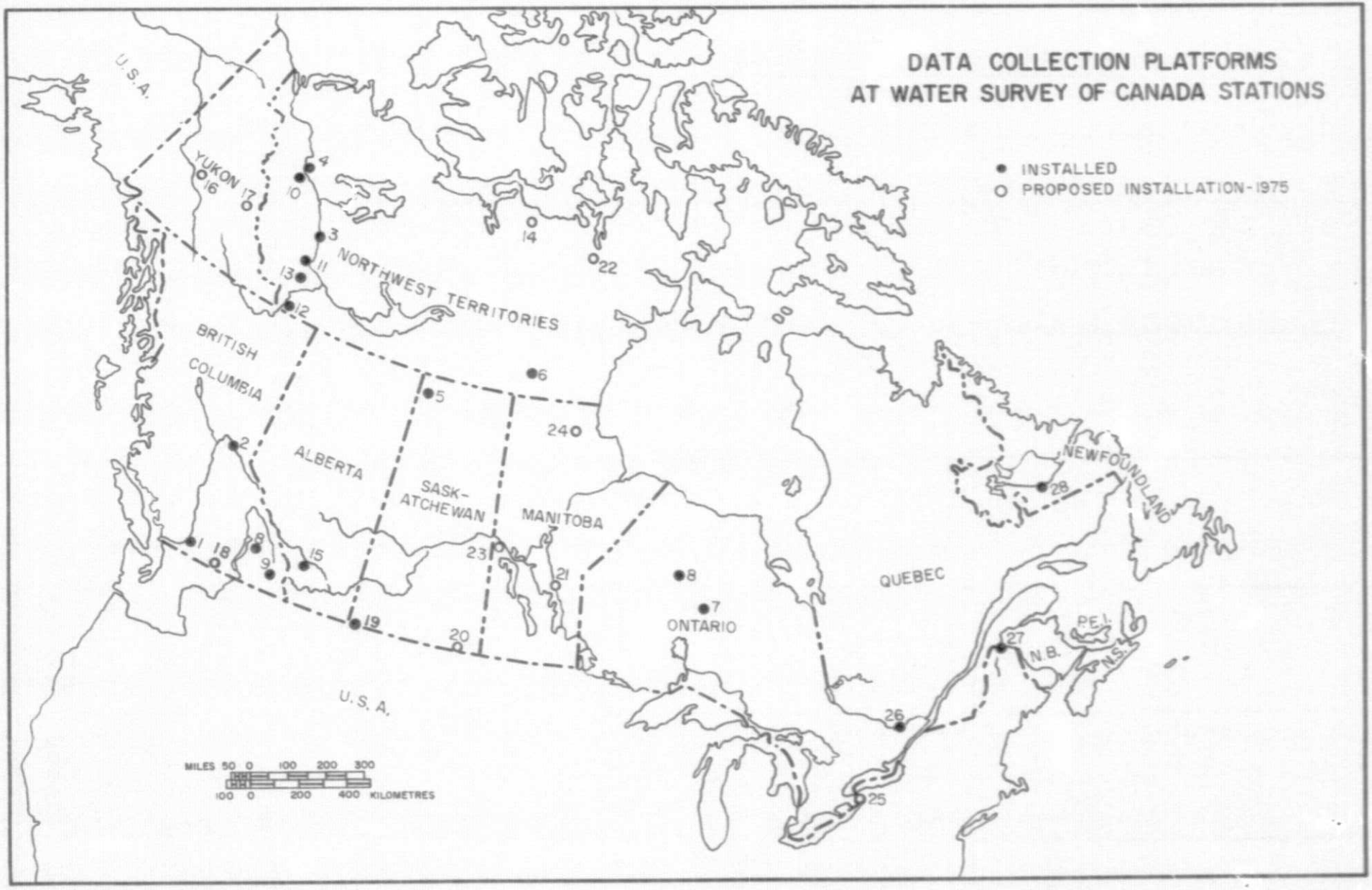
DATA COLLECTION PLATFORMS
AT WATER SURVEY OF CANADA STATIONS
● INSTALLED
○ PROPOSED INSTALLATION - 1975
U.S.A.
YUKON
NORTHWEST TERRITORIES
BRITISH COLUMBIA
ALBERTA
SASK-ATCHEWAN
MANITOBA
ONTARIO
QUEBEC
NEWFOUNDLAND
N.B.
P.E.I.
N.S.
U. S. A.
MILES 50 0 100 200 300
100 0 200 400 KILOMETRES

**FIGURE 2**
**DATA COLLECTION PLATFORMS IN THE MACKENZIE RIVER BASIN**


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