GEOLOGICAL SURVEY CIRCULAR 756

Collection, Storage, Retrieval, and Publication of Water-Resources Data

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Standardization of Hydrologic Measurements

By G. F. Smoot

Use of Earth Satellites for Automation of Hydrologic Data Collection

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FOREWORD

This publication represents a series of papers devoted to the subject of collection, storage, retrieval, and publication of hydrologic data. The papers were presented by members of the U.S. Geological Survey at the International Seminar on Organization and Operation of Hydrologic Services, Ottawa, Canada, July 15–16, 1976, sponsored by the World Meteorological Organization.

The first paper, "Standardization of Hydrologic Measurements," by George F. Smoot discusses the need for standardization of the methods and instruments used in measuring hydrologic data.

The second paper, "Use of Earth Satellites for Automation of Hydrologic Data Collection," by Richard W. Paulson discusses the use of inexpensive battery-operated radios to transmit realtime hydrologic data to earth satellites and back to ground receiving stations for computer processing.

The third paper, "Operational Hydrometeorological Data-Collection System for the Columbia River," by Nicholas A. Kallio discusses the operation of a complex water-management system for a large river basin utilizing the latest automatic telemetry and processing devices.

The fourth paper, "Storage and Retrieval of Water-Resources Data," by Charles R. Showen discusses the U.S. Geological Survey's National Water Data Storage and Retrieval System (WATSTORE) and its use in processing water resources data.

The final paper, "Publication of Water Resources Data," by S. M. Lang and C. B. Ham discusses the requirement for publication of water-resources data to meet the needs of a widespread audience and for archival purposes.

These papers represent the state-of-the-art today in the collection, storage, retrieval, and publication of water-resources data.

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STANDARDIZATION OF HYDROLOGIC MEASUREMENTS

By George F. Smoot

ABSTRACT

The need for standardization of the methods and instruments used in measuring hydrologic data is discussed. The process by which standards are derived is then described. The ongoing standardization efforts in the United States are reported, including the activities of the Federal Interagency Work Group for the Designation of Standards for Water Data Acquisition and the activities within the American Society for Testing and Materials. On the international front, work being done by the various Technical Committees of the International Organization for Standardization, the World Meteorological Organization, and other international groups is described. Recognition of some duplication of effort is noted. The recommendation is made that better liaison and cooperation be established between the various standards-writing organizations.

INTRODUCTION

Standards are rules that specify how a thing should be done, just as laws are rules that specify how individuals should behave in society. Civilization would never have evolved without acceptance of laws and standards. As the world's population increased, so did the need for more and more specific laws. As technology became more complex, the need for more detailed and effective standards increased proportionately.

Concern over the quantity and quality of the world's water resources has deepened in recent times. Water in a stream in a specific locality knows no jurisdictional boundary, local or national. That same water may eventually move to any other part of the earth through the hydrologic cycle. Therefore, water data are needed from all parts of the earth to enable hydrologists to discover the quantity and quality of the earth's water resources on a comprehensive and continuous basis.

Hydrologists cannot validly compile water data that have been gathered by nonstandardized methods. In many cases the data on streamflow or quality of water are not even compatible. This makes it impossible to compare them in an effort to discern patterns or trends or to draw conclusions. Many individuals and organizations who are concerned with water data have recognized the need for standardization.

A system of developing standards that is founded on voluntary consensus works best. No one element of society, whether industrial or governmental, is competent to keep pace with a rapidly changing technology. A standard written by representatives from all affected segments is more likely to be unbiased, authoritative, and utilized. In the process of formulating such a standard, people with diverse interests come together, resolve their differences, and make mutual concessions that result in the greatest good for the greatest number. The standard produced by such a process protects everyone's interests while seriously injuring none. The key to a sound standard is compromise.

Some fear standardization, taking the viewpoint that it tends to lead to uniformity, inhibit innovation, and generally retard progress. These fears are unfounded. Standards are not meant to be restrictive but to make the use of a particular method uniform so that data derived will be compatible and comparable. The hydrologist may choose the method that best suits the particular situation from the many available. Only proven methods and instruments should be standardized, and the door should be, and is, left open for new developments.

The fact that there is a standard method in no way deters hydrologists from searching for an even better method. For example, the only standardized and accepted method for calibrating current meters at present is by towing them through sensibly still water in a straight open tank at known velocities. The method is a good one, but certainly not perfect. It is time consuming and costly. Moreover, there is a spread in the standard deviation of repeated calibrations of the same meter which can be attributed in part to persistent thermal currents and (or) threads of circulating currents stirred up in the water by previous passages (Smoot and Carter, 1968).

