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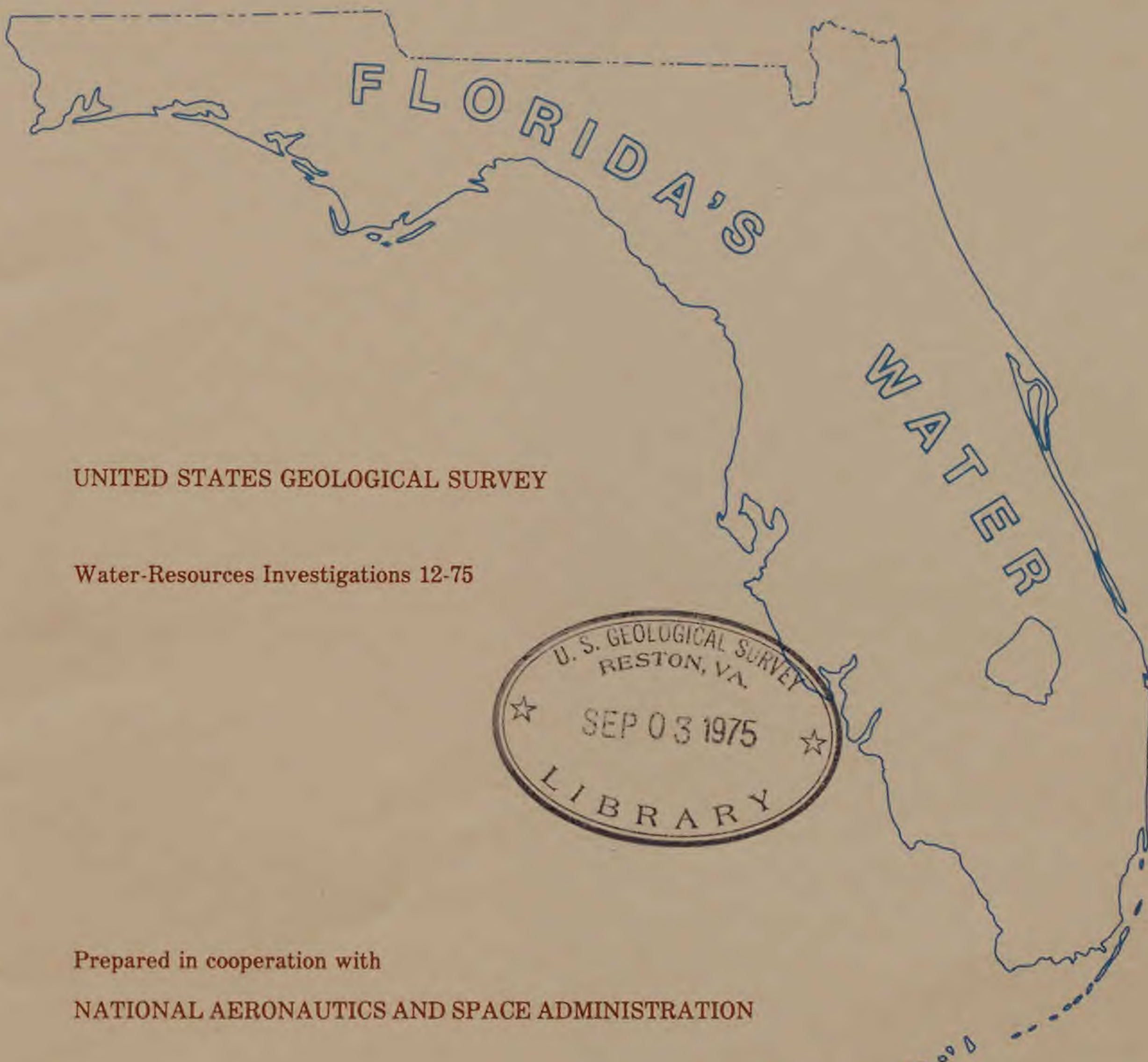
SATELLITE RELAY AND PROCESSING OF HYDROLOGIC DATA IN SOUTH FLORIDA



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ILLUSTRATIONS

FACTORS FOR CONVERTING ENGLISH UNITS TO METRIC UNITS

Multiply English units	By	To obtain metric units
inches (in.)	25.4	millimetres (mm)
	.0254	metres (m)
feet (ft)	.3048	metres (m)
miles (mi)	1.609	kilometres (km)

SATELLITE RELAY AND PROCESSING OF HYDROLOGIC DATA IN SOUTH FLORIDA

By

E. T. Wimberly

ABSTRACT

Management of water in south Florida requires current hydrologic data on water levels and rainfall. This need is being met by a data processing system which provides near-real-time data from remote areas. The flow of data is from data-collection platforms at field sites via LANDSAT-1 satellite to the National Aeronautics and Space Administration's (NASA) ground-receiving stations to the NASA Data Processing Facility at Goddard Space Flight Center to the Miami office of the U.S. Geological Survey to data users. The process requires only a few hours, and current data are provided to water-management agencies in several different forms. The system has proven to be dependable.

