1-P

E7.4-10.5 1 6.
CR-138266

RETRANSMISSION OF WATER RESOURCES DATA USING THE ERTS-1 DATA COLLECTION SYSTEM

by

R.A. Halliday*, I.A. Reid*, and E.F. Chapman**

(E74-10516) RETRANSMISSION OF WATER RESOURCES DATA USING THE ERTS-1 DATA COLLECTION SYSTEM (Department of the Environment, Ottawa) 15 p HC $4.00 CSCL 08H G3/13

N74-25841

Unclas 00516

Presented at the ERTS Principal Investigator's Symposium, December 10-14, 1973, Washington, D.C.

* Applied Hydrology Division, Water Resources Branch, Department of the Environment, Ottawa, Canada.

** Applied Hydrology Division, Water Resources Branch, Department of the Environment, Calgary, Canada.

RETRANSMISSION OF WATER RESOURCES DATA USING THE ERTS-1 DATA COLLECTION SYSTEM

R.A. Halliday, I.A. Reid, E.F. Chapman (Canada - Department of the Environment)

ABSTRACT

The Water Survey of Canada operates a network of approximately 2400 gauging stations at which water level data are collected. In most cases the water level data are used in conjunction with periodic discharge measurements to produce daily river discharge data. These data may be used for design of structures and works, flow and flood forecasting, project regulation and for pollution control. In many cases it would be desirable to obtain data on a near real time basis. However, the isolated locations of most of the gauging stations have made the cost of land line telemetry prohibitive. Fewer than 100 gauging stations have been equipped with telemetry systems.

Therefore, when the ERTS Data Collection System became available in 1972 it seemed worthwhile to investigate the possibility of using a satellite retransmission system to collect discrete water level readings at least once daily from a few gauging stations and to use these data for operational purposes. In this way a valid assessment with regard to reliability, costs and other aspects of the whole system could be carried out and decisions made with respect to the feasibility and advantages of establishing a much larger network of DCPs dependent on future satellite facilities.

To perform this assessment, nine DCPs were installed in isolated areas of northern and western Canada. It was felt that DCPs in these locations would be exposed to climatic conditions severe enough to provide a check on system reliability. In addition, near real time data from the sites selected would help the Water Survey of Canada meet some of its operational needs.

Water level data are transmitted from all sites and, also, some of the DCPs are used to transmit ice break-up, water velocity, precipitation, air temperature, water stage recorder clock operation or DCP battery voltage. Consideration is being given to transmitting other parameters that would be of value in flood or flow forecasting.

Results of the project have been excellent. There has been no data loss that can be attributed to failure of a DCP although data were lost because of sensor malfunctions. The quality of data collected compares favourably with that of the hard record obtained at the remote sites. Costs of using the ERTS Data Collection System are reasonable.

INTRODUCTION

The Earth Resources Technology Satellite (ERTS-1) was launched on July 23, 1972. This satellite provides for the repetitive acquisition of high resolution multispectral data of the earth's surface on a global basis. In addition, the satellite has the capability of retransmitting data from remote, widely distributed, earth-based sensor platforms to receivers in the United States. This data retransmission capability has been used by the Water Survey of Canada for acquisition of water resources data from nine remote sites on a near real time basis.

The Water Survey of Canada operates over 2400 gauging stations at which water level data are collected. At most stations, the water level data are used to compute river discharge data. These data may be used for the design of structures such as hydro electric power plants and for flow and flood forecasting, project regulation and for pollution control. In many instances, it would be desirable to obtain data on a near real time basis; however because of the isolated locations of most gauging stations, the cost of doing this has been prohibitive. Fewer than 100 gauging stations have been equipped with telemetry systems.

Therefore, when the ERTS Data Collection System was proposed it seemed worthwhile to investigate the possibility of using a satellite retransmission network to collect a discrete water level reading at least once daily from a few gauging stations and to use these data for operational purposes. In this way the dependability, costs and other aspects could be studied and decisions made with respect to the feasibility and advantages of establishing a much larger network of Data Collection Platforms (DCPs) dependent on future operational satellite data retransmission facilities.

This paper discusses site selection, sensors used, field installation of DCPs, data handling, results and future plans.

Site Selection

The sites were selected on the basis that real time data would be very valuable for flow forecasting and other operational purposes. In addition, the severe climatic conditions at the sites would provide a good test of the DCP's performance.