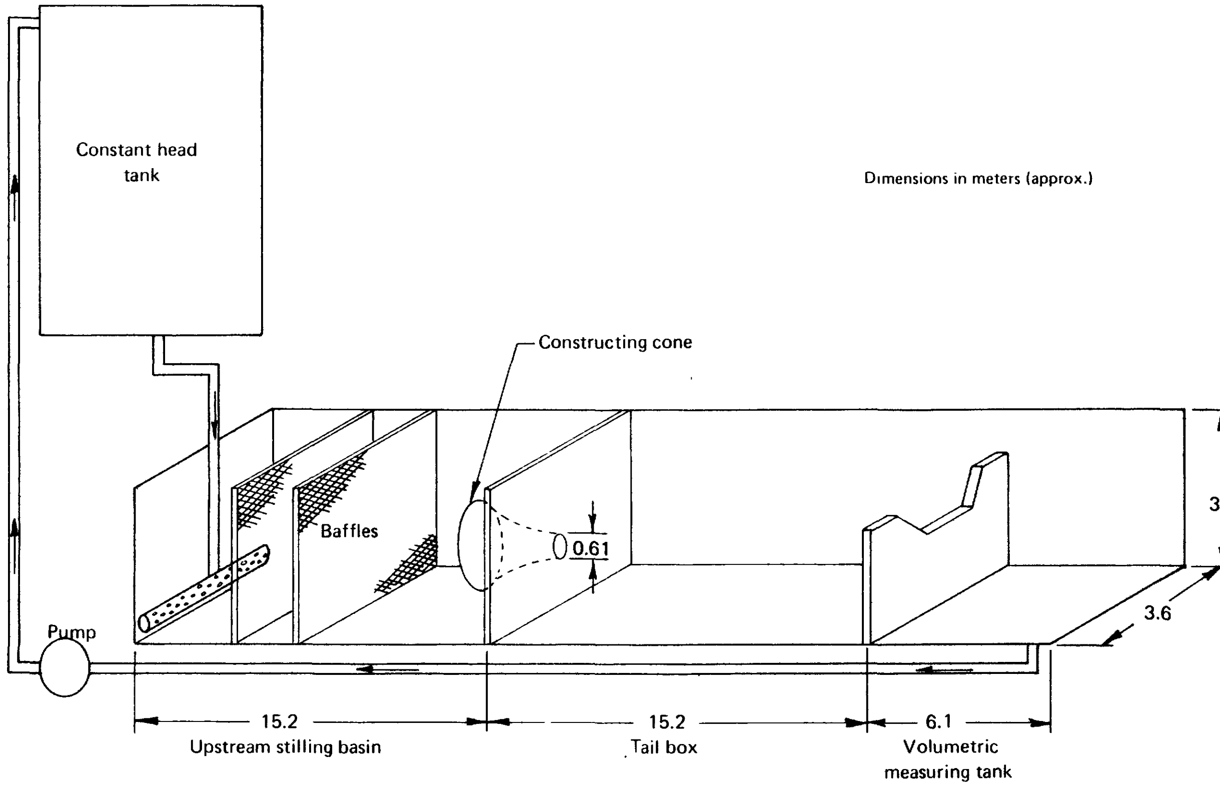

FIGURE 1.—Sketch of submerged jet calibration facility.

In an attempt to overcome some of these objections, the U.S. Geological Survey is investigating the feasibility of calibrating meters in a submerged jet issuing from a conelike nozzle. Test results of a prototype system were sufficiently encouraging to warrant further study and provided the design criteria for a permanent structure which has been constructed at the Geological Survey's Gulf Coast Hydroscience Center in Bay St. Louis, Miss. (Davidian, 1970). In this facility, water from a constant head tank is introduced into an upstream stilling basin and, after baffling, flows smoothly into a contracting conical section. The jet issuing from the conical section is submerged in a tail box, and the getaway flow is recirculated (fig. 1). The velocity field from the submerged jet is uniform and can be easily changed and quickly stabilized. At each established velocity, many meters can be successively placed in the jet and calibrated very quickly, with a consequent saving in costs.

The Geological Survey is conducting tests to determine the suitability of this method for calibrating current meters. Velocity traverses with a Pitot tube are being taken at the end of the cone section to verify that the velocity field from the submerged jet is truly uniform. Concurrently with the traverses volumetric measurements of flow are made. Different types of current meters are being calibrated both in the submerged jet and by the straight open-tank methods, and their calibrations are being compared. Results to date certainly indicate that the submerged jet is a satisfactory method of calibrating current meters. However, not until exhaustive tests have been conducted and conclusive evidence accumulated that it is indeed a satisfactory method will it be accepted by the Geological Survey. Of course, the test results will be published; and, if they are sufficiently conclusive, the method will be accepted by the hydrologic community and eventually be standardized.

STANDARDIZATION EFFORT IN THE UNITED STATES

Within the United States, several groups are presently engaged in the preparation of standards for instruments and methods of water-data collection. Prior to the recent increased environmental concern, standardization and quality control were looked upon largely as internal operations and responsibilities; that is, each organization established its own procedures. Each organization had established, within the organization, standards for methodology to be used in carrying out the operational mission of the organization. Examples in the Federal sector are the technique manuals of the Geological Survey and the chemical and biologic laboratory manuals of the U.S. Environmental Protection Agency.

In 1970, the Office of Water Data Coordination of the U.S. Geological Survey impaneled a Federal Interagency Work Group for Designation of Standards for Water Data Acquisition. The tasks of the work group encompassed six areas: (1) Surface water including storage, stage, streamflow, and gage data; (2) chemical and physical quality including inorganic constituents, dissolved gases, temperature, conductance, pH, radiochemical analyses, and nutrients; (3) biologic quality and organic substances including coliforms, microorganisms, pesticides, detergents, and carbon; (4) sediment including concentration, size, and load; (5) ground water including storage, water level, discharge, lithology, and aquifer characteristics; and (6) automatic water-quality monitors (Langford and Doyel, 1974).

More than 70 scientists and engineers representing 17 Federal agencies participated in the activities. Their efforts resulted in the production in December 1972 of a report, "Recommended Methods for Water Data Acquisition." During preparation of the report, all concerned Federal agencies were kept informed of the progress of the effort through representation of the work group, through the Department of the Interior's Interagency Advisory Committee on Water Data, and through the Water Resources Council's Committee on Hydrology. Prior to publication, the report was subjected to rigorous review by the concerned Federal agencies.

It was recognized that the production of the report was only a beginning and that a continuing activity was needed. Therefore, the Interagency Advisory Committee on Water Data has recommended (1) that the activity continue, (2) that the scope be expanded to cover all phases of the hydrological cycle, (3) that the results of the activity be distributed in the form of a handbook, which would be updated continuously, and (4) that a more formal structure for continuing the activity be developed. The activity has been continued with an expanded scope and a more formal structure (fig. 2). Completion of the first handbook was scheduled for 1976 and involved a major effort to keep standards consistent with those already in existence.