INTRODUCTION

A Data Collection System (DCS), using the LANDSAT Satellite (LANDSAT-1) as a data-relay platform, has been tested in south Florida. The purpose of DCS is to transmit water data to the user in near real time, even from remote areas. This report describes DCS as it is being used in south Florida.

Thousands of square miles of south Florida (fig. 1) are inundated many months of the year when the only practical access is by airboat or helicopter. A system of water-conservation areas, canals, levees, pumps, and control structures, provides a means of water management for preservation of the ecosystems of the Everglades National Park, and for supplying water to the highly populated areas of southeast Florida. Gaging stations provide basic information for water management and flood protection. The need for near-real-time data becomes imperative during times of crisis, such as a hurricane, because rapid evaluation of the situation and operational decisions are mandatory. Serious consequences to life and property could result if management decisions are not optimal.

In October 1972 a DCS began transmitting to the U.S. Geological Survey Office in Miami, water-level and rainfall information from gaging stations in the water-conservation areas, Everglades National Park, and Big Cypress Swamp. The path of data flow is shown in figure 2. The time for this transmittal is about 45 minutes. The system has provided the needed information rapidly and reliably and is functioning in an operational mode although the satellite is still considered experimental.

After receipt of the data in Miami from the NASA Processing Facility at Goddard Space Flight Center (GSFC), the data are fed into a programmable calculator for processing into a finished product, which is telecopied to the water-management agencies daily and more frequently when needed. The entire process from gage to user can be accomplished within 2 hours.

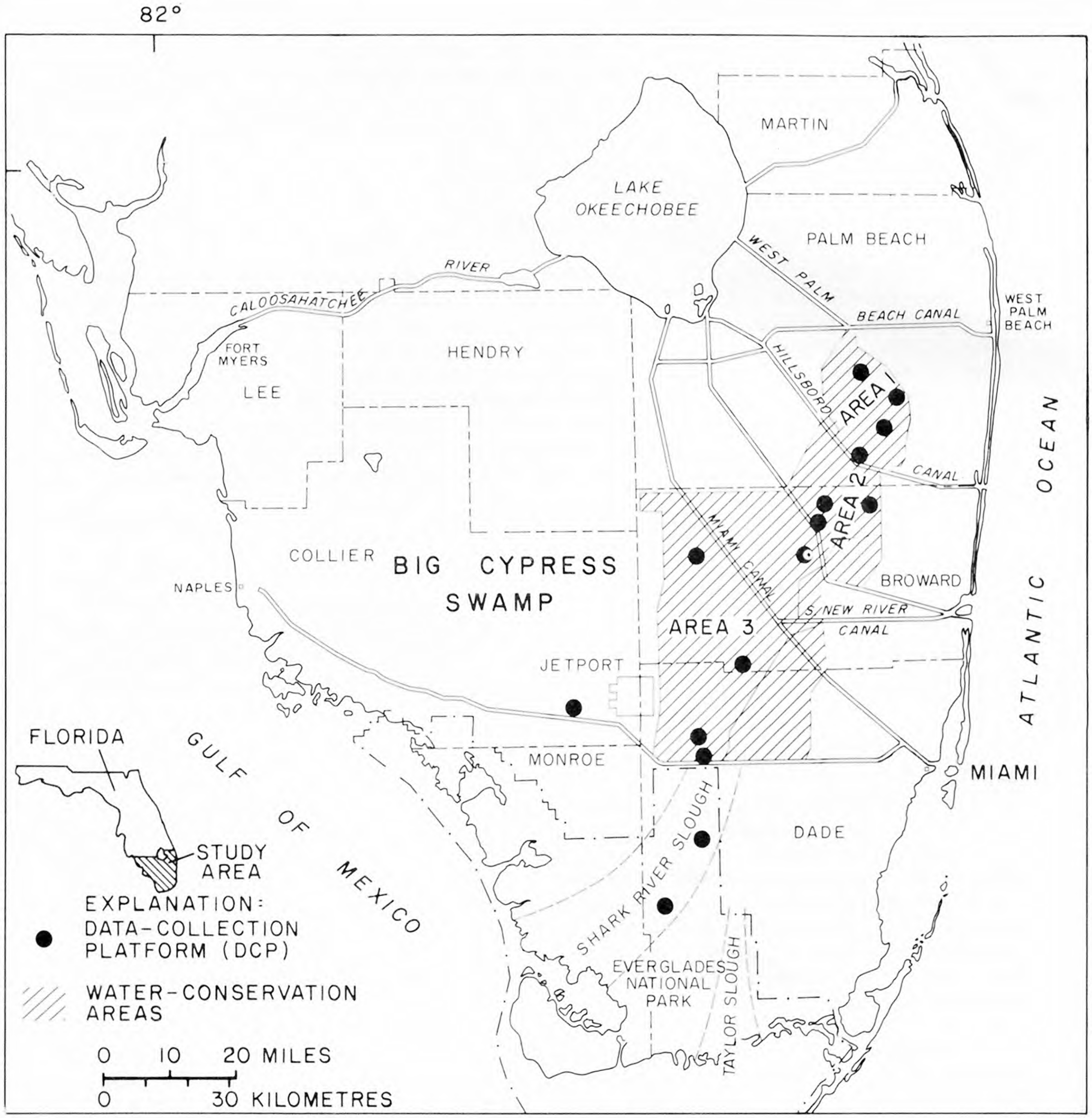

Figure 1.--Locations of water-conservation areas and data-collection platforms.

