REMOTE SENSING OF WATER QUALITY AND WEATHER IN GREAT SMOKY MOUNTAINS NATIONAL PARK: PHASE I

RESEARCH/RESOURCES MANAGEMENT REPORT No. 30

U.S. DEPARTMENT OF THE INTERIOR
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SOUTHEAST REGION

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PHASE I

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ABSTRACT

Four self-contained Convertible Data Collection Platforms (CDCP's) have been developed and deployed as an integral part of a comprehensive water quality and environmental monitoring program for remote natural areas at Great Smoky Mountains National Park. Multiple parameter sensor packages regular monitor: (1) water quality parameters (dissolved oxygen, hydrogen ion concentration (pH), oxygen reduction potential, conductivity, and temperature); and (2) meteorological parameters (wind direction and speed, ambient temperature, relative humidity, barometric pressure and cumulative precipitation).

The monitoring system is comprised of the multi-parameter sensor packages, the CDCP unit, a transmitting antenna, and a power source. The data platforms are evaluated relative to interfacing and support requirements, operational practicality, implementation and maintenance requirements, and data validity.

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ACKNOWLEDGEMENTS

The progress to date on this project would have been hindered greatly without the support and cooperation of several agencies and individuals within those agencies: Mr. Meryl Nelson, GOES Satellite Data Coordinator of NOAA/NESS; Mr. Stan Addess, Data Systems Engineer of NASA's EROS Program; Mr. Richard Paulson, Data Collection Systems Project Coordinator, Mr. Charles Merk, Data Processor, and Mr. Marshall Jennings, Project Chief, all of the U.S. Geological Survey.

NOTE

The use of the commercial products described in this document do not constitute an endorsement of the same by the U.S. Department of the Interior, National Park Service, or any other agency of the Federal Government.

INTRODUCTION

Current National Park Service research focuses on broad-spectrum environmental monitoring under "natural" anthropogenic factors. Recognition that natural preserves, even those containing large remote areas, are not isolated from the effects of anthropogenic factors results in a greater planning emphasis on long-term projects and permanent sampling regimes. This overall monitoring effort includes both the identification and evaluation of satellite monitoring data required to test hypotheses and to answer resource management questions.

The potential of remote sensing platforms in providing both management and theoretically orientated information to National Park Service scientists is being tested at Great Smoky Mountains National Park. Remote sensing instruments are employed as practical tools for unobtrusive long-term environmental monitoring with emphasis on the environmental parameters and biological phenomena being monitored.

This investigation is directed toward the practicality of *in situ* monitoring and the attainment of the shortest information turnaround time possible. Accomplishment of these primary goals will present an objective evaluation of a monitoring system while testing the value of real-time environmental parameters and monitoring for the benefit of resources management.

This paper presents the problems encountered and the operational history of recent experiments, both in concept and through actual implementation, which have resulted from the application of remote satellite monitoring techniques in Great Smoky Mountains National Park during Phase I of the field investigations.

Major results to date are restricted to the equipment and program development phase of the project. Although late equipment deliveries, unexpected interfacing problems and equipment malfunctions initially contributed to a delay in the field testing program, water quality and weather data in Great Smoky Mountains National Park are now being generated by the sensor units, transmitted by the Convertible Data Collection Platforms (CDCP's) and received via the Geostationary Operational Environmental Satellite (GOES). All four National Park Service GOES stations are operational and have been undergoing field testing since June, 1977.

PROJECT ACTIVITY DESCRIPTION

The use of satellite associated data collection platform systems is considered to be a promising method of gathering data from remote natural areas. In response to an invitation from the U.S. Geological Survey's Earth Resources Observation Division, the National Park Service submitted a proposal for the use of the Convertible Data Collection Platforms in gathering data from remote sites in order to determine the validity, reliability, and complexity of such systems. The National Park Service's Southeast Regional Office, Natural Science and Research Division was provided with four such platforms which have been tested in Abrams Creek, Great Smoky Mountains National Park as potential tools for providing data on a near real-time basis (Figure 1). As first perceived, the purpose of Phase I of the satellite program was to meet 5 objectives:

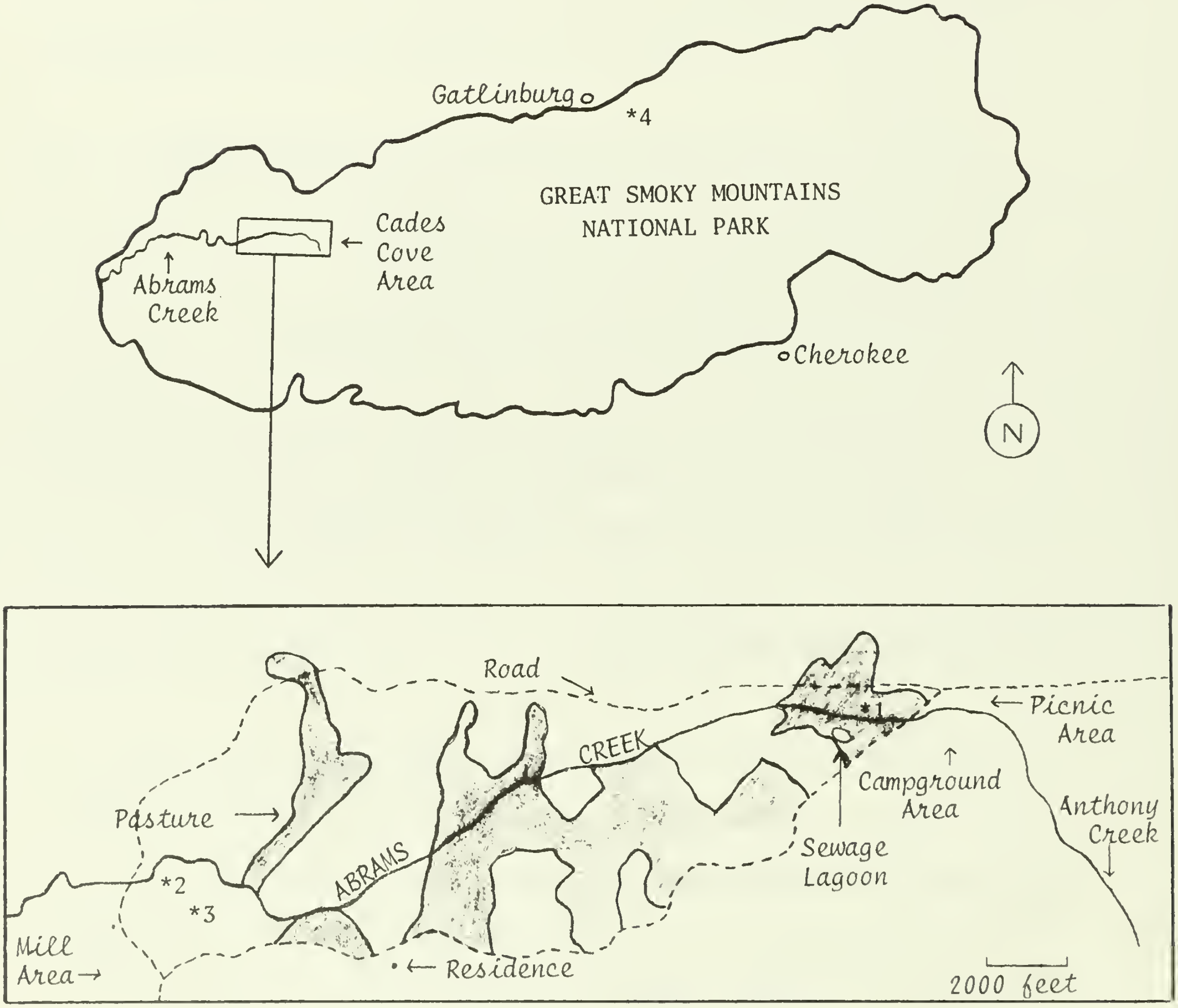
1. Establish the feasibility of a portable continuous monitoring station.
2. Meet a 60-day or greater maintenance cycle requirement.
3. Provide near real-time data capabilities.
4. Provide dependable data parameter values.
5. Achieve simplicity in operation and maintenance.

The data obtained from this system has been found to play an important role in aiding research and management personnel in the formulation of decisions affecting the operation or activity of their park.

