UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

A NETWORK FOR CONTINUOUS MONITORING OF WATER QUALITY IN THE SABINE RIVER BASIN TEXAS AND LOUISIANA

By

J. F. Blakey and P. W. Skinner
U.S. Geological Survey

Open-File Report
73-25

Prepared by the U.S. Geological Survey
in cooperation with the
Sabine River Authority of Texas and the
Louisiana Department of Public Works

May 1973

CONTENTS

ILLUSTRATION

TABLES

A NETWORK FOR CONTINUOUS MONITORING OF WATER QUALITY IN THE SABINE RIVER BASIN TEXAS AND LOUISIANA

By

J. F. Blakey and P. W. Skinner
U.S. Geological Survey

ABSTRACT

The proposed water-quality network for the Sabine River Basin of Texas and Louisiana consists of nine monitoring stations, a central-control station, a slave-central station, and a leased-line telecommunications system. This monitoring network would provide continuous transmission of water-quality data to the office of the water manager.

Level I operations at a proposed site would monitor current and potential problems, water-quality changes in subreaches of streams, and water-quality trends in time and place. Level II operations would monitor current or potential problems only. An optimum system would require Level I operations at all nine stations. A minimum system would require Level II operations at most of the stations.

INTRODUCTION

The Sabine River Authority of Texas and the Louisiana Department of Public Works are preparing a water-quality management plan for the Sabine River Basin in cooperation with the Environmental Protection Agency, the Texas Water Quality Board, and with other State agencies in Texas and Louisiana.

The management plan requires the design of and a cost estimate for a monitoring and data-handling system. The Sabine River Authority of Texas and the Louisiana Department of Public Works, through the Sabine River Compact Administration, requested the U.S. Geological Survey to design a network of continuous water-quality monitors for the Sabine River Basin and to estimate the cost of installation and operation.

The purpose of the network is for water management, which requires real-time data on the quality and quantity of water in the basin. Continuous monitoring of hydrologic conditions at key locations and continuous transmission of these data to the office of the water manager will provide the necessary information.

The proposed network, in regard to the number of sites, site locations, and parameters to be monitored, is designed to provide options in the initial establishment of the data-collection system. Depending on economic and other constraints, these options allow for an initial installation ranging from a minimum to an optimum level. The proposed equipment provides flexibility for future adjustments in the network, such as additions or changes in the parameters monitored at a site or an increase in the number of monitoring sites.

The existing equipment and facilities of the Sabine River Authority and the U.S. Geological Survey that are compatible with the proposed monitoring network are considered to be available at no cost. Estimates for equipment, installation, and operation are based on 1973 costs.

CONTINUOUS-MONITORING STATIONS

The basic equipment required at each monitoring station is a water-stage recorder, a water-quality monitor with an on-site recorder, a remote digital-telemetry unit, and a pump. Water-stage recorders for determining continuous water-quantity data are currently operated at some of the proposed monitoring sites and a water-quality monitor is currently operated at site 9 (fig. 1). Requirements for new water-quantity equipment or modification of existing equipment were considered in the installation cost for each site.

Location of the central-control station is proposed for the office of the Sabine River Authority in Orange, Texas. The slave-central station would be located in Longview, Texas. A leased-line telecommunications system linking the monitoring stations and the central stations is proposed because of greater reliability and lower installation and maintenance costs.

The total costs for constructing an optimum network is estimated at $239,330. The cost of a minimum network is estimated at $181,040. The costs for operation and maintenance of the network is estimated at $93,550 per year.

Appendix A of this report presents the specifications for water-quality monitors, and Appendix B presents a functional description and the specifications for a digital-telemetry system.

The water-quality monitor should be a solid-state potentiometric system designed to accept up to 10 separate channels of input and to automatically program these signals into the recorder. The four parameters proposed for recording at each site in the minimum network are specific conductance, water temperature, dissolved oxygen, and pH. The recording of additional parameters such as turbidity, precipitation, sunlight intensity, and air temperature are proposed at selected sites in the minimum and optimum networks.

The functional specifications for the water-quality monitors are given in Appendix A. These specifications should be reviewed and updated before the monitors are purchased to take advantage of any improvements in the design of the equipment.

The on-site recorder should be an ADR (analog-to-digital recorder) that punches inputs in BCD (binary-coded decimal) form on 16-channel paper tape. The ADR provides a continuous backup record for periods when data transmission is interrupted. Digital-punched paper-tape recording for water-quality parameters is recommended instead of analog strip-chart recording because: (1) Water-stage is recorded on 16-channel punch tape; (2) both quality and quantity records are in common form for computer processing; (3) digital recorders are less expensive than analog recorders; and (4) data in BCD form are available for the digital-telemetry system.

The digital-telemetry system is considered to be a more secure and reliable means of data transmission than an analog system. Operating costs are generally lower, and the available hardware provides a low-maintenance, long-life system. The functional description and specifications of the proposed digital-telemetry hardware for monitoring stations are given in Appendix B (Smoot and Billings, 1969).

Delivery of water to the monitor's sensor tank should be by a 1/2-horsepower, 120-volt, A C, submersible pump. The pump must deliver at least 6 gallons per minute and neither aerate nor deaerate the water. Pumps usually last less than a year because of the adverse operating conditions.

The proposed locations for continuous monitors in the basin are shown on figure 1. The parameters to be recorded at each site, in relation to an optimum or minimum network, are designated as Level I or Level II operations (table 1).

Level I operations at a particular site, in addition to monitoring current and potential problems, requires installation of equipment to detect water-quality changes in subreaches of streams and to determine trends in time and place. Level II operations at a site requires installation of equipment to monitor current or potential problems only.

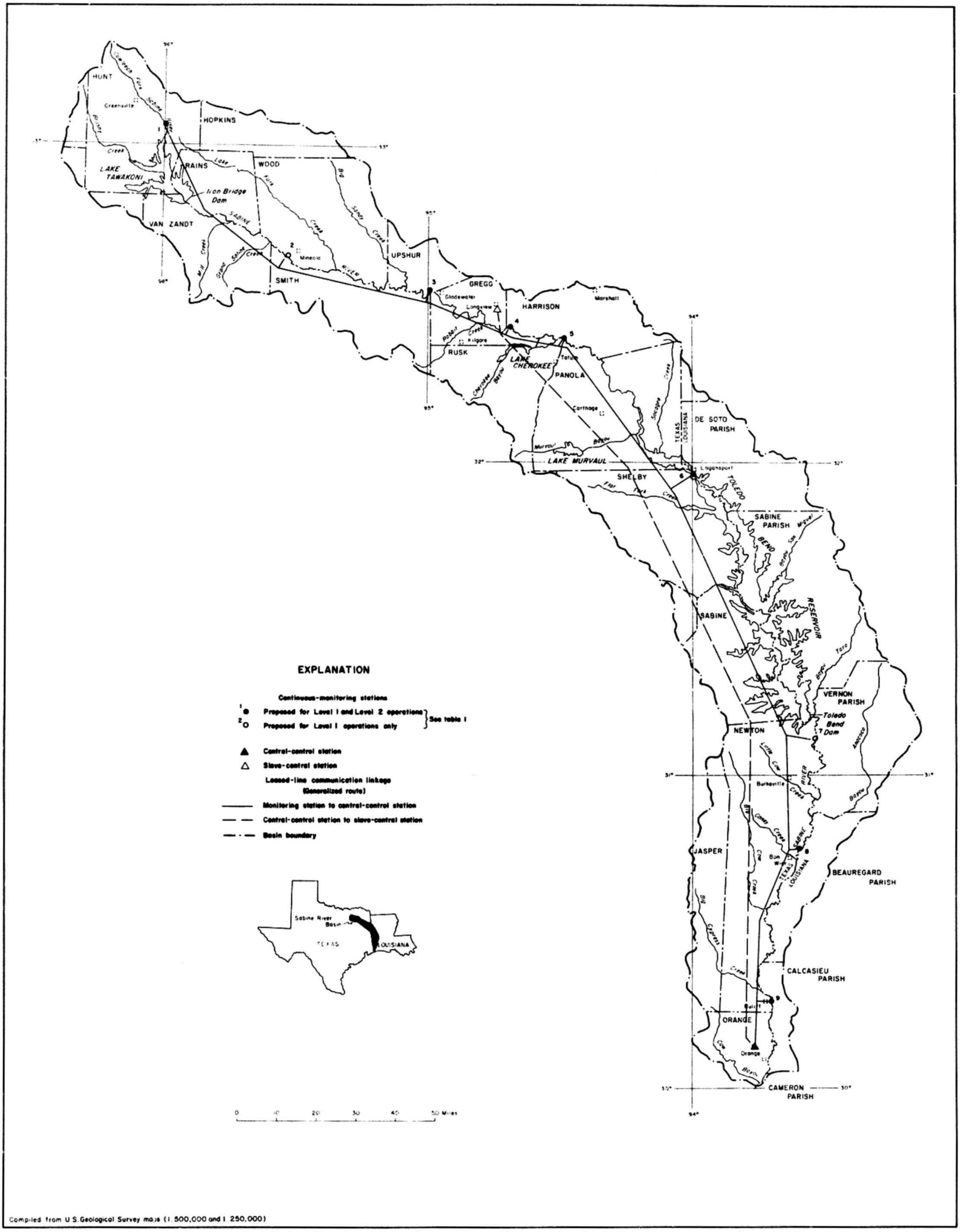

FIGURE 1.-Locations and operational levels of proposed water-quality monitoring sites, generalized route for communications linkage, and proposed locations of control stations