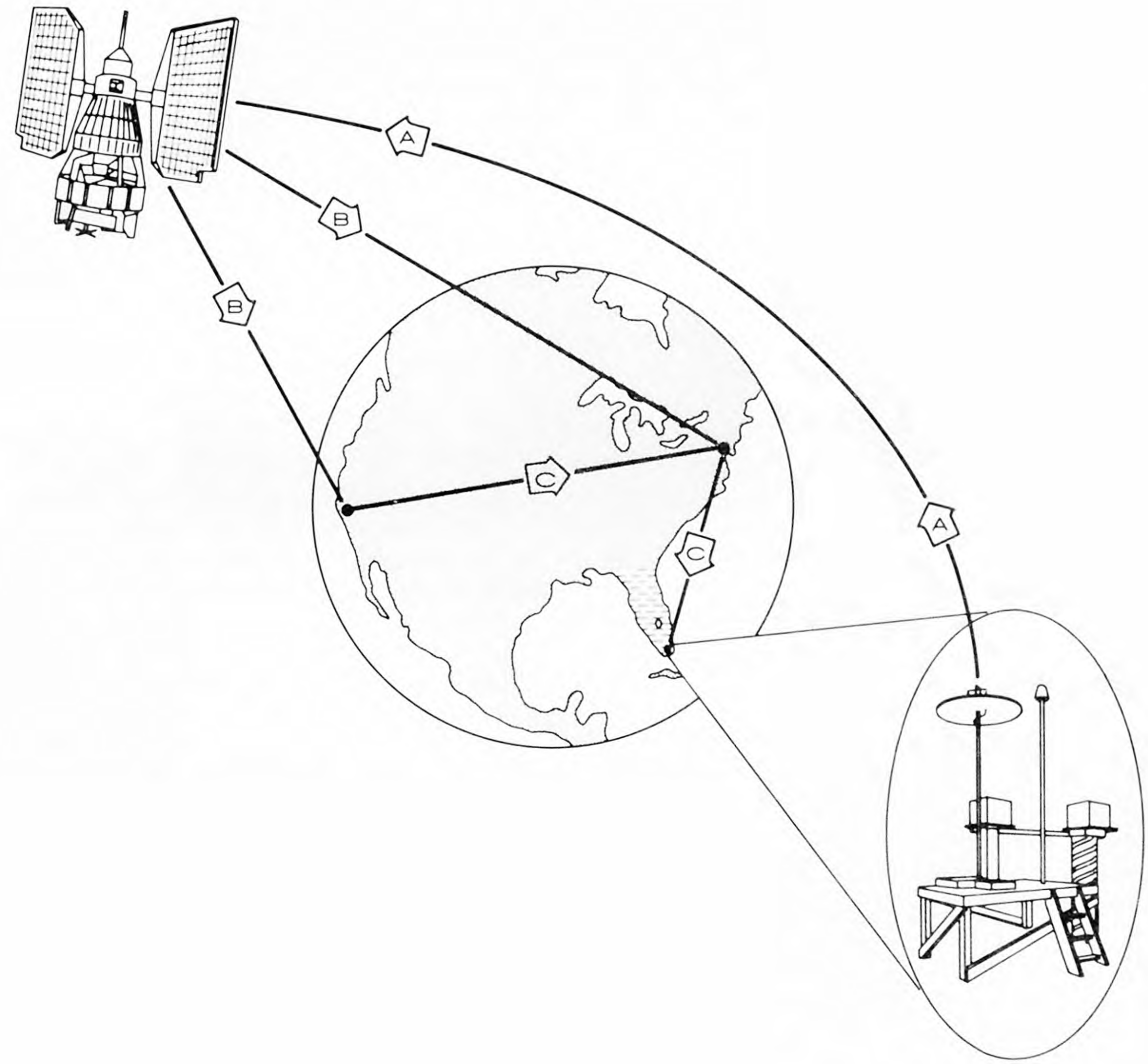

Figure 2.--Route of data flow on LANDSAT-1 Data-Collection System from a data-collection platform installation in the Everglades to Miami, (after Higer and others, 1974). (A is a path from field installation to LANDSAT-1 satellite. B are the paths data take from satellite to remote stations in Greenbelt, Md. and Goldstone, Calif. C are ground communication paths that the data take from remote receiving stations to Goddard Space Flight Center, Greenbelt, Md., and then to Miami.)