Another major effort in standardization of hydrologic instruments and methods is sponsored by the American Society for Testing and Materials (ASTM). In 1973, ASTM's Committee D–19 on Water, in response to a demand for more standards, methods, and recommended practices for flow measurement, initiated new activity in the areas of hydraulic sampling, velocity, and flow measurement. Hence, Committee D–19 is currently "concerned with the study of water, the promotion of knowledge thereof, and the standardization of terminology and of methods for (1) sampling and analysis of water, water-formed deposits, waterborne materials, and wastes; (2) surface water hydraulics and hydrological measurements; and (3) the determination of the performance of materials used to modify water characteristics."[1]

The technical activities of Committee D–19 are carried out by the following subcommittees:

- D–19.01 Biological Monitoring
- D–19.02 General Specification and Technical Resources
- D–19.03 Sampling of Water and Water-Formed Deposits, and Surveillance of Water
- D–19.04 Methods of Radiochemical Analysis
- D–19.05 Inorganic Constituents in Water
- D–19.06 Methods for Analysis for Organic Substances in Water
- D–19.07 Methods for Testing of Water-Formed Deposits and the Properties of Water
- D–19.08 Membranes and Ion Exchange Materials
- D–19.09 Saline Water
- D–19.10 Identification of Waterborne Oils

Of particular interest here is that part of the expanded activity assigned to Section D–19.03.03, Hydraulic Sampling, Velocity and Flow Measurement, and placed under Subcommittee D–19.03. Section D–19.03.03 is further subdivided into seven task groups for the development of the specific standards. The task groups and their as-

[1]From the Introduction, 1975 Annual Book of ASTM Standards, Part 31.

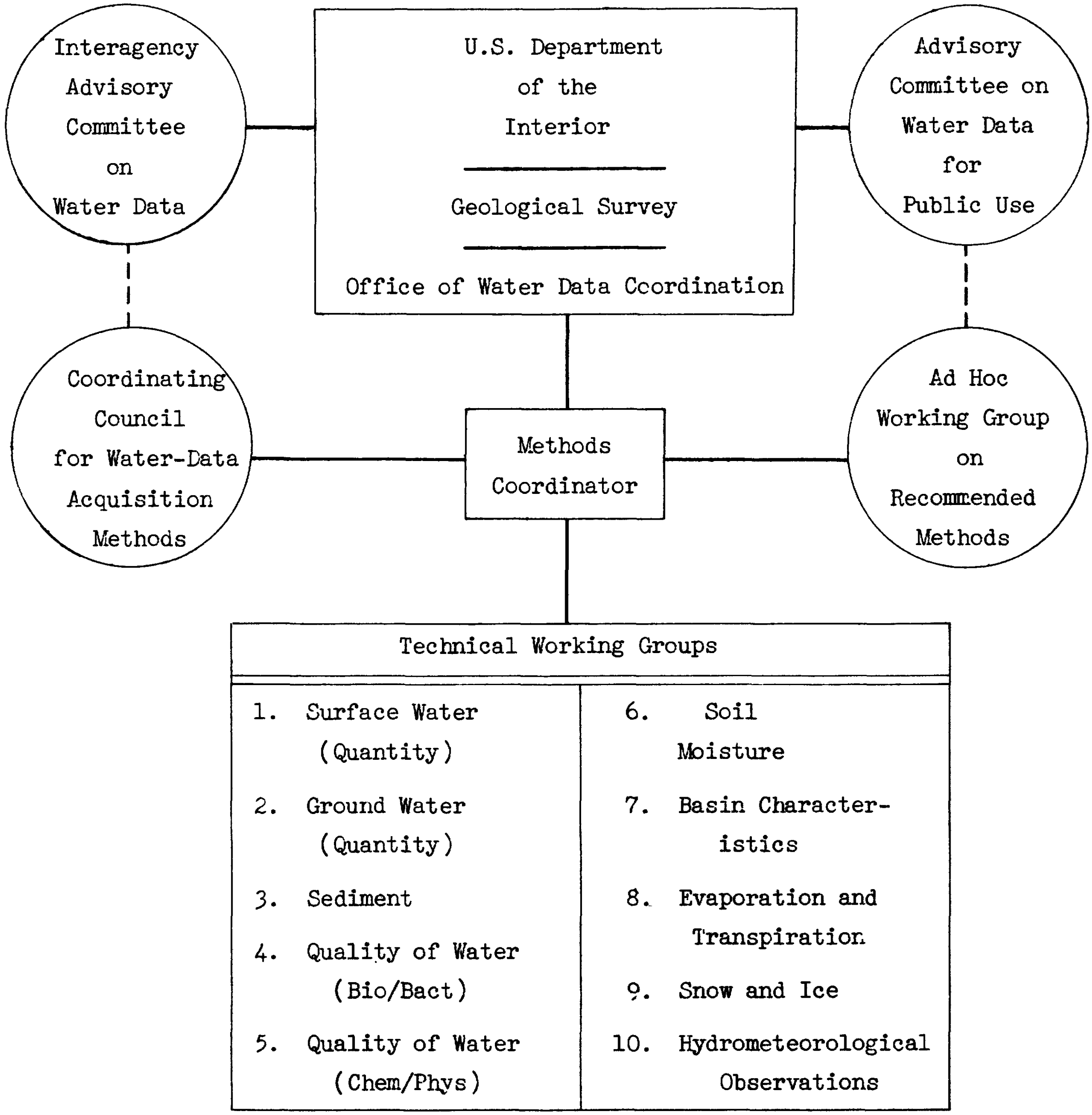

FIGURE 2.—Organizational relationships involved in the recommended methods activity.

signed subject matter are as follows:

Task Group D–19.03.03.01—Hydraulic Sampling and Measurement: Work in this task group will cover standard methods and (or) standard practices for measuring stage, pressure, depth, capacity, volume, and area of water bodies. This work will also include standards for position fixing, direction, and measurement of cross section.

Task Group D–19.03.03.02—Velocity Measurements: Work in this task group will involve standard methods and practices for measuring the velocity of water in open channels and closed conduits. This work will cover the techniques and methodologies for the various types of current meters (cup-type, propeller, deflection, optical, and pendulum), ultrasonic methods, dye, Pitot tubes, differential pressure, surface floats, manometers, and electromagnetic methods of *velocity* measurements.

Task Group D–19.03.03.03—Velocity-Area Flow Measurements: Work in this task group will cover standard methods and standard practices for measurement of flow in open channels using velocity-area techniques. Methods used for assessing velocity distribution, subsectioning the stream cross section, mean velocity measurement in subsections, and determination of total flow (discharge) will be covered. Methods for accommodating oblique flow, pulsating flow, velocity deflection, unsteady flow, and depth effects will be tested. Assessment of mean velocity distribution by various methods such as one-point, two-point, surface one-point, alternative one-point, and integration methods and the measurement procedures will be documented. The principles, methods, and techniques for indirect determination of flow (slope area, etc.) for flow measurement in tidal or backwater reaches and for flow measurement using new techniques or special devices (moving-boat technique, for instance) are possible considerations.