Table 1.--Proposed monitoring stations and parameters to be measured in Level I and Level II operations

Site no.	Location	Level of operation	Stream-flow	Specific conductance	Water temper-ature	Dissolved oxygen	pH	Tur-bidity	Precipi-tation	Sunlight intensity	Air temper-ature
1	Cowleech Fork Sabine River	I	X	X	X	X	X	X	X	X	X
	below Greenville, Texas	II	X	X	X	X	X		X		
2	Sabine River near Mineola, Texas	I	X	X	X	X	X				
3	Sabine River near	I	X	X	X	X	X	X	X		
	Gladewater, Texas	II	X	X	X	X	X				
4	Sabine River below	I	X	X	X	X	X	X	X	X	X
	Longview, Texas	II	X	X	X	X	X	X			
5	Sabine River near	I	X	X	X	X	X	X			
	Tatum, Texas	II	X	X	X	X	X				
6	Sabine River at	I	X	X	X	X	X	X	X	X	X
	Logansport, Louisiana	II	X	X	X	X	X				
7	Sabine River below Toledo Bend near Burkeville, Texas	I	X	X	X	X	X	X	X		
8	Sabine River near	I	X	X	X	X	X	X			
	Bon Wier, Texas	II	X	X	X	X	X	X			
9	Sabine River near	I	X	X	X	X	X	X	X	X	X
	Ruliff, Texas	II	X	X	X	X	X				

Site 3. Sabine River near Gladewater, Texas

Site 3 is proposed for both Level I and Level II operations. This station would monitor inorganic pollution from upstream sources and would monitor the chemical and physical quality of water entering the industrialized area of Gladewater, Kilgore, and Longview, Texas.

The drainage area above this site is 2,791 square miles, with about 2,000 square miles below Lake Tawakoni. In addition to degradation by saline inflow from Grand Saline Creek, the quality of surface waters in the area below Mineola is affected by oil-field operations. In an optimum network, the Mineola (site 2) and Gladewater (site 3) stations would provide data for separating the effects of the different sources of pollution.

Site 4. Sabine River below Longview, Texas

Site 4, which is about 8 miles downstream from Longview, Texas is proposed for both Level I and Level II operations. Municipal and industrial effluents from the Gladewater, Kilgore, and Longview, Texas, areas enter the Sabine River in the 35-mile reach between the Gladewater station (site 3) and the station below Longview (site 4). Data collected at these sites and at site 5 (Sabine River near Tatum) would provide information for measuring the effect of these effluents.

Site 5. Sabine River near Tatum, Texas

Site 5, which is about 17 miles downstream from site 4, is proposed for both Level I and Level II operations. This station would monitor changes in water quality in this reach, especially the changes in dissolved-oxygen concentrations. Depending on the amount of oxygen-demanding wastes entering the river above site 4 and the hydrologic and atmospheric conditions at the time, an oxygen sag or oxygen recovery may be monitored at site 5. Continuous observations at sites 3, 4, and 5 would provide information for management action to prevent major oxygen sags in this reach of the river.

Site 6. Sabine River at Logansport, Louisiana

Site 6, which is at the upper end of Toledo Bend Reservoir and near the head of the Texas-Louisiana State-line reach, is proposed for both Level I and Level II operations. This station would monitor the quality of water that is entering Toledo Bend Reservoir from the upper basin in Texas.

Site 7. Sabine River below Toledo Bend near Burkeville, Texas

Site 7, which is 17 miles downstream from Toledo Bend Dam, is proposed for Level I operations only because most of the streamflow passing this station would be water released from Toledo Bend Reservoir.

In a minimum program, periodic field determinations of specific conductance, water temperature, dissolved oxygen, and pH at this station should be an acceptable alternative to continuous monitoring.

Site 8. Sabine River near Bon Wier, Texas

Site 8, which is 59 miles downstream from Toledo Bend Dam, with an intervening drainage area of about 1,000 square miles, is proposed for both Level I and Level II operations.

Most of the flow at site 8 would be water released from Toledo Bend Reservoir, but during periods of minimum releases from the reservoir, this station would monitor the effects of runoff from the intervening area, including the flow of Bayou Anacoco, which is affected by paper-mill wastes (Shampine, 1971, p. 31). Bayou Anacoco discharges into the Sabine River about 13 miles above site 8.

Site 9. Sabine River near Ruliff, Texas

Site 9, which is the most downstream continuous-monitoring station in the proposed network, is proposed for both Level I and Level II operations. This station would monitor the quantity and quality of water contributed to the tidal area of the basin by the main-stem Sabine River.

Rawson and others (1969) reported that about 5 miles downstream from the Ruliff station, the Sabine River branches and part of the flow enters Old River. Below this point of divergence, most of the streams in the basin are tide affected. During low-flow periods, much of the flow entering this area is diverted for industrial and agricultural uses, and during high-flow periods, the streams overflow into poorly drained swampland.

Continuous monitoring at permanent sites below site 9 is not considered practical.

CENTRAL-CONTROL AND SLAVE-CENTRAL STATIONS

The proposed location of the central-control station is the office of the Sabine River Authority of Texas in Orange, Texas (fig. 1). The equipment requirements and options are described in Appendix B. Although any digital-recording device could be used for receiving data, the teletypewriter is recommended. In addition to the printer output, this unit will record data or punch paper tape. The punch tape would provide computer input to the Sabine River Authority's computer for comparing current water-quality conditions against stream standards, for computing loads, and for examining trends in time and place.

The proposed location of the slave-central station is in the Longview area (fig. 1). The slave-station communications linkage is with the central-control station; it performs no interrogation function but provides a current display of all data inputs from the remote stations (monitoring sites) that are received by the central-control station. The equipment requirements are described in Appendix B.

The purpose of the Longview location is to provide headquarters for an operation and maintenance staff. The current record displayed at the slave station will alert service personnel to any change in conditions at the monitoring stations. Personnel can be at any station shortly after a change is noted and can collect additional information on the water quality or correct an equipment malfunction.

COMMUNICATIONS LINKAGE FOR DATA TRANSMISSION

The communications linkage for telemetry can be leased line (telegraph or voice grade), radio, microwave, or a combination of these systems. A leased-line (voice-grade) communication linkage is recommended because the distance from Greenville (site 1) to the central-control station at Orange is more than 300 miles. Any method of continuous-data transmission for this distance will be expensive. The installation cost of a radio system is estimated at $80,000 to $100,000, including the cost of radios, transmission towers, and four or five repeater stations. Because of the low elevations at most sites and because of the heavily forested areas in the basin, a secure radio system would be difficult to establish. An annual maintenance-contract cost for a radio system is estimated at about $12,000.

A system using microwave transmission would provide a more secure system than radio, but because of higher tower requirements for line-of-sight transmission, the installation cost of a microwave system would probably exceed $200,000, with annual-maintenance costs of $25,000.

Leased-line communication was discussed with Messrs. Vic Lester and C. S. King, Southwestern Bell Telephone Co., Beaumont, Texas (oral comm., 1973). Southwestern Bell Telephone Co. would contract to install and maintain a voice-grade, leased-line system for the proposed network. This contract would include all negotiations and subcontracting with other telephone companies in the basin.

Installation costs for the leased-line system, which is estimated at $10,000 for the optimum network, would be limited to the expense of extending telephone lines from the nearest lines to the remote stations. The telephone lines can accompany the power lines to most remote stations, with both lines on the same poles or buried in the same trench. Messers. Lester and King estimated the annual leased-line costs, including all maintenance of communications linkage, at $25,000.

TIME REQUIREMENTS FOR ESTABLISHING THE NETWORK

A minimum of 12 to 15 months would be required to establish a complete operational network. Manufacturer's delivery time for major equipment, such as water-quality monitors and telemetry systems, is 6 to 9 months after a contract is awarded. Messrs. Lester and King, Southwestern Bell Telephone Co., estimate a minimum of 12 months to establish the leased-line communications linkage. From 1 to 2 months probably would be required for testing and calibrating the equipment before the system could be completely operational.

COST ESTIMATES

Equipment and Installation

Equipment and installation costs for the monitoring network are given in table 2. Costs for Level I and Level II operations are based on the proposed activities at monitoring stations listed in table 1.