DATA RETRIEVAL

The starting point for sending data by DCS is a station such as that shown in figure 3. Housed at this particular station are the data collection platform (DCP) containing the electronic unit and its antenna, water-stage recorder, rainfall recorder, and timer and power supply for both recorders. The network of existing DCS stations in south Florida is shown in figure 1. Before transmitting the data to the satellite, the DCP (fig. 4) receives the data from a recorder and encodes it into a form transmittable by radio signal. Although the DCP normally transmits a signal every 3 minutes, it can be set to transmit every 90 seconds. When the LANDSAT-1 satellite is in communication simultaneously with a DCP and a receiving station, data are transmitted from the DCP and relayed by the satellite to NASA receiving stations at Greenbelt, Md. or Goldstone, Calif. This mutual communication is completed during 3 to 6 orbits per day. One to 4 distinct messages from a station can be completed if the DCP is transmitting every 3 minutes.

At the NASA receiving station the data are decoded and sent by NASA communication line to the Operations Control Center and then to NASA Data Processing Facility at Goddard Space Flight Center. At the processing facility, the data are verified and put in a form to be teletyped to Miami. The data are received by teletype (fig. 5) as perforated tape and printout. A sample printout of the data is shown in figure 6.

From left to right on a line or message (fig. 6), the following data are given: In column headed S, the letters N or G (not shown) designate the remote receiving station, Greenbelt (N) or Goldstone (G). The column headed Y contains the last digit of the year. The next nine columns show the numerical day of the year and Greenwich Mean Time in hours, minutes and seconds. The column headed PID is the DCP identification number. Column C represents the confidence level of the message, and column CS on the right edge represents the confidence level of the data in columns D1 through D8. Both C and CS range from 0 to 7 where 7 is the highest level. Columns headed D1 through D8 contain the data words in octal form (number system based on eight) which must be converted to the engineering units used. The octal numbering system is used because it saves space and because it facilitates converting from the binary numbering system which is used by computers.

On an average day, data are received in Miami 2 to 3 times each morning and 2 to 3 times each night.

Redundant data are being received, as shown in figure 6, where DCP 6122 transmitted identical messages at 0214, 0217, 0220 and 0223 hours. The recorder, from which the DCP receives the data, updates every hour. If a memory device were installed, each hourly update of the recorder could be stored, then transmitted when the satellite is in range.

At future stations, where parameters such as wind direction or velocity are to be monitored, data will be required more frequently. Data memory devices, which will store recorder readings for deferred transmission, can be installed at the stations to provide a complete set of hourly values even through periods when the satellite is not available for relay.

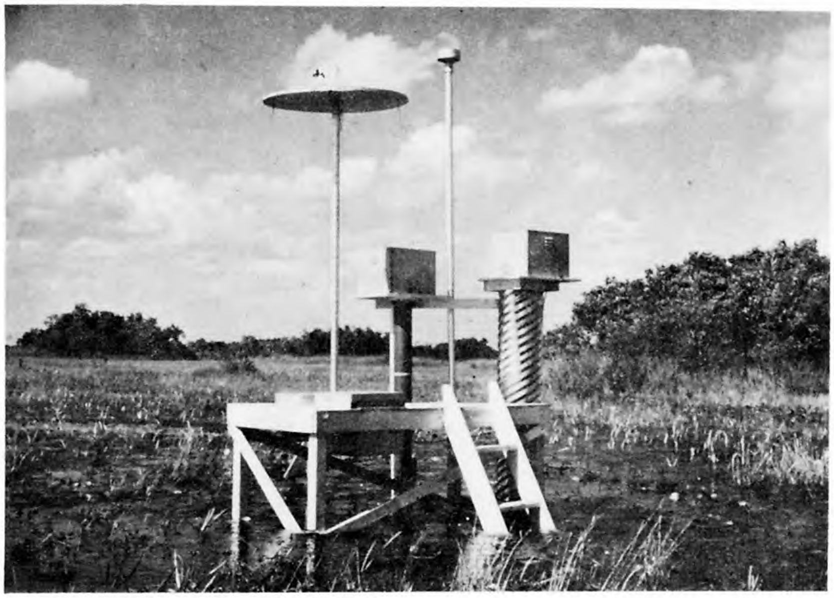

Figure 3.--Typical LANDSAT-1 satellite-data collection platform station in the Everglades.