Nine sites were selected for experimentation with satellite retransmission by ERTS. Three of the sites are in southern British Columbia, two in the western arctic, one in northern Saskatchewan, one in the eastern arctic, and two in northern Ontario. These sites are located in northern or mountainous regions. Because of the range in climatic and areal conditions, it is considered that these locations would provide a good test on the operational aspects of the data collection. Table one lists the nine sites now in use.

TABLE ONE

WATER SURVEY OF CANADA GAUGING STATIONS
HAVING ERTS DCPs

	Station Name	I.D.	Lat.	Long.
1.	Duncan River below B.B. Creek	6126	50°38'	117°03'
2.	Nahatlatch River below Tachewana Creek	6232	49°57'	121°52'
3.	McGregor River at Lower Canyon	6354	54°14'	121°40'
4.	Mackenzie River near Wrigley	6260	63°16'	123°36'
5.	Mackenzie River at Sans Sault Rapids	6366	65°46'	128°45'
6.	Lake Athabasca at Crackingstone Point	6150	59°23'	108°53'
7.	Kazan River at Outlet of Ennadai Lake	6353	61°15'	100°58'
8.	Albany River above Nottick Island	6102	51°38'	86°24'
9.	Winisk River below Asheweig River	6137	54°31'	87°14'

Site 1) is in the Columbia River basin. Data are supplied by the Water Survey of Canada to Canadian and United States operating entities who use the information to forecast runoff especially spring runoff when there is an ever present threat of flooding. Also, the Columbia River Basin Permanent Engineering Board uses the information to check operating schedules of the Treaty dams.

Sites 2) and 3) are in the Fraser River basin. Data from these sites are used as an index of tributary inflow into the Fraser River for flood forecasting purposes. In most years the spring runoff on the Fraser presents a flood threat to major population centres.

The principal method of transporting bulk cargo in the western arctic is by means of barges on the Mackenzie River. Because the shipping season is short, it is desirable that barges carry the maximum possible tonnage and yet not be subject to the risk of running aground. The Water Survey of Canada makes predictions of water levels three times weekly for navigational purposes. The real time water level readings from the two Mackenzie River sites (sites 4) and 5)) allow the barge operators to transport the cargo efficiently and economically.

Lake Athabasca (site 6)) is a naturally controlled reservoir augmenting low summer flows in the Slave and Mackenzie Rivers. The wildlife in the area, along with that on an adjoining lake provides the means of livelihood for nearly all the native people in the area. Both the wildlife and native people are now affected by the control exercised by the power development on the connected Peace River. Real time data at Lake Athabasca is considered beneficial for monitoring purposes.

The Kazan River (site 7)) in the barren lands of the eastern arctic is accessible only by chartered air service with the river serving as a landing strip. Flows in this river are representative of conditions in a wide area of the eastern arctic. Therefore, if prevailing river conditions at this site were known, considerable savings might be possible in scheduling hydrometric and other activities in the area. Ice formation and break-up could be detected and the aircraft equipped with the appropriate landing gear.

The Albany and Winisk Rivers (sites 8) and 9)) are major rivers in northern Ontario that are accessible only by fixed and rotary winged aircraft. A knowledge of river conditions in the area would aid activities in this part of northern Ontario. The two rivers are fairly representative of most rivers in the area and have been under investigation for a major water resources development.

SENSORS

Water Level

Water level is the primary parameter retransmitted from Water Survey of Canada gauging stations by ERTS-1. Two systems are used by the Water Survey of Canada to sense water level. The first is a float and pulley operating in a stilling well that is connected to the river. Where it is not feasible to install or operate a stilling well system, because of climatic or economic reasons, a nitrogen purge system is used to sense the head of water above a fixed orifice near the river bed. The pressure of the head of water over the orifice is transmitted by the pressure exerted on the gas in the bubble tubing to a servo-manometer which converts this pressure to a shaft rotation. At conventional gauging stations the output shaft from the servo-manometer or the float system is connected to a Leupold & Stevens Type A analogue water stage recorder.

At the ERTS DCP sites a Leupold & Stevens Memomark II is used in conjunction with a float or servo-manometer to encode and store the water level as four binary coded decimal digits. This enables water levels ranging from 0000 to 9999 to be transmitted. No interface is needed between the Memomark II and the DCP.