Table 2.--Estimated equipment and installation costs for the Sabine River Basin monitoring network

Site no.	Location	Equipment costs 1/		Installation costs 2/		Total costs	
		Level I	Level II	Level I	Level II	Level I	Level II
I.	Continuous-monitoring stations--costs are related to level of operations given in table 1.						
1	Cowleech Fork Sabine River below Greenville, Texas	$ 15,300	$12,760	$10,300	$ 8,960	$25,600	$21,720
2	Sabine River near Mineola, Texas	12,240	--	6,120	--	18,360	--
3	Sabine River near Gladewater, Texas	14,550	12,240	5,970	4,930	20,520	17,170
4	Sabine River below Longview, Texas	15,300	14,030	23,810	22,160	39,110	36,190
5	Sabine River near Tatum, Texas	14,030	12,240	8,730	7,990	22,760	20,230
6	Sabine River at Logansport, Louisiana	13,060	10,000	7,310	4,930	20,370	14,930
7	Sabine River below Toledo Bend near Burkeville, Texas	12,310	--	3,060	--	15,370	--
8	Sabine River near Bon Wier, Texas	14,030	14,030	6,420	6,420	20,450	20,450
9	Sabine River near Ruliff, Texas	13,060	10,000	3,130	750	16,190	10,750
Subtotals		$123,880	$85,300	$74,850	$56,140	$198,730	$141,440
II.	Central-control and slave-control stations					14,000	14,000
III.	Communications linkage (estimated costs to extend telephone lines from remote stations to junction with telephone company lines)					10,000	9,000
IV.	Test instruments and service equipment					16,600	16,600
Total costs						$239,330	$181,040

1/ Includes water-quality monitor, telemetry unit, pump, and stage equipment.

2/ Includes shelter, AC power line, installation materials, and labor.

The high installation cost for the station below Longview (site 4) includes the cost of a cableway across the river. Because there is no bridge crossing in the area, a cableway is necessary to measure the discharge at this station. Installation costs at the Burkeville (site 7) and Ruliff (site 9) stations are low because shelters and other facilities are presently available at these stations. The water-quality monitor currently operated at site 9 would be replaced with new monitoring equipment.

Test instruments and service equipment (table 2, item IV) include instruments, tools, and other items necessary to equip two service vehicles and a testing and repair shop at Longview. A 20 percent replacement cost is included in the annual operation and maintenance costs for replacement parts and equipment (table 3, item III).

Operation and Maintenance

Estimated annual operation and maintenance costs are given in table 3. The costs are based on a proposed servicing operation that includes visiting all monitor stations every 3 or 4 days for preventive maintenance and calibration checks and for making field observations and collecting samples. Special visits will also be made to stations when a problem is indicated on slave-central display.

Table 3.--Estimate of annual costs for operation and maintenance of the Sabine River Basin monitoring network

I. Personnel			
A. Salaries			
Hydrologist (or hydrologic technician)	$12,000		
Electronic technician	8,000		
Hydrologic technician	8,000		
		$28,000	
B. Employee benefits and overhead		9,000	
			$37,000
II. Travel expense			
A. Vehicles (75,000 miles per year at $.12 per mile)		7,650	
B. Per diem (200 days at $24 per day)		4,800	
			12,450
III. Replacement parts and equipment			14,100
IV. Field and office supplies			2,000
V. Rental space (office and service shop in Longview)			3,000
VI. Leased line for communications linkage (Southwestern Bell Telephone Co.)			25,000
Total costs			$93,550

REFERENCES CITED

Rawson, Jack, Johnson, S. L., and Smith, R. E., 1969, Quantity and quality of low flow in Sabine and Old Rivers near Orange, Texas, September 12-15, 1967: Texas Water Devel. Board Rept. 90, 17 p.

Shampine, W. J., 1971, Selected hydrologic characteristics of the Sabine River and Bayou Anacoco, Louisiana and Texas: Sabine River Compact Administration, 34 p.

Smoot, G. F., and Billings, R. H., 1969, Digital telemetry, functional description and specifications: U.S. Geol. Survey open-file rept., 27 p.

APPENDIX A

SPECIFICATIONS FOR WATER-QUALITY MONITORING SYSTEMS

U.S. GEOLOGICAL SURVEY

SPECIFICATIONS FOR WATER-QUALITY MONITORING SYSTEMS

1.0 Definition and Scope: This specification details in various subsections the functional requirements and technical data for the elements and components that make up a variety of water-quality data-collection systems.

By selection of appropriate components from the specification, systems of varying degrees of sophistication can be assembled that will monitor and record water-quality parameters.

2.0 Composition: Elements for assembling the various water-quality data-collection systems are:

Programmed servo-drive

Signal conditioners

Flow-through sensor module

Individual sensors

Instruction manual and wiring diagrams.

Because the systems are of modular construction and may be expanded at a later date, all components shall be compatible. The width and depth of the programmer module, the signal-conditioning module, and the flow-through sensor module shall be consistent between modules so that they may be stacked to form a system. The width shall be 22 inches and depth 20 inches. Fasteners shall be provided for locking these units together when they are stacked.

3.0 Components: Detailed specifications for the various components are as follows:

3.1 Programmed Servo-Drive: The programmed servo-drive shall be composed of a scanner programmer, amplifier, and servo-positioning motor designed to operate a Model 1542 Fischer-Porter ADR (Analog-to-Digital Recorder).[1/] It shall start itself on command from an externally-mounted model 33-E Chelsea timer (ADR and timer supplied by the U.S. Geological Survey, position the ADR code disk to the proper value, and activate the punching operation sequentially for each of the active input channels (adjustable from 1 to 10). After completion of all operations, it shall shut itself down until a new start command is received from the timer. It shall be housed in two separate sections, hereafter referred to as the programmer section and the drive unit. These sections shall be connected solely by multi-conductor electrical cable.

3.1.1 Mechanical: The programmer section shall house the scanner programmer, the servo amplifier, and all required power supplies. Space shall also be provided for housing 10 plug-in signal conditioners. The programmer section shall not exceed 12 inches in height (see section 2.0 for width and depth).

A hinged, gasketed front and back cover shall be provided for access to all controls, connections, and signal-conditioner units.

Drip-proof and dust-proof access ports for sensor leads shall be provided.

1/ The use of named products in this report is for identification only and does not imply endorsement by the Geological Survey.

3.1.2 Scanner Programmer: The scanner programmer shall be activated by an external timer at selectable intervals of 15, 30, or 60 minutes, once each interval. This shall activate the system and index operation to Channel 1. It shall allow time for the servo system to position the code disk of the ADR to the proper value before issuing a punch command for recording Channel 1. The scanner shall then index to Channel 2, if active, and the above sequence repeated until all active channels have been indexed and recorded. At the completion of the punch command for the last active channel, the punch-command circuit shall be inactivated, the scanner shall sequence through any inactive input channels to the initial index position, and all power to the system shall be switched off. The scanner shall not dwell on any inactive channel for more than 0.2 second. Solid-state logic, with at least 6V (volts) signal-line noise margin, shall be used in the construction of the programmer. The servo motor shall be inactivated during the punch command part of each sequence.

Once each cycle, the timer shall be automatically wound for not less than 15 seconds nor more than 30 seconds.

Push-button switches shall be provided on the front panel for manually stopping the programmer without disturbing the timer and for manually initiating a scan cycle.

A swich shall be provided on the front panel for stopping the scanner in any channel position for checking and calibrating the sensor in that channel. A safety device to automatically return the switch to the RUN position or a warning device to indicate that the switch is in the HOLD position shall be provided.

Time required for positioning the ADR and recording each active channel shall be a nominal 30 seconds.

When a signal-conditioner card is not plugged into its respective socket, no punch-out shall occur in that particular channel.

An indicator showing the channel to which the scanner is indexed shall be provided. The channel indicator shall function at all times when operating on AC (alternating-current) line power, but shall be automatically disabled when switched over to standby battery power. All other lights shall be disabled when on battery power.

Telemetry identification outputs must be available from signal-conditioner channels 1 through 9. They must supply 100 microamperes at an output of +3V to +6.5V during the period when their associated channel is being recorded on the ADR and sink 3 milliamperes at an output of -1V to +0.5V otherwise. These outputs must be available, along with a system ground, through a 10-pin connector on the cabinet.

3.1.3 Servo amplifier: Voltage amplification shall be by means of a low-current drain, solid-state amplifier provided with an output circuit to drive a reversible DC (direct-current) motor. The motor-drive circuit shall be logically disabled at all times other than the actual servo-balance interval.

Amplifier gain and zero adjustment shall be provided.

3.1.4 Power Supply: The power supply shall be compatible with the system-accuracy requirements in section 3.1.5.

A voltage source shall be provided so that when the scanner is in the off position a mid-scale check can be made. The recorder shall balance but no punch-out shall occur.

3.1.5 Drive Unit: The drive unit shall consist of a separate power head for positioning the code disk of the ADR and shall be mounted directly to the frame of the ADR using existing holes.

The drive unit, in conjunction with the programmer, shall provide a system accuracy of ±0.25 percent or ±2.5 millivolts, whichever is greater.

An output of 10 revolutions of shaft position, linearly proportional to the input variable, shall be provided within the stated accuracy. The tape punch shall read in percentage of the full scale based on zero representing 1,000 and 100 percent representing 2,000.