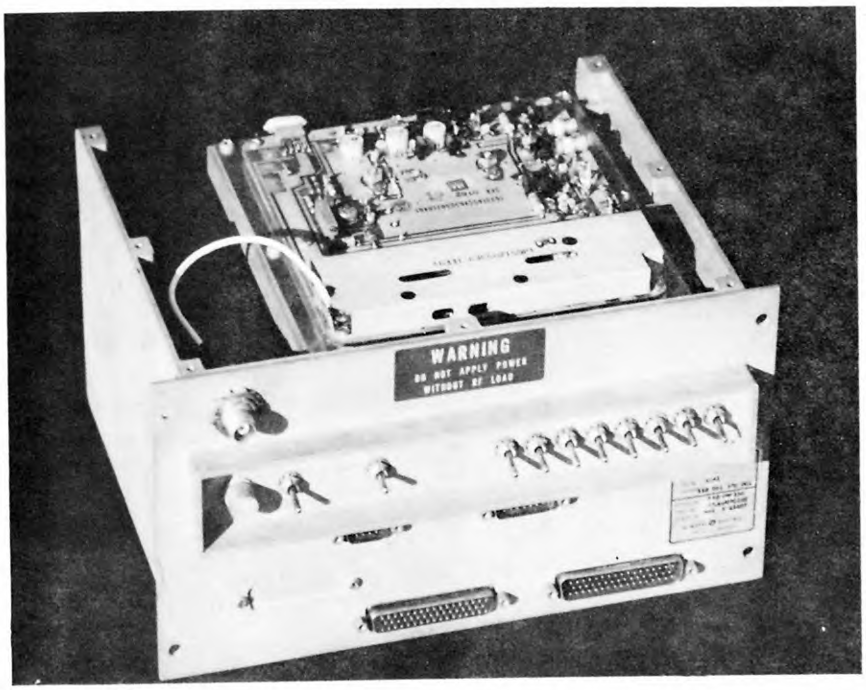

Figure 4.--DCP electronic unit.

Figure 5:--LANDSAT satellite data printout being received by teletype in Miami.

REF ERTS DCS
ATT A HIGER USGS MIAMI PHONE 305 350 5332

S	Y	DDDHHMM	SS	PID	C	D1	D2	D3	D4	D5	D6	D7	D8	CS
N	4	720214	39	6122	7	352	153	376	172	377	377	377	377	0
N	4	720217	42	6122	7	352	153	376	172	377	377	377	377	0
N	4	720220	45	6122	7	352	153	376	172	377	377	377	377	0
N	4	720223	48	6122	7	352	153	376	172	377	377	377	377	0
NO MESSAGES				6141										
N	4	720219	21	6157	7	370	267	376	357	377	377	377	377	3
N	4	720215	52	6214	7	370	166	375	276	377	377	377	377	0
N	4	720218	45	6214	7	370	166	375	276	377	377	377	377	0
N	4	720216	34	6236	7	372	376	377	377	377	377	375	377	7
N	4	720219	32	6236	7	372	376	377	377	377	377	375	377	7
NO MESSAGES				6250										
N	4	720216	55	6252	7	372	331	375	355	377	377	377	377	2
N	4	720219	43	6252	7	372	331	375	355	377	377	377	377	2
N	4	720222	32	6252	7	372	331	375	355	377	377	377	377	2
NO MESSAGES				6256										
N	4	720216	32	6303	7	352	156	374	214	377	377	377	377	6
N	4	720219	16	6303	7	352	156	374	214	377	377	377	377	6
N	4	720214	58	6313	7	370	176	376	230	377	377	377	377	0
N	4	720217	46	6313	7	370	176	376	230	377	377	377	377	0
N	4	720220	35	6313	7	370	176	376	230	377	377	377	377	0
N	4	720223	24	6313	7	370	176	376	230	377	377	377	377	0
N	4	720217	17	6321	7	356	247	376	276	377	377	377	377	5
N	4	720220	06	6321	7	356	247	376	276	377	377	377	377	5
N	4	720217	17	6362	7	352	177	376	367	177	377	377	377	2
N	4	720220	13	6352	7	352	177	376	367	177	377	377	377	2
N	4	720216	30	6363	7	377	377	377	377	377	377	377	377	7
N	4	720219	33	6363	7	377	377	377	377	377	377	377	377	7
N	4	720222	36	6363	7	377	377	377	377	377	377	377	377	7
N	4	720225	40	6363	7	377	377	377	377	377	377	377	377	7

TOTAL MESSAGES TRANSMITTED USER 4 33

13/0259Z MAR GERS

Figure 6.--Teletype data as received in Miami from Goddard Space Flight Center, Greenbelt, Maryland.

The DCP operates in serial digital, parallel digital, and analog modes. The data transmitting capacity of a DCP is eight data words, and the capacity of each word is eight data bits. Any one of the data words can be transmitted in any of the three modes. The mode can be changed by positioning switches on the DCP. The combinations of parameters that can be transmitted from any one DCP are dependent on the total number of data bits required by the parameters. The data bits required to transmit data for parameters range from less than a data word to the eight data-word capacity of the DCP. For example, some DCP's in the Everglades are transmitting upstream water stage, downstream water stage, and precipitation. To transmit these data in parallel digital mode a total of five and one half data words are used, two words for each stage, and one and one half words for precipitation. Because the DCP has capacity for eight data words, two and one half data words are left for monitoring other desired parameters. The number of parameters which can be transmitted by the present DCP is restricted by the availability of sensor probes which have been interfaced to the DCP. Parameters for which sensors are available are: water stage, water velocity, precipitation, wave action, soil moisture, temperature, pressure, wind velocity and direction, hydrogen-ion concentration (pH), dissolved oxygen, specific conductance, turbidity, specific-ion concentration, radiation and smoke detector.