Task Group D–19.03.03.04—Weirs, Flumes, and Notches: This task group will consider standard methods and standard practices for measurement of flow in open channels using various types of weirs (triangular or V-notch, rectangular, trapezoidal, broad crested, Cippoleti, and so forth) and various types of flumes (Parshall, Venturi, standing wave, and so forth). Installation, instrumentation, limitations, measurement procedures, calibration, and accuracy will be documented for the information of potential users.

Task Group D–19.03.03.05—Flow Measurement by Dilution-Tracer Methods: Work in this task group will involve standard methods and standard practices of measurement of flow by various dilution-tracer methods such as salt dilution, color dilution, radioisotope tracers, and radioactive-isotope dilution techniques. Methodology will include documentation of types of tracers, site selection, various methods, injection procedures, sampling, measurement of concentration, and computation of discharge (flow). Limitations on use will also be documented.

Task Group D–19.03.03.06—Flow Measurements in Conduits: This task group will be concerned with standard methods or standard practices for flow measurement in conduits through the use of nozzles, Venturi flowmeters, orifice meters, propeller (totalizing) flowmeters, trajectory methods, laminar meters, variable area meters, turbine flowmeters, magnetic flowmeters, positive displacement meters, and ultrasonic flowmeters. The advantages, limitations, general operating procedures, configurations, and calibration will be documented.

Task Group D–19.03.03.07—Definitions (including units of measurement): This task group will be concerned with defining terms and units of measurement used in the standard methods, and standard practices written under Section D–19.03.03 which are not already defined and identified in D–1129–72 or other associated standard method designations.

In 1975, Task Group D–19.03.03.06, Flow Measurements in Conduits, was discontinued and that portion of the activities of Section D–19.03.03 dealing with flow in closed conduits was eliminated. The Section will confine its efforts to flow measurement in open channels. This action was taken by agreement of ASTM and the American Society of Mechanical Engineers (ASME), to avoid duplication of effort because of the existing ASME Standards Committee on Measurement of Fluid Flow in Closed Conduits.

Another standardization activity is that of the National Oceanographic Instrumentation Center (NOIC), which is chartered for the purpose of evaluating, calibrating, and standardizing oceanographic instruments. Although this activity is not directly involved with what is normally considered to be hydrology, many of the instruments used are similar to, and some identical to, those used by hydrologists.

INTERNATIONAL STANDARDIZATION EFFORT

Internationally there is a large ongoing effort in the preparation of standards directly or indirectly related to hydrology. Among the organizations engaged in this effort are the International Organization for Standardization (ISO), World Meteorological Organization (WMO), International Electro-Technical Commission (IEC), International Current Meter Group (ICMG), and International Association of Scientific Hydrology (IASH).

Three technical committees of ISO are working in the general area.

ISO Technical Committee 113, Measurement of Liquid Flow in Open Channels, is composed of the following six work groups:

WG1—Velocity Area Methods
WG2—Notches, Weirs, and Flumes
WG3—Glossary of Terms
WG4—Dilution Methods
WG5—Flow Measuring Instruments and Equipment
WG6—Sediment Flow Measurements

The work of this committee has resulted in the following documents:

ISO Standards

ISO 555—Dilution Methods for Measurement of Steady Flow–Part I, Constant Rate Injection Method; Part II, Integration (Sudden Injection) Method
ISO 748—Velocity-Area Methods
ISO 772—Vocabulary and Symbols
ISO 1070—Slope-Area Method
ISO 1088—Velocity-Area Methods—Collection of Data for Determination of Errors in Measurement
ISO 1100—Establishment and Operation of a Gaging Station and Determination of the Stage-Discharge Relation
ISO 1438—Liquid Flow Measurement in Open Channels using Thin-Plate Weirs and Venturi Flumes
ISO 2537—Cup-Type and Propeller-Type Current Meters
ISO 3454—Sounding and Suspension Equipment

ISO Draft International Standards

DIS 2425—Measurement of Flow in Tidal Channels
DIS 3455—Calibration of Current Meters in Straight Open Tanks
DIS 3716—Requirements and Characteristics of Suspended Sediment Load Samples
DIS 3846—Free Overfall Weirs of Finite Width (Rectangular Broad-Crested Weirs)
DIS 3847—End-Depth Method for Estimation of Flow in Rectangular Channels with a Free Overfall
DIS—Triangular Profile Weirs
DIS—Cableway System
DIS—Water Level Measuring Equipment
DIS—Method of Measurement of Suspended Sediment
DIS—Uncertainty in a Single Measurement of Discharge (Joint document with ISO/TC30)

Standards in Preparation

In addition to the above, there are approximately 20 documents in various stages of completion on measurement of flow in open channels.

ISO Technical Committee 147, Water Quality, is composed of six subcommittees dealing with all aspects of water quality. TC 147 is a relatively new committee and has only recently begun preparation of documents. They do not, as yet, have any published standards.

ISO Technical Committee 30, Measurement of Fluid Flow in Closed Conduits, is a very active committee. Although their work is not directly in the field of hydrology, several areas are very closely related. Their work in measurement of flow by dilution methods, glossary of terms, current meters and their calibration, and several other instruments is similar to that being done by ISO/TC113.

One of the purposes of the WMO, as laid down in the Convention, is to promote the standardization of meteorological observations and to ensure the uniform publication of observations and statistics. With this aim in mind, the World Meteorological Congress has adopted from time to time *Technical Regulations* which lay down the meteorological practices and procedures to be followed by the member countries of the organization. These Technical Regulations are supplemented by a number of *Guides*, which describe in more detail the practices, procedures, and specifications which members are invited to follow or implement in establishing and conducting their arrangements for compliance with the Technical Regulations (World Meteorological Organization, 1970).