3.1.6 Power Requirements: Power requirements shall be met by battery or AC line with automatic switchover to battery in event of loss of line power. Both capabilities shall be an integral part of the instrument. Switchover shall occur without upsetting the programmer.

The AC line power shall be 120 $\pm$7V, 60 cycles per second, $\pm$10 percent. Battery power shall be provided by two 7.5$\pm$1.5V dry-cell batteries connected in series.

The batteries shall provide power to only those circuits necessary in maintaining a correct time sequence of punched-tape numbers, with no attempt to establish any correlation between these numbers and the measured variables. The batteries should also protect the programmer against momentary AC line failures.

3.1.7 Signal Conditioners: The signal conditioners shall be provided with quick-disconnect plugs for easy removal.

The signal conditioner shall accept the input from its sensor and give an output of 0 - 5V.

The signal conditioners shall be sufficiently adjustable in zero and span to provide the required ranges $\pm$50 percent. These adjustments shall be made with a screwdriver at the front of the cabinet without the necessity of removing the electronic cards.

An interchange of signal conditioners shall be possible on any of the 10 channels.

3.2 Flow-Through Sensor Module: The sampling tank shall serve as a container holding a representative sample of water under test and for presenting this sample to the individual sensors in a manner in which it can be utilized without deterioration or contamination. The water shall be introduced to all units in such a manner that the water shall flow through all cells in parallel compartments as opposed to flowing in series from one cell compartment to the next--so that interaction between individual sensors is prevented.

The height of the module shall not exceed 21 inches (see Section 2.0 for width and depth).

This module shall provide compartments for housing not fewer than seven "in-water" type sensors.

Water connections and electrical connections to the sensor module shall be readily removable without special tools to enable the complete sensor module to be removed from the system assembly.

All sensors mounted in the sensor module shall be quickly removable through the use of coded disconnect plugs.

The sampling tank shall be mounted to facilitate inspection of the sensors and removal of algae and dirt accumulation without removing the unit from service.

It shall be possible to obtain a water sample from the tank without affecting any of the measurements.

The design of the sampling tank shall facilitate disassembly for cleaning. No special tools are to be required to either drain, disassemble, or reassemble the sampling tank.

The sampling tank shall withstand corrosive attack by the water passing through it for a period of at least 2 years.

The sampling tank shall be designed to minimize accumulation of sediment.

An increase of 100 percent inflow rate above set point flow shall not cause spillage.

The sampling tank shall be designed so that an increase of 100 percent in designed rate of flow does not affect the magnitude of any measurement by more than 1 percent.

The module shall have front and rear doors or covers. The front cover shall completely close the module when in place. Water-supply and drain connections shall be provided at the rear of the tank.

A base shall be provided on which the module shall be mounted. It shall not exceed 5-3/4 inches in height and shall be the same width as the sampling module. It shall extend forward a sufficient amount to prevent the system from tipping when the sampling tank is withdrawn for inspection.

3.3 Individual Sensors: Individual "in-water" type sensors shall have mounts provided for mounting in the compartment of the sampling tanks located in the sensor module. Sensors shall have a cable (maximum 24-inches long) terminating in a plug connector to facilitate quick removal. Connectors shall perform satisfactorily under conditions up to and including 100 percent relative humidity.

3.3.1 Temperature Sensor: The temperature sensor shall be a Rosemont Model 104MB or equivalent.

The measuring range of temperature shall be -20 to +65^{o}C (degrees Celsius).

The calibrated accuracy of the temperature measuring system shall be within $\pm$0.3^{o}C between 0 and 40^{o}C. This includes the system from the sensor to the recorder.

The temperature system shall have a time constant (63.2 percent response to a step change) of less than 30 seconds.

Temporary removal of the water-temperature sensor from the system shall not affect its calibration.

The calibrated accuracy of the water-temperature measurement system will be determined by comparing the indication of the temperature on the recorder scale to a precision mercury thermometer that has been checked against a precision thermometer certified by the National Bureau of Standards, accurate to $\pm 0.2^{\circ}C$.

3.3.2 <u>Conductivity Sensors</u>: The conductivity sensor shall be all metal and plastic construction and exhibit nonfouling characteristics, operating satisfactorily when submerged in water for prolonged periods of time.

The sensor shall operate under the potentiometric principle, providing a measurement of voltage drop across its electrodes due to the conductance of the water.

The sensor shall contain a pair of current electrodes that furnish the source of 400 Hertz AC.

The sensor shall include two or more voltage-measuring electrodes positioned between the pair of current electrodes.

All electrodes shall be in a fixed position.

The sensor shall permit measurements over a maximum range of from 0-60,000 µmhos (micromhos) with four selectable ranges as follows: 0-1,500, 0-6,000, 0-30,000, and 0-60,000 mhos.

Accuracy of calibration of the conductivity system shall be within ±1 percent full scale at constant temperature. This includes the system from the sensor to the recorder.

The accuracy of this measurement shall be checked by using potassium chloride solutions standardized at 25, 50, and 75 percent of full scale in each selectable range and prepared in accordance with the methods detailed in "Standard methods for examination of water and waste water," 12th edition, 1965, pages 280-284 (American Public Health Association, 1965).

Temporary removal of the conductivity sensor from the system shall not affect its calibration.

The time constant of the conductivity sensor (63.2 percent response to a step change) shall be less than 2 minutes.

The conductivity sensor shall be temperature compensated from 0 to 30°C to refer measurement to 25°C based on the potassium chloride conductivity temperature curve, to within ±3 percent full scale over the temperature range.

It shall be possible to disconnect and remove the conductivity sensor from the system without special tools.

3.3.3 Dissolved-Oxygen Sensor: The D.O. (dissolved-oxygen) sensor shall be a Delta Scientific Model type galvanic silver-lead made by Delta Scientific Company (or equivalent), and shall use a premounted replaceable membrane.

The range of this sensor shall be from 0 to 20 mg/l (milligrams per liter).

The D.O. sensor shall be temperature compensated for water temperature changes from 0 to 35°C and shall be capable of satisfactory operation from the freezing point to 55°C.

The accuracy shall be within ±1 percent full scale or ±.05 mg/l, whichever is greater, at constant temperature and pressure.

The D.O. sensor time constant (63.2 percent response to step change) shall be less than 2 minutes.

The calibration accuracy of the D.O. sensor shall be determined by comparing the indication of the D.O. on the recorder scale to an analysis of a water sample. The analysis shall be in accordance with the Alsterberg Modification of the Winkler method of dissolved-oxygen determination. (Reference: "Standard methods for the examination of water and waste water," 12th edition, 1965, pages 405-415, American Public Health Association, 1965.)

Temporary removal of the D.O. sensor from the system shall not affect its calibration.

It shall be possible to disconnect and remove the D.O. sensor from the system without special tools.

3.3.4 pH Sensor: The pH sensor shall include the electrodes and the thermal compensator.

The lead from the pH electrode shall be shielded and connect directly to the signal conditioning board.

The range of the pH sensor shall be 0-14 pH units.

The reference electrode shall have the capability of supplying sufficient electrolyte for a minimum of 4 weeks under operating conditions.

The time constant of the pH sensor (63.2 percent response to a step change) shall be less than 2 minutes.

The calibrated accuracy of the pH sensor shall be within ±0.1 pH units from 2 to 12 pH units at constant temperature. This includes the system from the sensor to the recorder.

The pH sensor shall be calibrated by placing the sensing elements in standard pH buffer solutions (Fischer Scientific 11-505 series or equivalent). The buffer ranges selected shall be nominally 5, 7, and 9 pH units. The calibration shall be determined by comparing the indication of the pH on the recorder scale with the buffer-solution values.

Temporary removal of the pH sensor assembly from the system shall not affect its calibration.

The pH sensor assembly shall be easily removable from the system without special tools.

By means of a Beckman Thermo-Compensator (or equivalent) the unit must automatically adjust for a temperature range of 0 to 50°C.

3.4 <u>Instruction Manual</u>: A complete installation, operation, and trouble-shooting manual must be provided with each system. The trouble-shooting manual shall provide all circuit and wiring diagrams necessary.

APPENDIX B

DIGITAL TELEMETRY, FUNCTIONAL DESCRIPTION AND SPECIFICATIONS,

BY GEORGE F. SMOOT AND RICHARD H. BILLINGS

69-262

Table of Contents

ILLUSTRATIONS

INTRODUCTION

The need for current-data availability has become increasingly important in the past few years. Many users of U.S. Geological Survey data require current information for the efficient operation of their facilities. In the past our transmission of data has been primarily limited to water stage, using the relatively slow, manually operated Telemark, or the equivalent Binary Decimal Transmitter. In some applications this type of telemetry is adequate: in many others a more complex system is required.

Telemetering systems fall into two categories, either analog or digital, with varying degrees of sophistication in each. Digital systems generally offer a more secure, reliable means of transmitting data, and they transmit with a higher degree of accuracy than analog systems. The purpose of this paper is to describe a digital telemetry system designed for transmission of hydrologic data. In addition to having the advantages mentioned above, this system also provides for data reception in a computer-compatible form. Usually, the main disadvantage of a digital telemetry system is its high initial cost. However, because the Geological Survey is already recording data at its sites in BCD (Binary Coded Decimal) form utilizing an ADR (Analog-to-Digital Recorder), a large part of the cost - that required for analog-to-digital conversion - is eliminated. Furthermore, due to the less stringent transmission facility requirements, operating costs generally are lower than comparable analog systems.