Use of LANDSAT-DCS system offers many advantages. It lessens the potential for data loss because failure at a station is detected by an early scan of the data received in the office (Wimberly and others, 1973). Furthermore, the stations are serviced only when batteries need replacing or when there is a failure. LANDSAT-DCS makes it possible to establish and maintain stations almost without regard to problems of accessibility. The DCP is portable, easily installed, and can be adapted to almost any existing structure by providing a mount for the antenna and an enclosure for the electronic unit which is 10¼ in. by 8½ inches by 6 3/4 inches. If a land-based telemetry system were used, large antenna towers probably would be required. In contrast, the DCP antenna can be mounted only a few feet above ground. LANDSAT-DCS is effective in severe weather because of the low power requirement that enables use of batteries as its power source. The radio wave transmitted to the satellite and back to earth is virtually unaffected by atmospheric conditions.

An important advantage of LANDSAT-DCS is the ease of processing DCS data because it uses a digital format. The digital format allows direct input to computer, thereby eliminating errors normally made when data must be processed manually.

DATA PROCESSING AND DISSEMINATION

Initially, two instruments were considered for handling the data received by teletype from LANDSAT-DCS; one was a programmable calculator, and the other a central computer. The programmable calculator was selected to assure speed and reliability of data processing because other activities could have a higher priority for the central computer. Also, certain user agencies have different data requirements and could need data output in a special format. In the Miami office data are converted from the form in which it is received into a more usable form by the programmable calculator and then stored on cassette tapes. Future plans include the use of a central computer because of its greater data-storage capacity. However, the data will continue to be reduced locally by programmable calculator.

After data are received in Miami by teletype, the perforated tape from the teletype is fed into the calculator through a tape reader (fig. 7). Equipment shown are the calculating unit, thermal printer, paper tape reader, x-y plotter, hopper card reader, cassette memory recorder, extended memory unit and acoustic coupler. The cassette memory recorder allows data and programs to be stored external of the programmable calculator. The extended memory unit is attached to the calculator which increases the calculator memory-storage capacity. The calculator first translates the teletype data from its octal form into engineering units; these units represent water stage in feet or cumulative rainfall in feet. Second, the calculator sorts the data chronologically by station. Then it calculates daily rainfall in inches and prints the stage and rainfall data in the desired format (fig. 8). The data are then scanned for errors. If the data are correct they are telecopied or mailed to users depending on real-time needs.

After the data have been calculated, sorted and sent to the users in the form shown in figure 8, the data are condensed by eliminating all but daily readings, and stored on cassette tapes in annual data files. Upon receipt of the data, the users calculate the quantities of water remaining in storage in the water-conservation areas, and the rate at which storage was changing from the previous set of readings. These are the data upon which management of the stored surface water in southeast Florida is based. As a visual aid to the user, hydrographs of key stations are printed out from data fed into the plotter (fig. 7). Three sample hydrographs of stations in the water-conservation areas are shown in figure 9. Hydrographs are usually updated each month and mailed to the users. Since the hydrographs show the rate of recession of water stages during the dry season, they can be used in predicting water-short areas and formulating decisions on water allocations. The data are further used in the preparation of a monthly summary report of hydrologic conditions, which has wide distribution in south Florida.

A list of programs being run on the calculator in Miami is shown below:

1. Reads teletype tape and converts to gage heights or dial readings.
2. Prints out weekly summary table of stage and rainfall.
3. Stores midnight readings of stage and rainfall for each day.
4. Prints daily calendar year plot of stage.
5. Prints daily water year plot of stage.

Additional programs for the programmable calculator are being written to analyze water-quality and additional meteorological data collected from LANDSAT-DCS stations now being installed.

Figure 7.--Data reduction facility at U.S. Geological Survey office in Miami. Equipment shown starting in the foreground are the acoustic coupler, paper tape reader, cassette memory recorder programmable calculator and thermal printer, card hopper-reader, and x-y plotter.