DATA COLLECTION SYSTEM DESCRIPTION

The Convertible Data Collection Platform (CDCP) acquires data from various types of remote sensing instruments and periodically transmits this data to the Geostationary Operational Environmental Satellite (GOES). This satellite is stationary with respect to the transmitting platform and can receive transmissions continuously. An alternate mode, the Earth Resources Technology Satellite (ERTS, now called

Figure 1. Great Smoky Mountains National Park, showing satellite data collection platform stations



* Convertible Data Collection Platform Stations

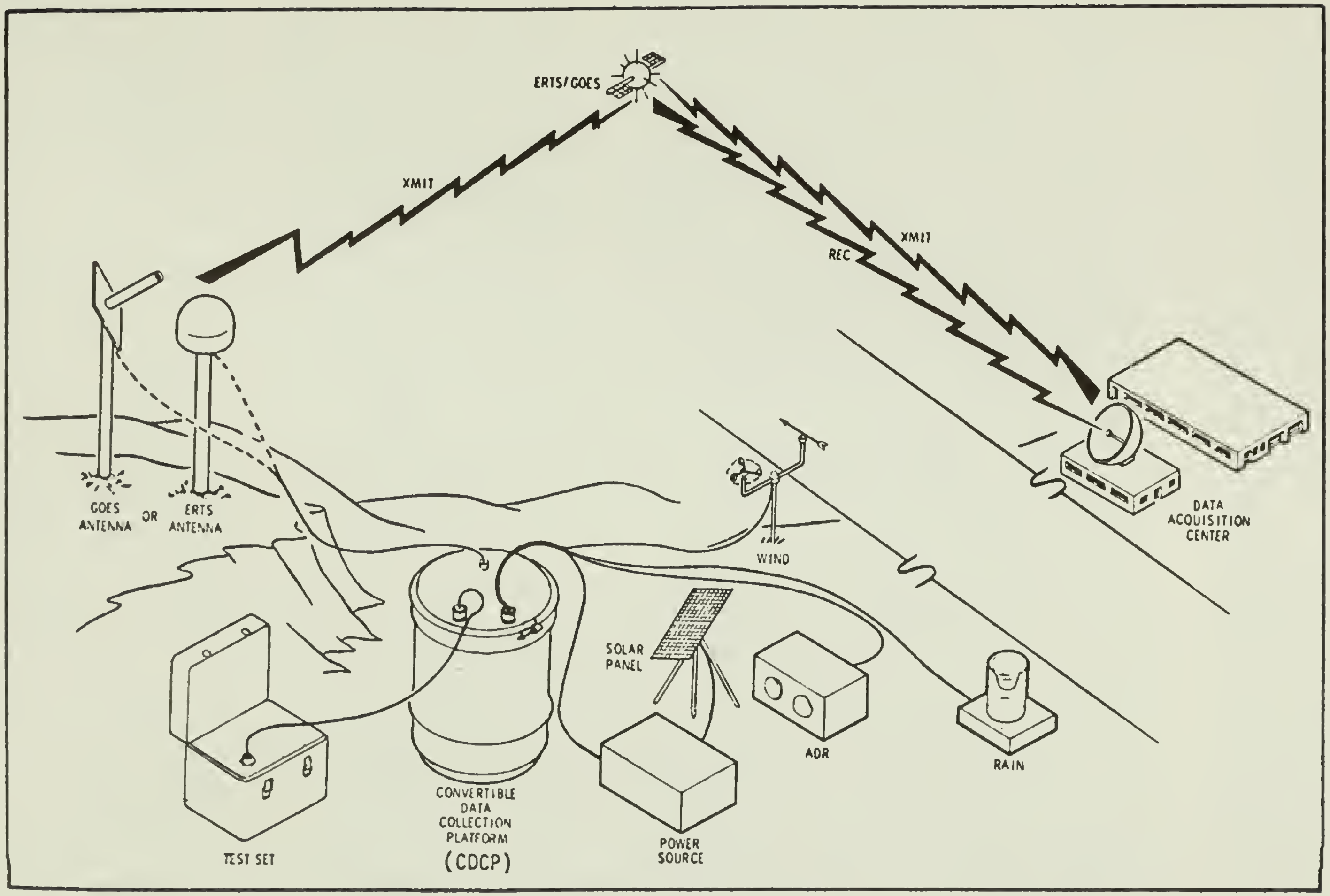


Figure 2. Typical ERTS/GOES Convertible Data Collection Platform installation.

(from LaBarge Corporation, Tulsa, Oklahoma)

LANDSAT), which is in a near polar orbit, is not employed. The data transmitted by the CDCP to the GOES satellite is then relayed to a Data Acquisition Ground Station. This data is then accessed by remote terminals and disseminated to the park.