Precipitation and Air Temperature

In co-operation with the Atmospheric Environment Service, Department of the Environment, two Hydrometeorological Automatic Recording and Telemetering Systems (HARTS) were installed to encode and store data from a Fischer-Porter precipitation gauge and a platinum resistance bulb thermometer. Accumulated precipitation to the nearest 0.030m (0.1 ft.) and temperature to the nearest 0.055C° (0.1F°) are encoded for transmittal by ERTS. The HARTS system is described in (Fong, 1973) and has also been used for encoding of snow pillow and wind run anemometer data.

Water Velocity

River velocity is a useful parameter to record especially during those periods when the conventional stage-discharge does not hold. Using stage and recorded velocity data, it is possible to compute river flows at many gauging stations when a stage-discharge curve is not defined. (Strilaeff and Bilozor, 1973).

A Marsh-McBirney electromagnetic meter which has an output voltage of 0 to 1 volts corresponding linearly to a velocity of 0 to 10 feet per second is installed at one site. In order to obtain time averaged data, a velocity integrator has been designed.

"Ice-out" Indicator

A useful piece of information for computation of streamflow data and for planning of hydrometric operations is a knowledge of when the ice moves out of the river at a gauging station. Two methods that use the same principle were designed to detect this ice movement. The first was to connect a 4 1/2 volt battery to light wire, then put this voltage into one of the analogue channels. The battery is frozen into the ice surface of the river so that when the ice moves out, the cable is broken and the voltage level drops to zero. A second version of the same system uses one bit rather than an entire word. In this case a friction type plug is tied firmly near the water's edge with the male side of the plug shorted and connected to a line which is frozen into the ice. When the ice moves out, the plug pulls apart and the bit transmitted changes from a zero condition to a one condition. "Ice-out" indicators were installed at several sites.

DCP Battery Check

A battery check device (Kruus, 1973) has been installed at three sites to monitor the voltage level of the DCP power supply. The voltage of the DCP batteries is scaled to provide a voltage less than 5 volts. In order to conserve the DCP batteries the device is switched on by the data gate signal prior to a transmission. The battery check device uses one analogue channel.

Water Stage Recorder Operation Check

The Leupold & Stevens Type A recorder has very good cold temperature performance characteristics but is subject to clock stoppages at about -50°C (Chapman, 1971). Also, the clocks stop once in a while for reasons other than cold temperatures. Once stopped, it is very unusual for a clock to restart on its own. A method of checking clock operation using a cam and single throw, double pole micro-switch was devised. When the recorder clock is operating two parallel digital bits in the DCP message change from 01 to 10 to 01 and so on every 10 hours. A failure to change indicates that the recorder clock has stopped. A few of these devices are now in operation. One of the authors' chief concerns was to ensure that the device itself would not cause a clock stoppage.

INSTALLATION OF DCPs

The DCPs are installed in regions where severe climatic conditions prevail. Temperatures lower than -50°C can occur at some sites. Also, wind velocities in the order of 100 km/hr or snow depths of 2 m are possible. None of the sites are in high humidity areas.

Some of the DCPs were heated to protect them from severe temperatures. The method of heating consisted of constructing an insulated compartment of plywood and styrofoam around the instrument. This enclosure is heated using a catalytic propane heater having a 630KS orifice. One 45.4 kg (100 lb.) tank of propane is sufficient to last three to four months.

Three different DCP power supplies were used. One is a series-parallel combination of 6 rechargeable Union Carbide No. 564 batteries; another is two heavy duty 12 volt lead-acid batteries in series and the last, two snowmobile 12 volt lead-acid batteries in series. A set of air-depolarized carbon zinc batteries that, reputedly, have good low temperature characteristics and long life, have been purchased for installation during the winter of 1973-74.

Figure one shows a typical interior of a gauge house containing a propane tank for the heater, a nitrogen tank for the gas purge system, the Leupold & Stevens Type A-71 recorder, the CAE Aircraft water stage servo-manometer, the Leupold & Stevens Memomark II water level encoder and the General Electric DCP electronic box.

No special precautions were taken in erecting the antennas. Guy wires were used in those cases where strong winds or heavy snow loads were expected. Some antennas have been subject to winds speeds of 80 km/hr or snow loads of 1 m with no damage.

As the DCPs were installed in existing instrument or combined instrument and personnel shelters associated with a gauging station, the installation could be completed very quickly. About two man days were required to install the antenna, connect interfaces to existing sensors and activate the DCP.