WMO is now preparing its 3d edition of the "Guide to Hydrometeorological Practices." For the purposes of the guide, hydrometeorology is defined as: "hydrometeorology is concerned with the study of the atmospheric and land phases of the hydrological cycle, with emphasis on the interrelationships involved." The guide is concerned with the following elements of the hydrological cycle:

1. Precipitation (including dew)
2. Snow cover characteristics
3. Water levels of lakes and streams
4. Streamflow and storage
5. Evaporation and evapotranspiration
6. Soil moisture and groundwater
7. River and lake ice
8. Frost in the ground
9. Water temperature
10. Chemical quality of water
11. Sediment discharge
12. Radiation
13. Air temperature
14. Humidity
15. Wind

Both the IEC/TC4 and Hydraulic Turbines and the ICMG are concerned with current meters and their calibration and carry on some activities in this area. Additionally, the Hydrometry Committee of IASH publishes state-of-the-art reports covering a multitude of hydrometric equipment.

SUMMARY

There is no doubt that standardized methods of hydrologic measurement are needed, for without such methods data collected by different individuals or agencies cannot be compared. The validity of much valuable data which was not only costly and time consuming to acquire but irreplaceable in many instances would be questionable. There is no evidence to support the fear of some that standards retard the development of better methods by inhibiting innovation.

That the most effective standards are those which have been developed through the cooperative efforts of all concerned sectors is indisputable. However, this method is not without its drawbacks. This process is a slow and arduous one and frequently the instrument or method is approaching obsolescence before the standard is completed.

The size of the standardization effort, both on the national scene and on the international scene, appears to be adequate. As a matter of fact, one criticism is that there is a duplication of effort. Many of us frequently find ourselves preparing documents on the same subject for two or more organizations. There very definitely needs to be better liaison and cooperation between the various standards-writing organizations.

USE OF EARTH SATELLITES FOR AUTOMATION OF HYDROLOGIC DATA COLLECTION

By Richard W. Paulson

ABSTRACT

The U.S. Geological Survey is evaluating a recently developed earth-satellite technology that is expected to provide a cost-effective technique for the automatic collection of data from hydrologic stations. These data include water stage, water quality, precipitation, and snow depth. The technology, which is referred to as satellite Data Collection Systems (DCS), provides an opportunity to collect data from inexpensive battery-operated radios located at literally tens of thousands of hydrologic stations distributed over national or continental areas. The U.S. Geological Survey is evaluating the Data Collection Systems on three series of earth satellites to forecast the costs and benefits of using earth-satellite technology for a national operational system for the automatic collection of hydrologic data.

INTRODUCTION

During the last decade, worldwide communications using earth-orbiting satellites have become a cost-effective reality. Almost a hundred countries presently are members of the International Telecommunications Satellite Organization (INTELSAT), which provides telecommunications via satellite between many national capitals and major cities in the world. During the last several years a new application for satellite communication has been experimentally demonstrated. Using inexpensive battery-operated radios as the communication link to the satellite, environmental data have been collected in realtime via satellite from remotely located environmental sensors. Experiments have been performed to collect geologic data on seismic activity and land surface tilt and hydrologic data on water stage, water quality, precipitation, and snow depth. There is great potential for using this technology to automate the collection of hydrologic data.

The U.S. Geological Survey operates a network of hydrologic sensors that automatically record the data on site. These data routinely are manually retrieved at intervals of 4 to 6 weeks, are manually preprocessed, and are entered into the Geological Survey's national telecomputing network. This network, which includes a computer center at the Survey's National Center in Reston, Va., and computer terminals across the United States, is used to perform most of the Survey's basic hydrologic data processing and hydrologic analysis. Thus the Geological Survey operates a system of automatic hydrologic data recording stations, and a system of automatic data processing, but the two systems are linked by an operational procedure that requires a great deal of manual labor, which is becoming increasingly expensive. The satellite technology discussed herein offers an opportunity to link the two systems into a realtime system for automatic collection and processing of hydrologic data. Moreover, the total system would provide an opportunity for hydrologic organizations to have realtime hydrologic data available for forecasting and management.

This paper discusses recent experimental integrations of satellite Data Collection Systems (DCS) with the Geological Survey's networks of hydrologic sensors and computers, and discusses the potential for automatic data collection and processing.

SATELLITE DATA COLLECTION SYSTEMS

A satellite Data Collection System is a telemetry system that uses an earth-orbiting satellite to relay data from a very large number of widely distributed transmitting stations to one or a few receiving stations. There are three basic elements of any DCS, as shown in figure 3. The first is a field radio, usually called a Data Collection Platform (DCP), which could be connected to a hydrologic sensing device such as a precipitation or water-stage recorder. The second element is a radio transponder (receiver and transmitter) on an earth-orbiting satellite that can receive data from a large number of DCP's. The third element is the earth receiving station where data are retrieved from the satellites and disseminated to

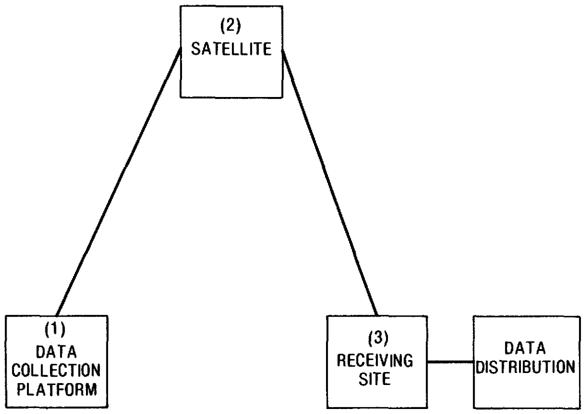

FIGURE 3.—Basic elements of a Satellite Data Collection System: (1) Remote site sensor and Data Collection Platform, (2) satellite transponder, and (3) data receiving sites and distribution system.