FUNCTIONAL DESCRIPTION

As data are recorded, they are stored in a memory bank in BCD form so that the information can be made immediately available for transmission. Recording and storage of data are initiated at preselected timed intervals using a timer contact closure (Figure 1). An Analog-to-Digital Recorder, ADR No. 1, is continually balanced by a water stage sensor and its value is immediately recorded once the initiating signal is received. The same contact closure (Sensor No. 0) also activates a water-quality monitor programmer. The programmer sequences its Sensor No. 1 (in our case, specific conductance) into the system, allows time for a servo-drive to balance ADR No. 2 and calls for the value indicated by the sensor to be recorded. It then sequences sensor No. 2 into the system, balances the ADR and records the value indicated. This procedure is repeated until all active channels, up to a maximum of ten, have been recorded. The programmer then returns to the off position and awaits a new initiating signal from the timer. It should be noted here that the system will also operate with only water stage and ADR No. 1, or with only the water-quality monitor and ADR No. 2.

At the time water stage is recorded on ADR No. 1, a set of electrical contacts within the ADR, representing the recorded value in BCD form is closed. This value is transferred into memory No. 0 through the Telemetry Memory Input Addresser. The value for specific conductance is recorded on ADR No. 2 a few seconds after the recording of water stage on ADR No. 1 due to a time lag in the WQM

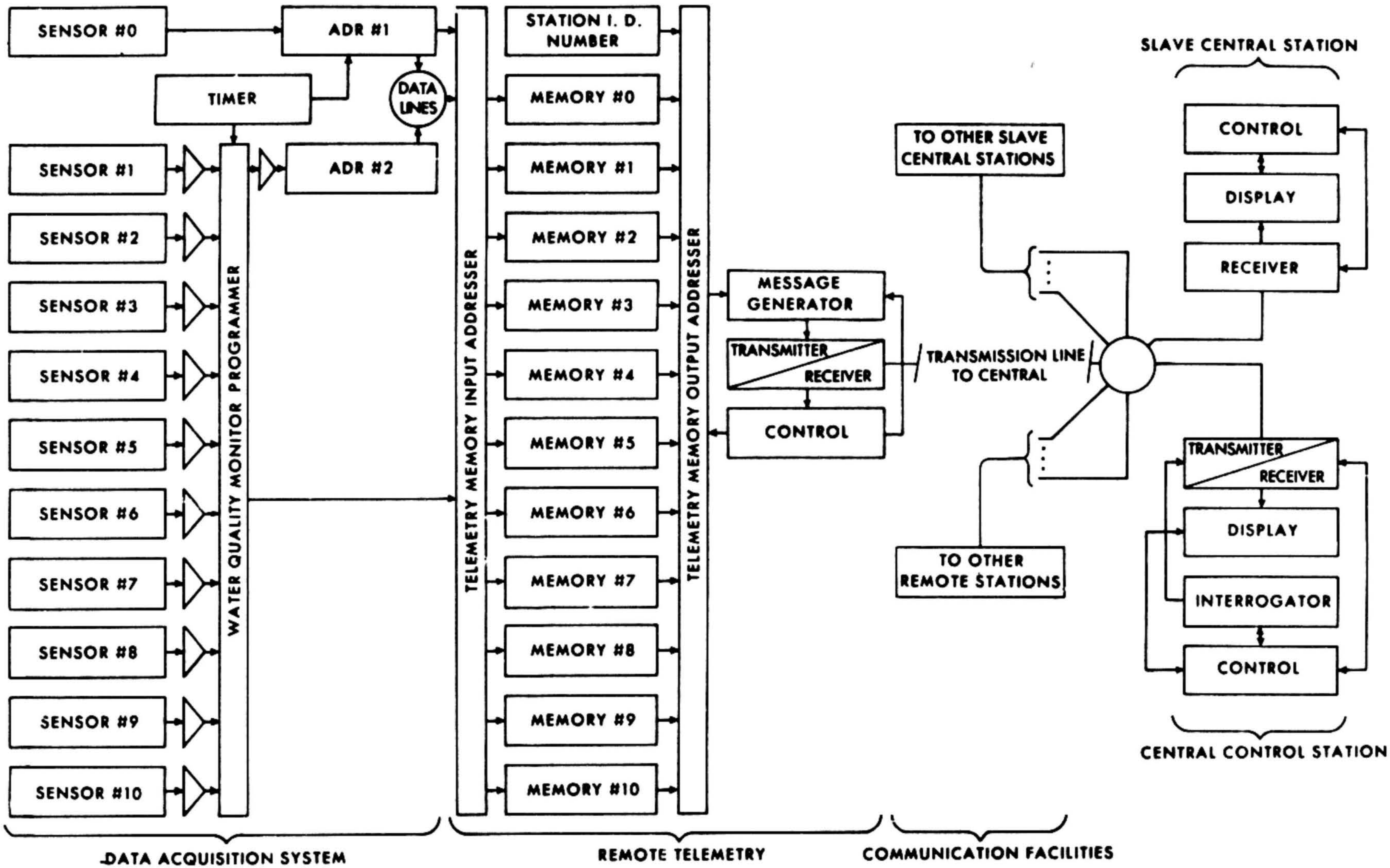

Figure 1 - Telemetry System Functional Block Diagram

(Water Quality Monitor) programmer. Its value, as represented by the set of electrical contacts in ADR No. 2, is transferred to memory No. 1 through the input addresser. The sequence is repeated until all parameters are entered into their appropriate memory modules. The input addresser relies on parameter identifier outputs from the WQM programmer and ADR No. 1 to determine proper memory locations. Upon completion of this cycle, digital data in BCD form are stored in memory and are ready for telemetering on command. These values will remain in memory until new values for the parameters are recorded, at which time the old values are erased and the new ones inserted in their places.

A telemetry network may consist of several remote stations reporting to a central control station. Each remote station may have several parameters. It is therefore necessary to provide both station and parameter identification. This is done by placing fixed identification numbers in each memory module. The first module always contains the station's identification number. The other modules represent data parameters with space for 5 digits of information in each. In the case of water stage the first digit in its module is wired to read 2 and the following four digits represent the value of water stage to the nearest one part in ten thousand. In the other individual parameter modules the first two digits are permanently fixed and represent the parameter identification numbers, ranging from 01 to 19. The last three digits represent the value of the parameter. This arrangement allows for an accuracy of one part in a thousand.

Parameter identification numbers have been assigned as follows:

Water Stage	2
Specific conductance	01
Temperature	02
Dissolved oxygen	03
pH	04
Chloride	05
Turbidity	06

Numbers 07 through 19 have been left uncommitted so that they may be assigned to less frequently used parameters.

Actual transmission of data is initiated by a timer at the central control station. The identification number of the remote station from which data are desired is formed by the interrogator and transmitted to all remote stations. Only the remote station which has this number stored in its station identification memory module responds, transmitting back its station ID number as a series of pulses. This transmission is received at the central station and displayed and/or recorded on a suitable output device, which is in our case a combination teletype page printer and tape punch unit. The Telemetry Memory Output Addresser then advances to the water stage storage module and these data are transmitted to, and recorded at, the central control station. This procedure is repeated until all information from the remote station has been transmitted and recorded. The interrogator then calls for the next remote station to report and the entire process is repeated. As many as 390 remote stations can be interrogated by a single central control station in this manner. In addition, slave central stations may be operated from the same system; however, they perform no interrogation function and are used only for display and/or storage purposes.

The communication linkage may be leased line (either telegraph or voice grade), radio, microwave, or a combination of these. Rate of transmission is limited by the type of communication linkage used, and the final output device capabilities. System speed is controlled by plug-in modules in the telemetry transmitter and receiver. These are easily exchangeable so that a system's speed may be selected to best suit the situation. Maximum rate over a telegraph grade line is 15 pulses per second; therefore approximately 2 seconds are required to transmit 1 parameter. Maximum rate over a voice grade line is approximately 2300 pulses per second and transmission time is reduced proportionately. Rates over both radio and microwave can be considerably faster. However, when combinations of the different types of linkages are used in a single system, transmission rates cannot be faster than the capabilities of the slowest speed linkage.

Because this is a modular system, a high degree of flexibility is obtained. For example, it is not necessary that a teletypewriter be used for recording data; any other digital recording device can be used. Also, accessories such as digital clocks may be added.

Thus, the system can be adapted to the specific needs of the user. A typical central control station is shown in figure 2, and a typical remote station with associated data acquisition equipment is shown in figure 3.