The only real problem was getting the DCP on site. In many cases, the bulky shipping carton could not be fitted into aircraft normally used in hydrometric operations. Therefore, the antenna, electronic package and hardware were removed from the carton and the antenna transported with no protection. Fortunately no antennas were damaged. A smaller ground plane would be a definite asset from a transportation viewpoint.

It's noteworthy that, despite the large size of the shipping container, two DCPs were lost during shipment by commercial air carriers.

Figures 2 and 3 show the typical exterior appearance of DCP installations at Water Survey of Canada gauging stations.

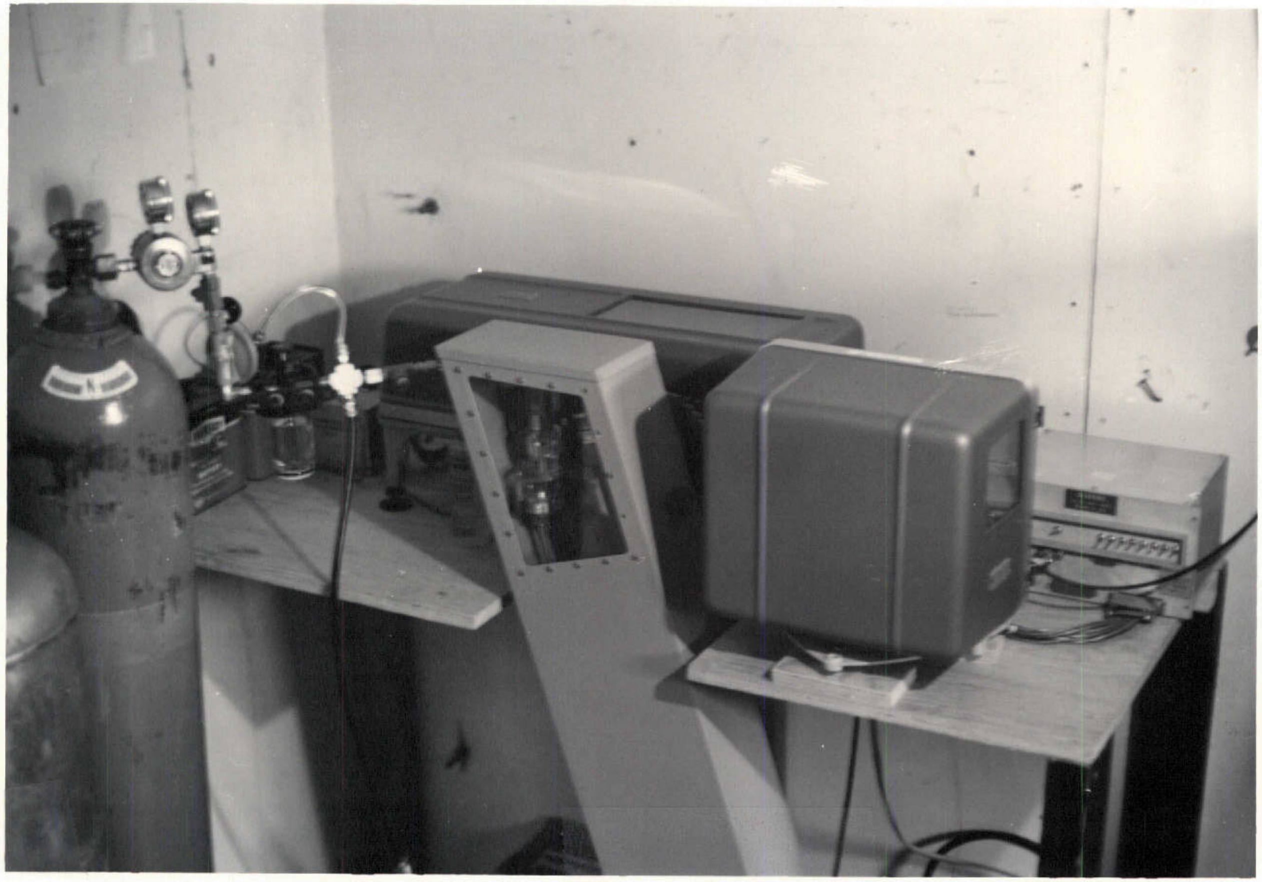

Figure One: Instrumentation Layout in Typical

Gauging Station

Figure Two: Typical Instrument Shelter
with ERTS DCP Antenna

Figure Three: Typical Instrument and Personnel Shelter
with ERTS DCP Antenna

The ERTS Data Collection System is composed of three subsystems: the DCP at a remote site, the receiving and transmitting equipment in the ERTS spacecraft, and the receiving site equipment at Goldstone, California and Greenbelt, Maryland.