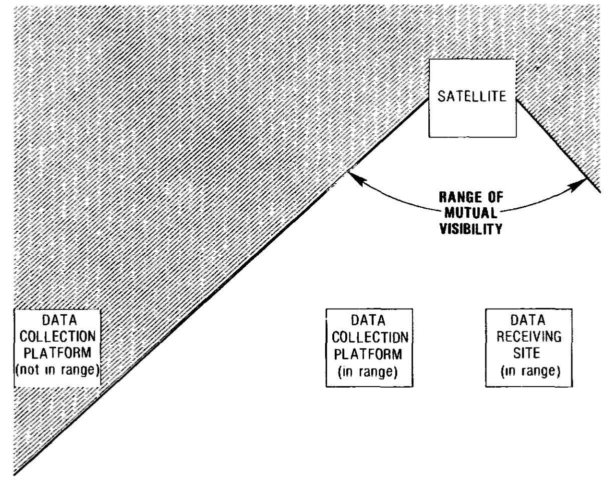

FIGURE 4.—Satellite communications occur only when a data collection platform and data receiving site are mutually visible from the satellite.

users. A satellite DCS can be configured in numerous ways which affect the cost, versatility, and ease of operation of the total system. Two major U.S. Government satellite DCS's are presently available for use in North America, and a third commercial-type system will be demonstrated in 1978. The existing U.S. Government systems are aboard the LANDSAT satellite series and the Synchronous Meteorological Satellite/ Geostationary Operational Environmental Satellite (SMS/GOES) series. The commercial-type system, to be demonstrated in 1977, is being designed by the COMSAT General Corporation. The following descriptions of the functional characteristics of these systems demonstrate three of many alternative systems designs that are possible.

LANDSAT DCS

The first of the U.S. Government's LANDSAT satellite series, formerly known as the Earth Resources Technology Satellite (ERTS) series, was launched in July 1972. The experimental LANDSAT-1 DCS provided the first large-scale field introduction of this technology to agencies responsible for environmental monitoring.

Many LANDSAT-DCS characteristics are controlled by the satellite's orbit. The satellite is in a near-polar orbit and, at an altitude of approximately 890 km (kilometers), makes one complete orbit of the earth every 103 min (minutes). The orbit periodically carries the satellite from the North Polar region down over the daylight side of the earth, crossing the equator at an angle of 99°, to the South Polar region, then up over the dark side of the earth to the vicinity of the North Pole. The relationship of the satellite's orbital plane to the centers of the sun and the earth remains constant while the earth rotates beneath the satellite. When the next orbital transit is made, the earth will have rotated on its axis about 25° under the satellite's orbital plane, and the path of the satellite is displaced to the west (of the previous orbit), crossing the equator about 2,900 km to the west of the previous orbit. At higher latitudes the distance between orbital transits is smaller.

The LANDSAT DCP is a small battery-operated radio that is designed to transmit 64 bits of earth-resources data plus station identification. This transmission lasts 38 ms (milliseconds) and is emitted from the DCP antenna once every approximately 180 s (seconds).

The antenna emits the radio transmission to a 140° cone above the antenna plane. At any instant the satellite is capable of receiving data from LANDSAT DCP's that are within radio range, which is approximately 2,000 km from the point on the earth's surface below the satellite. If both a DCP and a receiving station are within radio range of the satellite, and the DCP transmits a message, it is instantaneously relayed to the receiving station as shown in figure 4. DCS experiments in North America have shown that the typical DCP transmits data during two and occasionally three orbits to the receiving stations in Maryland and California during the daylight transits of the satellite. Two or three orbits also are used to relay data during the night transits of the satellite.

The modest power requirements of the DCP permit it to be powered by solar panels, or a series of low-cost disposable dry-cell batteries. Four 6-v (volt) dry-cell batteries have been used to power a DCP for periods of as much as 6 months. The average power drain is approximately 50 mW (milliwatts).

The LANDSAT DCS is a random-access system with one radio frequency channel. This means the times of a DCP's transmissions are completely independent of the times of transmissions of other DCP's and mutual interference from two or more DCP's is expected to occur at a random but predictable rate. In the event of mutual interference of the transmissions, no data are relayed by the system. Stochastic models are available to predict the probability of successfully relaying data through a random-access system. For the LANDSAT DCS there is a 95 percent probability that one transmission per DCP will be successfully relayed every 12 h (hours) for a network of 1,000 DCP's. The probability of successfully relaying a transmission through a random-access system is affected by the number of DCP's in the system, the radio frequency bandwidth, the data coding convention, the orbital characteristics of the satellite, and other system characteristics. The communications parameters, and the stochastic models required to predict the performance of this type of system, are well known to the communications engineering community.

In summary, a brief data transmission, known as a data burst, is emitted once every 180 s continually around the clock, regardless of whether the satellite is within radio range. During several orbits each day the satellite passes within range of the DCP, receives one or more data bursts, and relays the data immediately to a receiving station, if it is in range. For most locations in North America the satellite is within range of that location and a receiving station only about 2 to 3 percent of the 24-h day.

It is significant that technicians can easily install and operate the DCP's with a minimum of training. The random-access LANDSAT DCS permits the field technician to turn on the DCP after installation, with no requirement for knowing the time of satellite transit nor the precise time of transmissions of any other DCP's in the network

SYNCHRONOUS METEOROLOGICAL SATELLITE/GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITE (SMS/GOES)

The first satellite of the U.S. Government's SMS/GOES–DCS series was launched in May 1974. It was the first of a multisatellite system that is programmed for operation in the last half of the 1970's. In contrast to the experimental random-access LANDSAT DCS, the SMS/GOES–DCS is operational and uses 150 radio frequency channels for communication as opposed to the single channel employed by LANDSAT. The SMS/GOES–DCS operates in a time-ordered or interrogate mode.

In a time-ordered mode of operation, to which 50 SMS/GOES channels are dedicated, a DCP is assigned a frequency channel and time interval for transmission. A precision timer in the DCP is set to initiate a transmission during a predetermined time interval, for example, during a 2-min period once every 6 h on a particular channel. If the system is well managed, no other DCP will transmit during that time on that channel, and communications can be established. The communications rate of the SMS/GOES–DCP is much slower than the LANDSAT DCP, and the nominal transmission period for a self-timed DCP is in the range of 10 to 20 s. The DCP precision timer, which generally is designed to be accurate to 1 part in 10^6, is designed to permit a drift of no more than approximately 30 s per year in the time of message initiation. Thus, if self-timed DCP's are assigned 2-min reporting intervals and broadcast in the central point of their time interval, they should continue to operate with no mutual interference for at least 1 year. The SMS/GOES–DCS capacity of 50 self-timed channels, with DCP's reporting every 3 h with a 2-min reporting interval, totals 4,500 DCP's per satellite.