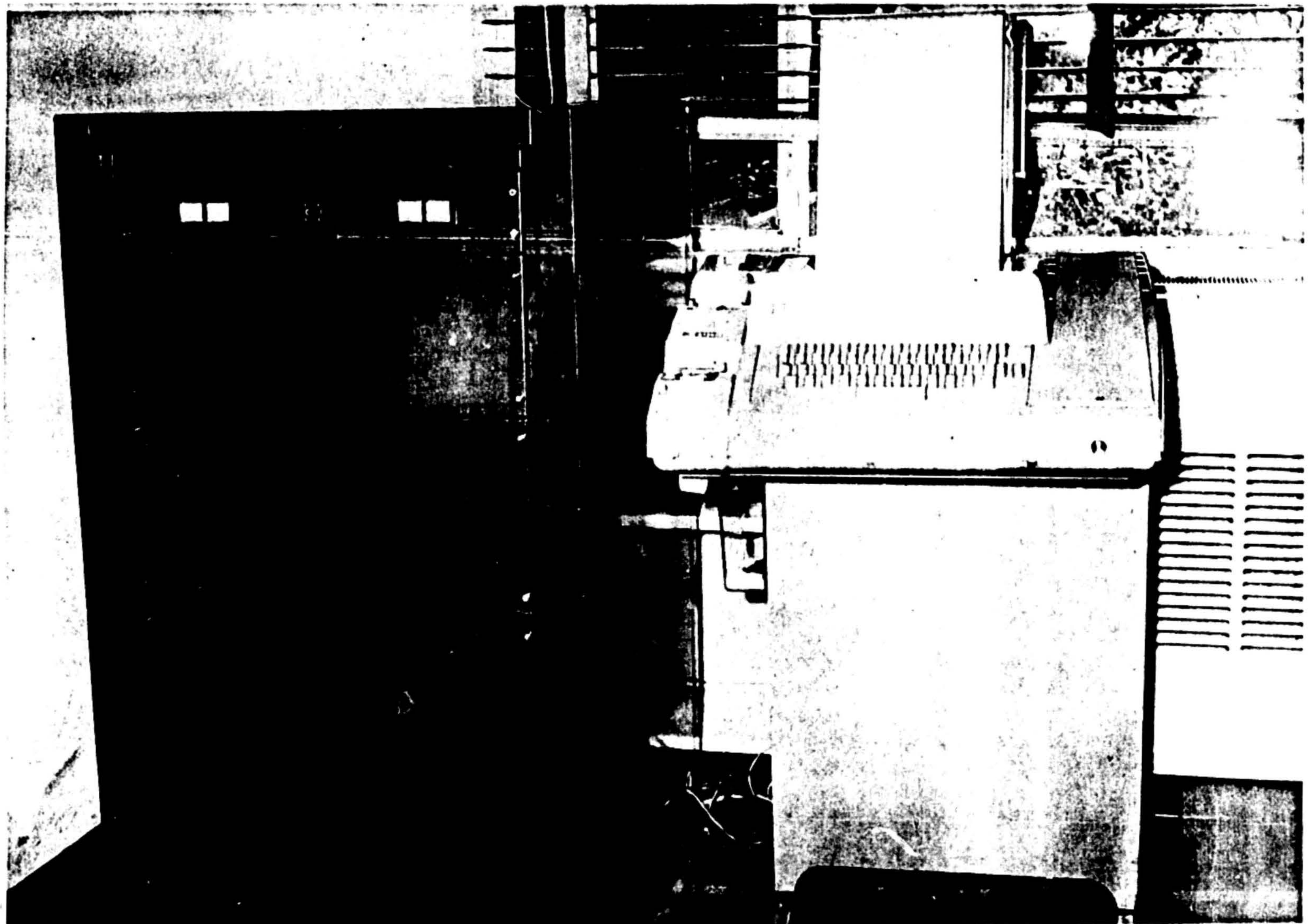

Figure 2. -- Central Control Station

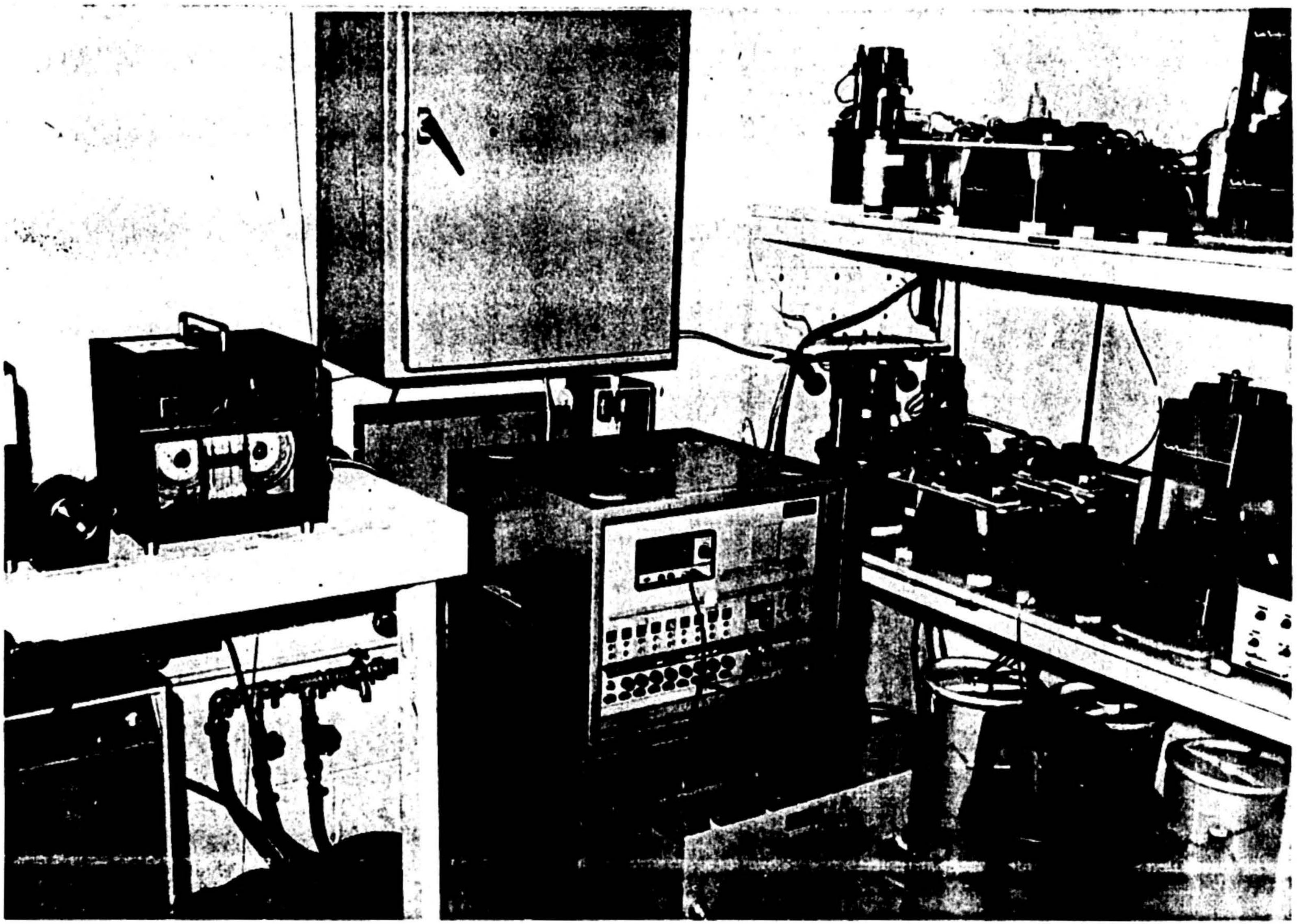

Figure 3. -- A Typical Remote Station with Associated Data Acquisition Equipment

1.0 Definition and Scope: This specification describes in various subsections the functional and technical characteristics of the elements and components which make up a variety of digital telemetry systems.

Although the specification is written particularly for systems utilizing a teletype output, there is no intention of limiting a system to only this type of output. The specification of output devices other than teletype shall require a restatement of certain sections contained herein. By the appropriate selection of components from this specification, systems of various degrees of sophistication and magnitude may be assembled.

1.1 General Description: The telemetering systems must be capable of transmitting, periodically or on command, groups of hydrologic data from remotely located measuring stations to a central location. In a basic system a central control station may operate from one to thirty-nine remote stations over a suitable communication channel. Channels may be added, up to a maximum of ten, to obtain a more complex system with a central control station operating up to 390 remote stations.

Data acquisition systems at the remote stations go through periodic measuring cycles, producing a sequence of sixteen bit, four digit, binary coded decimal (BCD) numbers, on punched tape. There may be up to eleven such numbers in the sequence. At the times of punching, the data are also made available to the remote telemetry stations for storage in prescribed memory modules. Most data variables are significant to only three places and thus require only twelve bits of storage, although at least one variable requires sixteen bits. Data variable-identification prefixes must be provided in the memory modules. Telemetry storage shall be updated with each cycle of the data acquisition system.

Each telemetry remote station will be assigned an identification number. Upon receiving an interrogation message containing this number in a prescribed format, the station must transmit its identification number and all of its stored data variables, prefixed by their identification numbers, according to a prescribed sequence and format. Interrogation during memory update cycles should result in the transmission of a partially updated record. In no case is the stored data to be affected by transmission.