The DCP accepts eight words of data, eight bits in length, from the user's sensors in analogue, parallel digital or serial digital form and transmits the encoded data along with a DCP identification number in a short burst at 401.55 MHz every three minutes. When the satellite is within mutual view of a transmitting DCP and a receiving site, the data are recovered.

Data received are formatted and transmitted over the NASA Communication System (NASCOM) to the ERTS Control Center where, after further processing, the data are supplied to users in card and printout form and, in some cases, by teletype. The Canadian cards and printouts are delivered to the Canadian Embassy in Washington, D.C., then carried by diplomatic bag to the Canadian Department of External Affairs in Ottawa where the data were mailed to Canadian users. This unwieldly procedure usually results in a delay in receipt of data of about two weeks.

In order to overcome this problem, the Canada Centre for Remote Sensing (CCRS) in Ottawa and NASA made arrangements for Canadian DCP data to be received at CCRS by dedicated telephone line after each orbit. Normally a delay of 30 to 40 minutes is experienced. The data received are recorded simultaneously on a teletype hard copier and a magnetic tape.

At present, these data are periodically inputed to 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. The user may then access his data file using either a teletype or telex remote terminal. Several users across Canada receive data on a daily basis by telex.

Arrangements to automatically input the data received from NASA into the CCRS computer system are in progress.

As data transmitted over the existing teletype line are sometimes degraded, the data received in card form are translated by computer into engineering units to provide a hard copy for comparison purposes.

RESULTS

The nine Water Survey of Canada platforms have been in operation for an average time of one year without experiencing a DCP failure. Two platforms have stopped transmitting because of DCP battery failures but started again when the battery was replaced. Also some placforms have been turned off to move them to different sites.

Four platforms are now installed at sites other than those originally specified in the submission to NASA. (One was never installed at the original location). The platforms were moved to sites where the data would be more beneficial to users and where the platforms would be exposed to more rigorous field conditions. The platforms were relocated once confidence was gained in the ERTS Data Collection System.

The communications link from the DCPs to the NASA Data Processing Facility (NDPF) has been extremely reliable with about 98 percent of the Canadian messages having been assigned the highest confidence level (7). Checks have shown that, when message confidence is 7, the data received via ERTS are identical to the values "seen" by the sensors.

The number of confidence 7 messages from the nine platforms are summarized in table two. All figures are based on the use of the 180 second transmit rate. In this table, transmissions from the same platform received at both Goldstone and Greenbelt at the same time are counted once.

TABLE TWO

SUMMARY OF RETRANSMITTED DATA

Platform Identification	Daily Mean Transmissions for Period of Operation	Transmissions Daily Max.	Transmissions Daily Min.
6126	7	10	3
6232	9	13	4
6354	8/9*	13	3
6260	9/6*	13	4
6366	8/8*	13	4
6150	14	19	6
6353	15	25	7
6102	15	20	6
6137	16	22	6

* two locations

The number of transmissions from a site seems to be dependant on the geographical location and the horizon elevation. Sites surrounded by deciduous trees such as that in figure 2, show no difference in transmission rates from summer to winter. Also the transmission rate seems unaffected by accumulations of over 0.5 m of dry snow on the ground plane. There is some evidence to suggest that the transmissions are attenuated slightly when this snow cover is melting.

A few platforms in the higher latitudes were operated on the 90 second transmission rate for short periods of time until it became apparent that sufficient data would be received at the 180 second rate. It's noteworthy that because of the high latitudes in which the platforms are operated, and despite the long distances to the receivers, that data are occasionally received on 8 orbits a day. Data are frequently received on 7 orbits each day.

The sensors discussed in an earlier section of this paper have all performed well. The main problem has been a failure of the water level encoder to update. This occurs when the encoder clock stops, either because of battery failure or for other reasons. Many batteries associated with the ERTS installations have been left operating until failure in order to evaluate their performance under load at low temperatures.

All of the Water Survey of Canada DCPs are installed in locations where site access is difficult and costly. Because of this, sites are visited as few as five times a year. Therefore when a sensor or other failure occurs at a DCP site several weeks may elapse before repairs can be made. The DCP data can be used to diagnose the problem and appropriate repair parts can be carried in to site. Also, if warrented, a special trip to the site may be scheduled in order to meet data users' requirements.