In the interrogate mode of operation, to which 100 channels are dedicated, a DCP is interrogated through the satellite from the data receiving station. Under command from the receiving station, the satellite initiates a request for a DCP with the specified ID (identification number) to reply on a preprogrammed channel. Upon recognizing its ID the DCP transmits its data. Under this mode of operation, the receiving station maintains control of the DCP's, causing them to adhere to the receiving station's schedule. In times of emergency, or if communications have failed for some reason, the receiving station can reschedule interrogation and attempt to initiate communications under a new schedule.

The SMS/GOES–DCS can initiate interrogation commands at a rate of two interrogations per second per satellite. At that rate 21,600 interrogations can be initiated in a 2-h period. That would permit up to 216 replies per channel per 3-h period, if each reply averaged 50 s per transmission. Although the actual system for managing 150 channels of the SMS/GOES–DCS is presently evolving, it is obvious that the system is capable of handling a large number of DCP's.

COMMERCIAL SATELLITE DCS

The COMSAT General Corporation will conduct a demonstration of a satellite DCS service for the U.S. Geological Survey in 1977 using, for this demonstration, an existing Telesat of Canada ANIK geostationary communication satellite. The commercial-type demonstration system will use a small part of one transponder on a commercial communication satellite, which normally has 12 communications transponders, each of which could carry data from several hundred thousand DCP's. The other transponder will continue to carry high volume commercial telecommunication traffic from and to major population centers. The demonstration is intended to show that the use of existing commercial satellites operating at the 4,000 and 6,000 MHz (megahertz) bands is technically viable, and that it is possible to share the use of the satellite on a noninterference basis with other commercial users. The economic viability of any satellite system depends heavily upon maximizing multiple usage of the expensive space segment to minimize unit utilization cost of the satellite for all users.

The characteristics of the commercial-type DCS system include some of the best characteristics of the LANDSAT and SMS/GOES systems. All of the DCP's in the commercial-type system will be operated in the random-access self-timed mode analogous to the LANDSAT system; however, use is made of a geostationary satellite, which means mutual visibility for a large geographic area is maintained. The DCP's are programmed to transmit as frequently as every 15 min, although some will operate at transmit intervals of 30 to 60 min. The DCP's will transmit at a frequency between 5,925 and 6,425 MHz, and the duration of message transmission will be about 150 ms. Each DCP message will transmit up to 64 bits of sensor data although the expansion to a larger data message is possible. In the demonstration, which will include the field testing of only about 15 DCP's in Virginia, Oregon, and Pennsylvania, the probability of mutual interference is small, and each DCP will transmit its message once at its assigned time. In an operational system each message would be transmitted two or more times to decrease the probability of unsuccessful relay of the data because of mutual interference. The DCP capacity of one transponder on a communications satellite is forecast by COMSAT General to be greater than 300,000 depending on the temporal reporting schedule of the DCP's.

Finally, in an operational commercial system the users could lease the DCS service from the commercial vendor, who would be responsible for procuring, installing, maintaining, and repairing all communications equipment, including the DCP. This can free the user groups from maintaining duplicate staffs of communication professionals required to perform these tasks, as they presently do with the government system.

COMPARISON OF LANDSAT DCS, SMS/GOES–DCS AND COMMERCIAL DCS

A comparison of the three systems shows the merits of several DCS design alternatives. The interrogate mode of operation provides great system control and flexibility, but increases the cost and complexity of the DCP because an interrogate DCP includes a receiver, which must be powered at all times. The capital expense and power requirements can be significant considerations for large numbers of remote site installations. The self-timed DCP operating in a time-ordered mode requires an expensive precision timer. Moreover, great care must be exercised in initiating the timer when the DCP is installed and maintained. A self-timed DCP, when operating in the random-access mode, does not require a receiver or a precision timer. To the contrary, the random-access mode is best served by an inexpensive inaccurate timer to insure temporal randomness in the transmissions of the DCP. An additional bonus to the random-access DCP is that no care is required in initiating the DCP.

A further comparison of the three satellite systems shows the tradeoffs that occur with the orbital characteristics of the satellite. A geostationary satellite has one obvious advantage over a single, or series of, polar orbiting satellites, the former is always in view of a specified geographic area. The alternative merits of a low-altitude orbiting satellite are that its launch cost is significantly less, and that it does have potential for global coverage. A LANDSAT-type satellite passes within DCS radio range of all inhabited parts of the earth at least twice daily, while the geostationary satellite is fixed relative to one geographical area.

It is possible for data to be retrieved from the satellites at numerous earth receiving stations, each serving a particular regional operational or research purpose. Although one receiving station must manage the schedule of interrogation for interrogate DCP's, data from all three types of systems (interrogate, time-ordered, and random-access) can be received by passive earth receiving stations. Each receiving site could acquire all DCP transmissions, but would further process only data from DCP's in the region for which the receive site is responsible. The tracking of a geostationary satellite by a receiving station is significantly easier than the tracking of a polar-orbiting satellite, since a fixed antenna can be used.

The LANDSAT and SMS/GOES series are multipurpose government satellites. Other data systems on the LANDSAT satellites are imaging systems that produce multispectral scenes of most areas of the earth's surface. The imaging systems provide data on scenes that are 185 by 185 km in area, and can provide the data on any land mass of the earth's surface between 81° north and south latitude, on an 18-day repeat cycle. Image data are being gathered from both operating LANDSAT satellites. The primary data system of the SMS/GOES satellite is an imaging system that gathers visible and thermal infrared data on the cloud cover on the surface of the earth that is visible to the satellite. The imagery can be collected as frequently as every 15 min.