The telemetry central station must control the activity of all remote stations, interrogating them, and receiving and storing and/or displaying their data records. Interrogation must proceed automatically on a prescribed time cycle, sequencing through all remote stations in the system. Any particular remote station's report must also be available through manual selection, on command. Logging of time for each interrogation cycle must be provided as an optional feature.

Slave central stations must be provided - also as optional equipment - to perform all the functions of a central control station except interrogation and transmission.

2.0 Transmission Code: Transmissions are to utilize a nonreturn-to-Zero, Pulse Duration Modulation (NRZPDM) code. This is a binary code, alternating between two states, mark and space (M, S). Information is derived from the time duration of a pulse as well as its state of mark or space. Pulse durations are based on a unity time duration (T), and are of three types: a SHORT bit of unity duration, a LONG bit of three times unity duration, and a PAUSE bit of six times unity duration. Data logic state "0" is represented by a SHORT bit in the mark or space state (1M or 1S), while data logic state "1" is represented by a LONG bit in the mark or space state (3M or 3S). The unity time duration is defined through the relationship,

$$T = 1/(2F),$$

where F is the frequency in pulses per second that is specified for transmission.

In this system, data is transmitted in an eight bit block form, of which six bits are data and the remaining two are parity and synchronization-pause bits. The data bits are the first six bits in the BLOCK, and are either SHORT or LONG, according to their logic states. The odd bits are in the MARK state, and the even bits are in the SPACE state. The seventh bit is parity in the MARK state, and is either LONG or SHORT as required to assure an odd number of LONG MARK bits in the BLOCK. The eighth bit is a PAUSE bit in the SPACE state for timing and synchronization. The data BLOCKS are grouped by prefixing a series of them with a special SYNC code consisting of a PAUSE bit in the MARK state followed by a SHORT bit in the SPACE state. Idle line is the SPACE state.

A message takes the form of a SYNC code followed by a string of data BLOCKS.

3.0 Interrogation Message Format: The interrogation message must be generated at the central control station, addressed to a specific remote station, and be responsible for initiating that station's data report. The address must be a six bit BCD number, representing two decimal digits of the form, XY, where Y must range from 0 to 9 in four bit BCD code and X must range from 0 to 3 in two digit BCD code. The format must be a SYNC code followed by two data BLOCKS, each containing the address number of the station being called, as specified above.

4.0 Data Report Message Format: The remote station's data report must be sent as a series of messages, one for the station ID number and one for each of the data variables. The first message must be the station ID number, a five digit decimal representation of the form, 30YXX, 30 identifying it as the ID number, Y identifying the channel (0-9), and XX identifying the station (01-39).

All the decimal numbers in this combination are to be transmitted as four bit BCD codes except the first one, 3, which must be transmitted as a two bit BCD code. This combination requires eighteen bits. The message must take the form of a SYNC code followed by three data BLOCKS.

The second message must be a four place data variable in the decimal form, YXXXX, where XXXX represents the four places of data in four digit BCD form, and Y, ranging from 0 - 3, is an identifier in two bit BCD form. The eighteen bit message must be SYNC code followed by three data BLOCKS. This format is to be used for any additional four-place variables.

The rest of the messages will normally be three place variables in the form, ZYXXX, where XXX represents the three places of data in four bit BCD form, and ZY is one of the combinations 01 to 19 with Y coded in four bit BCD form and Z coded in two bit BCD form. Eighteen bits and three data BLOCKS are required, preceded by a SYNC code for each message. Transmission of a four-place variable, according to the format specified previously, must also be allowed in any of these remaining messages.

5.0 <u>Transmission Security</u>: All messages must be generated according to the specific formats stated in sections 2.0, 3.0, and 4.0, and the validity of all information received over the transmission facilities must be subject to the following tests:

a) Input pulses less than twenty percent of unity duration, (T), are to be rejected on the assumption that they constitute spurious line noise.

b) All messages must be preceded by the SYNC code, section 2.0.

c) The parity condition described in section 2.0 must be satisfied.

d) Total pulse count for each data BLOCK must be correct.

e) The presence of the eight bit data BLOCK PAUSE must be tested to at least seventy-five percent of its required time duration, section 2.0.

If any of the above tests fail, the receiver must disregard the information and any that follows, until the beginning of a new message, as indicated by a SYNC CODE.

6.0 <u>Transmission Facilities</u>: The system must be capable of sending and receiving DC (direct current), AM (amplitude modulated) tone, or FM (frequency modulated) tone transmission. Tone transmitter outputs must be adjustable from -40db to +5db and receiver sensitivities must be adjustable down to -40db. Harmonic content must be down at least 42 db from fundamental, with stability of ± 2Hz or ± 0.1%, whichever is greater. Impedance levels are to be 600 ohms.

The facilities used may be telegraph or voice grade telephone lines, D.C. pairs, radio link, or microwave, and transmission may range from 15 pulses per second (pps) to 1200 pps.

7.0 <u>Specific Remote Station Functions</u>: The data variables are presented to the telemetering equipment by sixteen parallel contacts arranged in BCD form. In the open state they represent logic "0" and in the closed state, logic "1". All contacts are normally open (logic "0") and assume the coded combination for a period of approximately one half second during the actual punching of the paper tape. The variables are punched in a prescribed sequence on the tape and are presented by the contacts in the same time sequence. Each of the variables has an associated variable-identifier output. The one identifying the first four-place variable is a set of dry, normally open contacts which close during that variable's recording time. The other ten, representing each of the other ten possible three-(or four) place variables, are outputs with excursions from ground to a positive voltage level during their variable's recording times. The telemetry remote station must provide eleven memory locations for the storage of these variables. The first location must provide sixteen bits of storage for the first four-place variable and the rest must provide twelve or sixteen bits of storage, as required, for each of the other ten variables. Transfer of a data variable to the location indicated by the variable identifier outputs is to occur when at least one of the sixteen data contacts closes. In the case of three-place variables, the units, tens, and hundreds digits are to be stored. Only one level of memory per variable is required, and it is to be updated by each new recording of the variable.

In addition to the storage of data variables, each memory location must provide a means of prefixing the data with a fixed two-digit number represented by six bits in the case of three place storage, and a one-digit number represented by two bits for four-place storage. The formats for these prefixes are described in section 4.0. The five-digit station ID number must also be fixed in storage in the format described in section 4.0. These variable prefixes and station ID numbers must be available for change by a strapping arrangement. Each memory location must be on a separate plug-in circuit card. System expandability must be possible through addition of memory cards, without wiring changes.

The remote stations must receive transmissions from the central station and perform the security checks required in section 5.0. If the transmissions fail security they are to be disregarded. Valid messages are to be passed on for decoding.

A message decoder, provided with a strapped-in station ID number, must apply a comparison test to the message to determine whether it contains the proper address, as specified in section 3.0. If a positive result is obtained, a read-out cycle shall be initiated.

When instructed by the decoder, a message generator must gain access to the various memory locations and construct and pass on to the transmitting section a series of data report messages according to the formats described in sections 2.0, and 4.0. The station ID and first four-place variable messages must always be sent, followed by any selectable number of the remaining variables. Any scanned memory location which contains no card shall present the number, 00000, for transmission according to the format for the location.

7.1 Data Acquisition System Output Specifications:

Data Contacts - sixteen parallel, normally open dry contacts which assume a BCD code representation of the data for approximately one half to one second during data acquisition. Open contact is logic

"0". Closed contact is logic "1". The contacts are rated at 30ma, up to 24 V. On one side, the contacts are bussed to ground.

Four-Place Variable-Identifier Contact - a normally open, dry contact which closes while the first four-place data variable is being updated. The contact is rated at 30ma up to 24 V.

Three-Place (Or Additional Four-Place) Variable-Identifier Outputs - ten outputs, one associated with each data variable. The outputs are normally in the 0 to +0.5V, 5ma state, and take a +5 V, 1ma state while their associated variables are updating.

Contact bounce and RF noise, due to the presence of several small D.C. motors, are present on all outputs.

8.0 Specific Central Control Station Functions: A timer at the central control station must initiate automatic interrogation cycles. An address encoder must present the BCD representation of the station ID numbers specified in section 3.0 to a message generator in numerical order, starting with station number one.

The message generator, on command from control logic, must form the interrogation message according to the format in section 3.0, using the output of the address encoder as the station ID number. The message generator must then pass the message to the transmitter and to the system.

The remote-station report consists of a series of messages, as specified previously, and as each message arrives at the receiver, it should be passed on to display/storage control, providing it passes the necessary format and security specifications in sections 4.0 and 5.0. If a violation of this nature is detected, the message is to be disregarded.

The display/storage control must translate the messages and store and/or display them on a page printer, tape deck card punch, or any other suitable specified output device. The display/storage control shall be capable of controlling only one particular specified output device, and for these specifications, this is a teletype unit.

In the present system, the display/storage control unit must control the teletype motor, turning it on only while actually providing display data to the printer, and off the rest of the time. Also, the printer must be held in a mark condition during motor off-time to prevent spurious characters from appearing in the display.