USGS MIAMI FLA
DATA FROM ERTS SATELLITE
WATER SURFACE ELEVATION FT MSL

DATE DAY TIME	32 FRI 2343	33 SAT 2348	34 SUN 2354	35 MON 2359	36 TUE 2221	37 WED 2227	38 THUR 2355
128	16.62	16.61	16.61	16.59	16.56	16.53	16.52
141	16.48	16.47	16.49	16.46	16.44	16.43	16.42
142	16.44	16.42	16.42	16.41	16.39	16.37	16.35
111	12.36	12.34	12.33	12.30	12.27	12.26	12.23
112	12.10	12.07	12.05	12.02	12.00	11.98	11.97
62	9.42	9.38	9.38	9.36	9.31	9.26	9.21
63	8.67	8.64	8.64	8.61	8.58	8.56	8.54
64	8.47	8.46	8.46	8.44	8.43	8.42	8.41
65	8.41	8.40	8.39	8.38	8.37	8.36	8.35
5	5.67	5.66	5.65	5.64	5.62	5.62	5.61
15	2.77	2.76	2.75	2.74	2.73	2.72	2.71
105	6.71	6.67	6.65	6.61	6.57	6.54	6.50

RAINFALL IN INCHES

128	0.00	0.00	0.00	0.00	0.00	0.00	0.00
141	0.00	0.00	0.25	0.00	0.00	0.00	0.00
142	0.00	0.00	0.00	0.06	0.00	0.00	0.00
111	0.00	0.00	0.19	0.00	0.00	0.00	0.00
112	0.00	0.00	0.06	0.00	0.00	0.00	0.00
62	0.00	0.00	0.06	0.00	0.00	0.00	0.00
63	0.00	0.00	0.00	0.00	0.00	0.00	0.00
64	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
105	0.00	0.00	0.00	0.00	0.00	0.00	0.00

NOTE: READINGS WILL BE REVISED AS LATER DATA ARE RECEIVED.
STATION UNDER REPAIR

Figure 8.--Typical water-level and rainfall report which is telecopied to data users.

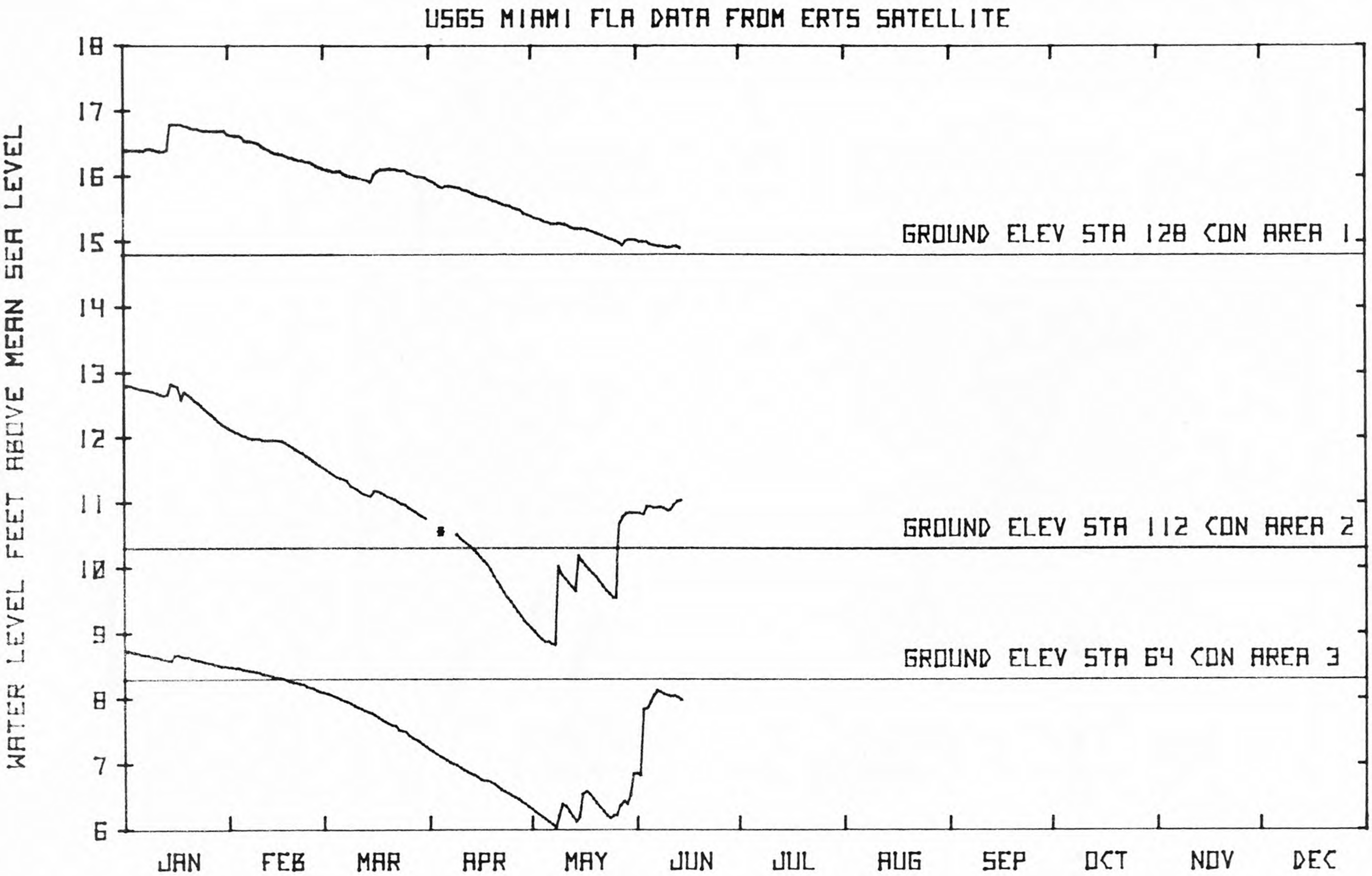

Figure 9.--Hydrographs of key stations in Conservation Areas 1, 2, and 3 (January 1, 1974 to June 15, 1974).