The complete Convertible Data Collection Platform system is comprised of the CDCP power unit, a power source, a CDCP test set, a transmitting antenna, and the sensor instrumentation (Figure 2). The CDCP units were manufactured by LaBarge Electronics of Tulsa, Oklahoma, and are individually packaged in sealed metal drums 11 1/2 inches in diameter and 14 1/2 inches high. Each is completely microprocessor controlled and has the capacity of storing 104 sets of analog data utilizing two memory spaces per set, or 52 sets of digital data utilizing four memory spaces per set, or a combination of both, not to exceed 208 memory spaces, the capacity of the buffer memory. The CDCP can be programmed to take analog data from up to eight sensors or digital data from up to four digital recorders in multiples of 6-minute or 15-minute increments for up to 255 increments, and can transmit this data at any interval from 15 minutes to 63 hours and 45 minutes (255 intervals). The power source is a 12 volt DC power pack (standard automobile battery or rechargable gel cell) which is in some cases recharged from a small, 3/4 ampere-hour solar panel. One power source is also used by the unit to automatically supply power to the sensor instrumentation at the assigned data sampling interval, and to power down after the data has been loaded into the memory of the CDCP unit.

The test set is a component electrically connected to the CDCP unit by a multicable connector and is used for programming and monitoring the functions of the units. All program constants and data memory locations can be addressed by the test set which is packaged in 10" x 12" x 9" instrument case.

Two antennas are available for data transmission; the one used is dependent upon whether the CDCP is programmed for transmission to the ERTS (LANDSAT) satellite or the GOES satellite. The GOES antenna is currently being employed and consists of a bifilar helix and reflective surface. The reflector is 24 inches square and the cylindrical protector over the bifilar helix is 42 inches long and 10 inches in diameter. It is connected to the platform by a standard RGU type RF coaxial cable.

The sensor instrumentation consists of a water quality monitor manufactured by Hydrolab Corporation of Austin, Texas, and a meteorological monitor package put together by LaBarge Electronics from instrumentation manufactured by Met-One, Inc., of Sacramento, California.

The water quality monitor, or "Hydrolab Surveyor", consists of two basic components. The first is the surface unit which houses the system electronics, operating controls and panel meter for visual display of sensor data output. This unit has been modified to amplify the low millivolt signal received from the various sensor probes to an analog voltage output of from 0 to 5 volts, which is necessary for interfacing to the CDCP unit. It has the capacity to handle up to six sensor probes.

The second component of the Hydrolab Surveyor, the sonde, houses the sensor probes, a small motor-driven circulator which provides a continuous flow of ambient water over and about the probes to insure accurate sampling and rapid thermal equilibration, and a preamplifier circuit for the pH and ion probes. These units are all environmentally sealed and are supported in the water column by the instrument power and signal cables. The National Park Service monitors five water quality parameters: dissolved oxygen, conductivity, hydrogen ion concentration (pH), oxygen reduction potential (ORP), and temperature. A sensor circuit for monitoring power source voltage has also been added.

The meteorological monitor consists of three basic components: the signal conditioning unit, the probes, and a tripod mast from which the probes are mounted. The signal conditioning unit performs the same function as does the surface unit for the water quality sensors. It amplifies the signals from the probes to an analog voltage acceptable to the CDCP unit and stores the cumulative precipitation data for input into the digital memory circuit of the CDCP. Six meteorological parameters are monitored: cumulative precipitation, wind speed, wind direction, barometric pressure, relative humidity, and ambient temperature, along with the power source voltage monitoring sensor.

RECORD OF OPERATION

Interfacing of the sensor instrumentation to the CDCP units was primarily accomplished by the manufacturer of the respective systems. The water quality monitors have functioned well, with no apparent interface problems encountered after approximately 14 months of cumulative operation. However, some problems have been encountered with these systems (Tables 1 and 2).

Some interface problems were encountered during the initial checkout of the weather system, in that the data stored by the CDCP unit was erratic and unstable. After several days of trouble shooting and testing, it was discovered that the ouput signal from the relative humidity sensor was somehow interfusing the other sensor outputs and causing the problem. The investigators also discovered a problem with the digital counter circuit of the cumulative precipitation sensor and a mechanical failure on one of the wind velocity sensors.

The meteorological monitors were received somewhat later than the water quality systems. Because of this and the initial interface problem experienced with them, only the failure after the first nine months of operation are summarized in Tables 3 and 4.