If any station fails to report within one hundred unity time periods (100T), the receiver must cause re-interrogation. If a second failure occurs, the station shall be left out of the record and the interrogation cycle continued. The end of a station's report shall be detectable as at least one hundred unity time periods (100 T) of idle line time, and cause the cycle to be continued. Continuation of the cycle involves incrementing the address encoder to the next station number and interrogating it.

The cycle must continue to a programmed point, at which time the address encoder shall terminate activity. This point must be adjustable from address two to address thirty-nine, inclusive, by a strapping arrangement.

An optional Channel Selector must be available, and provide a full ten channel capability. The Channel Selector must direct the interrogation cycle to channel number one, and utilize the normal end-of-cycle signal to initiate a second cycle, directing it to channel number two, and continue in this manner until a programmed stop is reached. The stop shall be adjustable through strapping to allow interrogation to cease at the end of any selected one of the 10 channel reports.

A manual interrogation capability must also be provided, allowing selection and interrogation of any remote station on command. This station should only be interrogated once, and if no report is received, the procedure should terminate. If a report is received, the normal procedure should be followed in displaying it.

A control panel containing the necessary switches and indicators to select remote stations by identification and channel number and to initiate manual interrogations must be provided. A status indicator shall also be furnished to aid in determining whether manual interrogation may be initiated. The internal logic of the system must protect the normal automatic activities of the station against interruption by manual initiation.

An optional digital clock may be required for time logging the interrogation cycle. Hours and minutes on a 2400 basis must be provided.

8.1 Central Station Teletype Display Format: Each remote station's report consisting of the station ID number followed by its data variables, as described in section 4.0, must be printed in the order received on one line of page printer copy. The items must be separated by a single space. Including the space, each item shall require six characters. Each station's report must be terminated with a single carriage return-line feed combination. The spaces, carriage returns, and line feeds, not being present in the transmitted report, must be supplied in the appropriate positions by the display/storage control section of the central control.

The complete data record of one interrogation cycle must consist of a series of line reports, one for each remote station in order of interrogation. Any variable message that fails to satisfy security or format requirements, or any station failing to report, should be missing from the record. As a means of blocking individual data records, the display/storage control, at the beginning of the interrogation cycle, should generate a single carriage return-line feed combination to the page printer, or, in the case of optional time logging, cause the output of the digital clock to be entered as four digits, followed by a carriage return-line feed combination.

An example of a display of a data cycle of three stations, numbered one to three, with time logging is given. The first station reports no four-place variable, and three three-place ones, numbered from one to three. The second station reports a four-place and three three-place variables numbered from one to three. The third station reports a four-place and two three-place variables numbered from two to three. The values of the variables are indicated by X's. Two cycles are shown.

0800

30001 00000 01XXX 02XXX 03XXX

30002 2XXXX 01XXX 02XXX 03XXX

30003 2XXXX 02XXX 03XXX

0900

30001 00000 01XXX 02XXX 03XXX

30002 2XXXX 01XXX 02XXX 03XXX

30003 2XXXX 02XXX 03XXX

The same report is next shown without time logging and with station two failing to report in the first cycle and failing security in three-place variable number two in the second report.

30001 00000 01XXX 02XXX 03XXX
30003 2XXXX 02XXX 03XXX

30001 00000 01XXX 02XXX 03XXX
30002 2XXXX 01XXX 03XXX
30003 2XXXX 02XXX 03XXX

9.0 Slave Central Station Functions: Slave central stations shall have no interrogation capability. The storage and/or display of data reports shall be according to the same format specified for a central control station. The unit must be provided with a means of detecting the beginning and end of individual reports from stations. All security tests applied to the data reports in the central control stations are to be similarly applied here.

10.0 Remote Station Assembly: The following sections detail the components required in a complete remote station.

10.1 Remote Station Logic Cards: Plug-in circuit boards shall provide all the controls and procedures necessary to utilize the memory cards, data acquisition system outputs, and line interface unit, and provide a system that meets all the requirements stated in section 7.0. Provisions must be made on the cards to strap in the interrogation ID number, the station's report message ID number, and the point at which memory scanning halts according to the specifications in section 7.0. One set of these cards is needed for a remote station.

10.2 Remote Station Enclosure: The enclosure shall be capable of being gasketed and heated in inclement environments, and be no larger than 24" wide by 24" high by 17" deep. The necessary power supplies, mounting racks, marked card connectors, and hardware to assemble a complete remote station must be provided. The unit shall be fully wired and capable of operating with the insertion of a full complement of cards and appropriate data inputs. The size of memory is to be adjustable by simply removing or adding memory cards as required, and making suitable card strappings. Marked terminal blocks shall be provided for the various data inputs. The enclosure shall contain facilities for mounting and connecting a specified line interface unit. The enclosure shall be provided with tabs for wall mounting.

11.0 Twelve Bit Memory Card: These plug-in circuit cards shall provide twelve bits of memory for three-place data variables. The cards must have facilities for prefixing the data bits with six bit identifiers, utilizing strapping arrangements according to the specifications given in section 7.0. One card is required for each three-place variable.

12.0 Sixteen Bit Memory Card: These plug-in circuit cards shall provide sixteen bits of memory for four-place data variables. The cards must have facilities for prefixing the data bits with two-bit identifiers, utilizing strapping arrangements according to the specifications given in section 7.0. One card is required for each four-place variable.

13.0 Central Control Station Assembly: The following sections detail the components required in a complete central control station with teletype output.

13.1 Central Station Logic Assembly Cards: These plug-in circuit cards shall provide all the logic functions and procedures necessary to make up the address encoder, message generator, display/storage control, and the central control functions as specified in sections 8.0 and 8.1. The logic for manual interrogation must be included. The system must be capable of operating either with or without the optional digital clock and channel selector. Arrangements for setting the point at which the address encoder halts, somewhere between the count of one and thirty-nine, must be provided, using a strapping procedure. One set of these cards is required at each central control station.

13.2 Cycle Timer: This timer must be capable of initiating the interrogation cycle at the central control station on a periodic time interval from thirty minutes to twelve hours as specified.

13.3 Central Station Enclosure: The enclosure shall be a floor mounted cabinet no larger than 24" wide by 26" deep by 30" high, and contain all the necessary power supplies, mounting racks, marked card connectors, and hardware to assemble a complete remote station consisting of the central station logic cards, the cycle timer, optional equipment, and the line interface units. The enclosure must also contain the control panel with the necessary equipment specified in sections 8.0 and 8.1. The unit should be fully wired and capable of operating with a full complement of cards and the appropriate connections to the page printer and external facilities. Marked terminal blocks must be provided for external connections.

13.4 Digital Clock Option: The clock must present a four-digit (sixteen bit) BCD output representation of the time in hours and minutes for time logging. Interfacing logic needed to use the clock in the system as specified in sections 8.0 and 8.1, is considered as part of the digital clock option.

13.5 Channel Selector Option: These plug-in circuit cards shall provide all the logic functions and procedures necessary for the automatic channel selection procedure described in section 8.0. The cards must provide a means of strapping in the stop position described in section 8.0. Manual interrogation must be possible through the use of a channel selector switch provided on the control panel.

14.0 Display Printer: The display printer shall be a model 33 ASR or model 35 ASR, Teletype Corporation automatic send-receive set, or a suitable equivalent. The unit must be furnished with the motor control facilities specified in section 8.0. Use of the tape punch and tape reader shall be optional.

15.0 D.C. Line Interface: This unit must be able to supply and receive D.C. keying and operate over standard telegraph lines. It must be compatible with the transmitting and receiving inputs and outputs of either the remote or central station. It must meet the transmission facilities specifications in section 6.0.

16.0 Tone Interface (AM or FSK): These units must be capable of operating with the transmitting and receiving outputs and inputs of the remote and central stations, and provide the send-receive capability detailed in section 6.0.

17.0 Slave Central Station Assembly: The following sections detail the components required in a complete slave central station.

17.1 Slave Central Station Logic Assembly Cards: These plug-in cards shall provide all the logic functions and procedures necessary for the proper operation of a slave central station as described in sections 1.0 and 9.0.

17.2 Slave Central Enclosure: The enclosure shall have the same dimensional and functional specifications as the central control station enclosure, with the exception that no control panel is to be provided.

18.0 Construction: All silicon solid-state plug-in printed circuit board construction, with maximum utilization of integrated circuits shall be provided. Components are not to be operated at more than half of their rated values. Commercial equivalent replacements are to be available for all components.

Circuit boards must be glass-epoxy and fitted with pull tabs. Circuit boards and receptacles must have gold plated contact surfaces.

Power supplies shall have short circuit and over voltage protection.

The system, with the exception of output devices, shall require no routine maintenance.

19.0 Power Requirements: The system shall operate from 115 VAC ± 10%, 60 cps power.

20.0 Environmental Specifications: The system shall operate over a temperature range of 0 to +60°C, and, with the exception of output devices, must be capable of operating over a range of relative humidities which includes the conditions of 90% at 30°C and 40% at 50°C.