SUMMARY

The ability to obtain hydrologic data from remote areas quickly and reliably is important to the water-management agencies. LANDSAT-DCS plus a programmable calculator are the primary instruments which make the retrieval, analysis, and distribution of selected hydrologic data in near real time a reality in south Florida. The data are encoded and formatted at the field station by a DCP which transmits the data for relay by the LANDSAT-1 satellite to receiving stations at the NASA Goddard Space Flight Center where the data are sent by teletype to the U.S. Geological Survey in Miami. In Miami, the data are processed by a programmable calculator, telecopied to the water-management agencies and stored. Data from the field can reach the data users within 2 hours. Analysis of the data by programmable calculator is proving to be quick and economical because it accepts data directly from teletype, thereby eliminating much human error.

In south Florida the system has been tested in an operational mode and the water-management agencies have requested the installation of additional stations and the measurement of additional parameters at all stations.

The user agencies are enthusiastic about the value of the system to meet their need for rapid knowledge of hydrologic conditions for water management operations. Future plans include: (1) expanding the number of gaging stations, (2) transmitting additional water-quality and meteorological parameters, and (3) reducing the data-handling time through improved automation.

REFERENCES

Coker, A.E., Higer, A.L., Cordes, E.H., and Wimberly, E.T., 1973, Mapping dynamic hydrologic conditions of surface water changes in south Florida using repetitive ERTS-1 data interfaced with DCP's: NASA Type I progress report, 6 p.

Cordes, E.H., and Higer, A.L., 1973, Monitoring the dynamically changing hydrologic regimes of southern Florida through ERTS-1 data acquisition: American Water Resources Association - International Symposium on remote sensing, 2 p.

General Electric Space Division, 1972, Earth Resources Technology Satellite Data Collection Platform field installation, operation and maintenance mannual: Contract No. NAS S-21697, Valley Forge Space Center No. 72SD 4208, March 27, 1972, 125 p.

Higer, A.L., 1972, Development data relay systems for monitoring hydrologic conditions in central and south Florida: NASA Type I progress report, 5 p.

Higer, A.L., Coker, A.E., and Cordes, E.H., 1973, Some aspects of automatic data processing imagery of central and southern Florida: 1st Pan American Symposium, 1 p.

Higer, A.L., Coker, A.E., and Cordes, E.H., 1973, Feasibility of using ERTS-1 multispectral imagery coupled with data collection platforms to construct water management models in Florida: ERTS-1 symposium, 6 p.

Higer, A.L., Coker, A.E., and Cordes, E.H., 1974, Water management models in Florida from ERTS-1 data: Third ERTS symposium and Proceedings of Eleventh Space Congress, 6 p.

Wimberly, E.T., Higer, A.L., and Cordes, E.H., 1973, Development data relay systems for monitoring hydrologic conditions in central and south Florida: NASA Type I progress report, 3 p.

Wimberly, E.T., Higer, A.L., Cordes, E.H., and Coker, A.E., 1973, Acquisition and processing program of ERTS data in south Florida: NASA Type II progress report, 8 p.

Wimberly, E.T., Higer, A.L., Cordes, E.H., and Coker, A.E., 1973, Advantages of ERTS Data Collection System in south Florida: NASA Type I progress report, 3 p.

Wimberly, E.T., Higer, A.L., Cordes, E.H., and Coker, A.E., 1974, Trouble shooting the DCP and related equipment by teletype: NASA Type I progress report, 3 p.

GLOSSARY

analog mode - in this report is the mode of a DCP in which data are accepted from a sensor as voltage

acoustic coupler - device used to link computers by telephone line

binary code - numbering system with a base two

conservation area - refers to areas reserved for storage of surface water

data bit - in binary code either 0 or 1 depending on whether a switch is open or closed

data word - composed of eight data bits as referred to in this report

digital mode - in this report it is the mode of a DCP where data are encoded, formatted and transmitted numerically

encode - to convert a message into code

interface - to form a common boundary between electronic equipment so that the equipment functions as a unit

octal code - numbering system with a base of eight

parallel digital mode - mode in which data in digital form are accepted simultaneously by the DCP

programmable calculator - electronic calculator that has a capability for programming

serial digital mode - mode in which data in digital form are accepted in a series one bit at a time

telecopier - device used to copy and transmit the print from a page by telephone to another telecopier at a distant station

telemetry - system for transmitting (usually by radio signal) information to a distant station and indicating or recording the information there