As ERTS is an experimental system, NASA and other agencies are paying some costs that would normally be charged to users. It is therefore not possible to produce rigorous cost comparisons between data retransmission by ERTS and by other means. Table three shows some approximate costs of installing water level telemetry service at an existing gauging station in southern Canada.

TABLE THREE

APPROXIMATE COSTS OF WATER LEVEL TELEMETRY

	Capital and Installation	Annual Maintenance	Annual Operating
Telephone	$ 1,400	< $ 100	$500
Radio	$20,000	$1,000	$500
ERTS-DCP	$ 4,500	< $ 100	low

It should be noted that in most parts of Canada the cost of installing telephone or radio telemetry systems is not economically feasible therefore satellite retransmission is the only means of obtaining water resources data from these areas.

FUTURE PLANS

ERTS Related

The main thrust of the Water Survey's program will be a move towards quasi-operational use of the ERTS Data Collection System. The number of platforms will be increased to about 30 and the DCP memory developed by the U.S. Geological Survey, Water Resources Division will be used at a few sites. Operation of this larger network of DCPs will enable a more thorough analysis of the costs and benefits of satellite retransmission to be carried out.

It is expected that a few additional sensors will be used. The most probable are water temperature and ice thickness. These data are useful for operation of hydrometric data gathering networks and may be of interest to data users.

Beyond ERTS

Additional ERTS platforms will be ordered keeping in mind future developments in the field of satellite retransmission. If the ERTS system fails, these platforms can be easily converted to operate as self-timed units using the Geostationary Operational Environmental Satellite (GOES) Data Collection System. The GOES Satellite, which is expected to be operational in late 1974, will be operated and controlled by the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce.

There are two Canadian satellites under consideration that would have data retransmission capability. The first of these is a low capacity geostationary UHF communications satellite (Walker, Card, Roscoe, 1973). The data retransmission system will be similar in many ways to that of GOES. A feasibility and design study for the platforms, that will be used with the satellite, has been completed under contract to the Canadian Department of Communications.

The second proposed satellite is an earth resources satellite that would be similar to ERTS in many respects. This satellite would have scanning and data retransmission capability. Both of the proposed Canadian satellites could be launched in this decade.

CONCLUSIONS

The original intention of the Water Survey of Canada in participating in the ERTS Data Collection System experiment was to determine if reliable water level data could be retransmitted twice daily from an isolated location on a near real time basis. It's apparent that the experience since the launch of ERTS-1 has amply demonstrated the technical feasibility of satellite retransmission, at least from low orbiting spacecraft.

The General Electric DCP has proven to be a versatile, rugged piece of hardware and has surpassed original expectations. No interfacing problems have been encountered. The quantity of reliable data gathered by the ERTS DCPs has proven very useful for water resources management and hydrometric field operations.

Canada is a large sparsely populated nation. These factors plus the country's rigorous northern climate and large surface water supply appear to make satellite retransmission of water resources data a logical extension of Space Age technology to the science of hydrometry.

REFERENCES

Chapman, E.F., Low Temperature Tests on Leupold and Stevens Type A-35 Recorders and Recorder Clocks, Technical Bulletin No. 54, Inland Waters Branch, Department of the Environment, Ottawa, 1971.

Fong, H., Hydrometeorological Automatic Recording and Telemetering System, Prototype HARTS-1 (ERTS), Atmospheric Environment Service, Department of the Environment, Toronto, January 8, 1973.

Kruus, Dr. J., A Water Resource Monitoring Platform, Type II Report for Period January to August, 1973, Department of the Environment, Ottawa, October, 1973.

Strilaeff, P.W. and Bilozor, W., Single Velocity Method in Measuring Discharge, Technical Bulletin No. 75, Inland Waters Directorate, Department of the Environment, Ottawa, 1973.

Walker, B.A., Card, M.L., and Roscoe, O.S., 1973, A Planning Study for a Multi-Purpose Communications Satellite Serving Northern Canada, Proceedings, Satellite Systems for Mobile Communications and Surveillance, London, England, March 13-15, 1973.

ACKNOWLEDGEMENTS

The authors wish to thank the many persons in the Department of the Environment who contributed their time and energy to this project. In addition the excellent co-operation of Mr. Howard Edel of the Canada Centre for Remote Sensing, Mr. Duane Preble of the USGS, Gulf Coast Hydroscience Center, and Mr. J. Earle Painter of NASA is gratefully acknowledged.