To date, these systems have evaded many of the failures previously reported by Schornick and Schaefer (1974). Major causes for failure during Phase I of this study differ from those reported by Schornick and Schaefer (1974) in the following ways:

1. In our study area, sensor fouling has not been found to be a problem.
2. Sensor failures have involved only the dissolved oxygen and relative humidity probes.
3. Power failures involving batteries are the most common source of down time to date, with the exception of one case of vandalism.

Tables 1, 2, 3, and 4 present the operational record of the CDCP's over the period of time from initial deployment in the field up through the summer of 1978.

Discounting the incident of vandalism to one unit and several other problems experienced with it which may be associated with the vandalism, the data indicates that the failures and loss of data can generally be attributed to the support equipment (batteries and/or sensors). From experience thus far it appears that new, freshly charged lead acid batteries will provide power to sustain a system for up to six months and possibly longer. However, once they become discharged, recharged batteries placed into operation again become discharged at a much faster rate (less than three months). It is planned in the future to compare solar panel supported lead acid batteries with solar panel supported gel-cell type batteries.

Table 1. Individual Operational History of Convertible Data Collection Platform # 1 Water Quality Station, located on lower Abrams Creek, Cades Cove, GRSM. System powered by heavy duty lead acid type battery with no solar power support.

Date	Period of Time System was: (+) Operating, all sensors active (*) Operating, one or more sensors down (-) Inoperative	Functional Characteristics and Nature of Failure
May 25, 1977	+ 3 weeks	System activated and operating
June 15, 1977	- 1 week	System failed (faulty lead-acid battery)
June 22, 1977	+ 2 weeks	Battery replaced, system reactivated
July 6, 1977	* 4.5 weeks	Oxygen sensor failed, faulty capacitor
August 8, 1977	+ 13 weeks	Oxygen sensor repaired and on line
December 16, 1977	- 29 weeks	System vandalized, cables damaged
July 10, 1978	+ 0.25 week	System reactivated after new cable fabrication and oscillator replacement in CDCP.
July 12, 1978	- 1 week	System failure, fuse blown in CDCP. Problem possibly associated with previous vandalism.
July 18, 1978	+ 0.25 week	Fuses replaced, system reactivated
July 20, 1978	- 4 weeks	System failure, fuse blown, CDCP returned to manufacturer for study.
August 17, 1978		System at manufacturer for repair. Replacement unit has been shipped by manufacturer as substitute.

Table 2. Individual Operational History of Convertible Data Collection Platform #3 Water Quality Station, located on upper Abrams Creek, Cades Cove, GRSM. System powered by lead acid battery.

Date	Period of Time System was: (+) Operating, all sensors active (*) Operating, one or more sensors down (-) Inoperative	Functional Characteristics and Nature of Failure
October 7, 1977	+ 23 weeks	System activated and operating
March 15, 1978	- 7 weeks	System failed, battery discharged, possibly caused by power transistor in CDCP failing in the power-on update mode.
May 3, 1978	+ 10 weeks	CDCP repaired, system reactivated.
July 12, 1978	- 2 weeks	System failed (battery discharged). An attempt was made to reactivate system with a recharged battery but it was apparently faulty and would not maintain a charge.
July 26, 1978	+ 3 weeks	A new lead acid battery was installed and system reactivated.
August 17, 1978		System continues to operate.

Table 3. Individual Operational History of Convertible Data Collection Platform #4 Weather Station, located at Uplands Field Research Laboratory, GRSM. System powered by a 20 amp-hour Gel-Cel battery with 1/4 amp-hour solar panel support.

Date	Period of Time System was: (+) Operating, all sensors active (*) Operating, one or more sensors down (-) Inoperative	Functional Characteristics and Nature of Failure
November 15, 1977	* 12.25 weeks	System activated and operating. Relative humidity sensor faulty upon initial functional check of system in laboratory.
February 5, 1978	+ 2.25 weeks	Relative humidity sensor returned from manufacturer after repair and installed.
February 21, 1978	* 2.5 weeks	Relative humidity sensor malfunctioning again, returned to manufacturer for repair.
March 10, 1978	* 1.5 weeks	Temperature sensor cable disconnected by mistake.
March 21, 1978	* 1.7 weeks	Temperature sensor reconnected.
April 2, 1978	* 20 weeks	Precipitation data invalid, intermittently.
August 17, 1978		System continues to function with relative humidity sensor down and precipitation data problem.

Table 4. Individual Operational History of Convertible Data Collection Platform #2 Weather Station, located on lower Abrams Creek, Cades Cove, GRSM. System powered by a 20 amp-hour Gel-Cel battery with 1/4 amp-hour solar panel support.

Date	Period of Time System was: (+) Operating, all sensors active (*) Operating, one or more sensors down (-) Inoperative	Functional Characteristics and Nature of Failure
November 15, 1977	+ 8 weeks	System activated and operating.
January 9, 1978	- 2 weeks	System failed (faulty Gel-Cel battery)
January 22, 1978	+ 18 weeks	New Gel-Cel battery installed, system reactivated.
May 30, 1978	* 11 weeks	Relative humidity sensor failure
August 17, 1978		System continues to operate, relative humidity sensor returned to manufacturer for repair.

The greatest amount of data lost due to sensor failure comes from the relative humidity sensors. Problems with these units were found upon initial functional checkout of the complete systems in the laboratory prior to deployment in the field. One of the probes has been returned to the manufacturer for the third time, and the second probe has now been returned for a study of the problems relative to both sensors (Tables 3 and 4).

One of the cumulative precipitation sensors began to generate invalid data and has had an intermittent problem for several weeks. A new circuit card for this sensor has been installed in an effort to correct the problem (Table 3).

DATA RELIABILITY

Data collected by the satellite systems from Abrams Creek in Great Smoky Mountains National Park have been shown to be comparable to field sampling data. Significant differences in the two data sets taken in Abrams Creek do not appear to exist. Absolute system reliability and dependability, however, cannot accurately be predicted at this date due to the short time span in which the systems have been in field operation. These systems have, however, met the project criteria (page 3). The results also indicate the need for a complete parts inventory in order to minimize down time when system malfunctions occur.

Phase II will monitor in situ atmospheric and water quality parameters for selected drainages in Great Smoky Mountains National Park. These data will form a matrix which in effect monitors water quality as related to meteorological conditions. This phase will require data storage in platform and on tape or disc at a NASA facility and a NPS laboratory or field station as well as sensor response and further ground truthing of some parameters. The data will be analyzed employing an Analysis of Variance (ANOVA) design to depict the interactions of meteorologic conditions and water quality parameters. Analysis of the resultant error components will be accomplished as part of Phase III. In Phase III, watershed activity will be monitored and will be correlated to the error component of Phase II ANOVA. When this relationship is established, Phase IV will commence; the parameters which are found to be significantly altered by watershed activity will be standardized to the Phase II baseline. When these parameters exceed an acceptable or defined range, the monitoring system will become an alarm system and the rapid real-time data turnaround will be employed to improve the resources management program of Great Smoky Mountains National Park.

CONCLUSIONS - PROJECT STATUS AND FUTURE

The first year of field operation (Phase I) has demonstrated the capability of the CDCP systems to provide dependable and regular closely-spaced data sets for all but one of the parameters tested. At this stage of the experiment the investigators have assessed to the degree possible the original five objectives (page 3) and found:

1. It is feasible to employ these portable continuous water quality and atmospheric monitoring stations.
2. These units have met the 60-day or greater maintenance cycle.
3. These units provide near real-time (every 3 hours) data response capabilities.
4. Values are comparable to field survey data collected using standard methods.
5. The units are not as simple to operate and maintain as one might have hoped; however, if sufficient spare components are stocked and made available through a parts inventory, service and maintenance delays will be minimized.

Thus our Phase I objectives (acquisition, calibration, testing and positioning) have been sufficiently met. These instrument systems will begin Phase II of their deployment in the remote areas of Great Smoky Mountains National Park.

SELECTED PUBLICATIONS AND REPORTS ORIGINATING FROM THIS PROJECT

Morgan, Eric L., Kenneth W. Eagleson, Raymond Herrmann, and Daniel L. Stoneburner. 1977. "Remote Biomonitoring by Satellite for Water Quality Assessment in an Impacted Park Stream." Third Annual Scientific Research Meeting of the Uplands Field Research Laboratory, Great Smoky Mountains National Park, Gatlinburg, Tennessee.

Mathews, Raymond C., Jr. 1979. Ecological Survey of Abrams Creek in the Great Smoky Mountains National Park. NPS SER Management Report #28.

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