The DCS's in the LANDSAT and SMS/GOES series are part of multiuse satellite missions. As a result, many of the satellites' characteristics are optimized for operating the imaging systems as well as the DCS systems. Feasibility studies have shown that purely DCS satellites do not require many of the stringent altitude and orbital control features that are required for satellites that collect imagery.

The commercial communication satellite that is used for the DCS application is also a multiuse satellite, in the sense that other transponders on the satellite are used for high-volume point-to-point telecommunications. One disadvantage to the high-frequency channel used on the commercial satellite is that the path from the DCP antenna to the satellite must be reasonably free of any obstruction, which is less the case for the LANDSAT and SMS/GOES systems. Moreover, great care must be exercised in positioning the azimuth and elevation angles of the antenna, which is not the case with other systems. The LANDSAT DCP omnidirectional antenna must be positioned generally in the horizontal orientation while the SMS/GOES DCP antenna must be pointed within 10° to 15° of the satellite position. The commercial DCP antenna must be pointed to within approximately 0.5° of the satellite's position. However, this is only an initial setup requirement and should pose no operational difficulty.

Table 1 is a summary of most of the important functional characteristics of the three systems discussed above.

STATUS OF LANDSAT, SMS/GOES, AND COMMERCIAL SATELLITES

Two LANDSAT satellites presently are in orbit. LANDSAT–1, which was launched in July 1972, is no longer transmitting DCS data. The fully redundant DCS, after successfully operating for 2½ years, has been turned off and is an in-orbit spare. LANDSAT–2 was launched in January 1975 and is providing effective DCS communications.

Three SMS/GOES satellites are presently in orbit. SMS–1 was launched in May 1974. After a brief period of operation, the interrogate mode of DCS communications failed. Although the satellite's communication equipment was designed to be fully redundant, the total interrogate system failed. The self-timed system has worked well, but, because of other failures in the satellite, the prospect of long-term continued operation is in doubt. SMS–2 was launched in January 1975 and all systems of the satellite are performing well. GOES–1 was launched in the fall of 1975, and also is functioning well.

A third LANDSAT satellite is programed for launch in 1977 or 1978. Fourth and fifth SMS/

TABLE 1.—*Comparison of functional characteristics of DCS systems under evaluation by the U.S. Geological Survey*

Name	LANDSAT	SMS/GOES	COMSAT General
Type	U.S. Government experimental	U.S. Government operational	Commercial lease service demonstration
Satellite orbit	Near polar	Geostationary	Geostationary
Satellite altitude	900 km	38,000 km	38,000 km
In-orbit redundancy	Multiple satellites	Multiple satellites	Multiple transponders on multiple satellites
DCP capacity per satellite	1,000	20,000	300,000
DCP type	Random access	Interrogate or self-timed	Random access
DCP reporting	Once per 12 hours	On demand (interrogate) per 3–6 hours (self-timed)	Once per 15 minutes
DCP sensor input[1]	Parallel digital, serial digital, analog	Parallel digital, serial digital, analog	Parallel digital, analog
DCP radio frequency	401.55 MHz	401.7 to 402 MHz	5,925 to 6,425 MHz
Antenna type	Ominidirectional	Directional, 15° pointing accuracy required	Directional, 0.5° pointing accuracy required

[1]Depends on DCP manufacturer.

GOES satellites are being constructed. The operational plan for the SMS/GOES satellite series includes two operational satellites at 75° to 135° west longitude, and an in-orbit spare, which will be activated upon failure of one of the operational satellites.

There is a growing population of domestic communications satellites that can be used for a commercial communications service.

From the end of 1974, when 24 transponders were in orbit on U.S. domestic commercial satellites, to the end of 1977, when 148 transponders are forecast to be available, the capacity will grow by a factor of six. If the use of the commercial satellite is successful, the technology can be used on any domestic satellite operating in the 6,000 MHz uplink frequency.

HYDROLOGIC DATA PROCESSING

The Data Collection Systems described above may provide a potentially cost-effective and timely technique for retrieving hydrologic data from thousands of stations and providing them to a central data processing facility. The data being collected experimentally with these systems are being processed at the Geological Survey's central computer facility at the National Center in Reston, Va.

The Geological Survey's national telecomputing network consists of two 370/155 computers in Reston and a network of over 180 remote computer terminals across the United States. The terminals are located in district, regional, and project offices of the Survey. A modest but increasing number of these terminals are being acquired by other agencies to enable them to directly acquire hydrologic data from the Survey's WATSTORE (National Water Data Storage and Retrieval) system. The WATSTORE system is a collection of computer programs and files that are used by the Survey to process virtually all the water-resources data that the Survey collects. One of the tasks being undertaken in the Survey's testing of the satellite DCS's is the experimental use of the WATSTORE system for processing and filing the satellite-relayed data.

All DCS data relayed through the LANDSAT system are routinely sent in realtime to the LANDSAT Operation Control Center in the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center in Greenbelt, Md. Under a NASA–U.S. Geological Survey agreement these data also are sent in realtime via a dedicated line to Reston where they are recorded on a 9-track magnetic tape recorder. Periodically these data are transferred to an online disk file in the Reston computer center, where programs are available to retrieve, process, and disseminate the data over the remote terminal network.

All DCS data relayed through the SMS/GOES system are routinely received by a National Oceanic and Atmospheric Administration/

National Environmental Satellite Service (NOAA/NESS) tracking station at Wallops Island, Va., and sent in realtime to the NOAA World Weather Building in Suitland, Md. These data are filed in a NOAA/NESS minicomputer. Under a NESS–Geological Survey agreement this minicomputer, one or more times a day, will sign on to the Reston computer and will enter a computer job containing all of the Survey's DCS data that have been accumulated since the last time of data entry. These data then are processed and placed in an online file in the computer for retrieval.

The DCS data to be relayed through the commercial COMSAT General system will be accumulated at the COMSAT General earth station in Southbury, Conn. At regular intervals, the DCS data will be automatically transferred from a COMSAT General computer to the Reston computer, where they will be filed on an online disk file. In addition, the two Geological Survey district offices in Harrisburg, Pa., and Portland, Ore., using their Reston computer-compatible terminals, may connect to the COMSAT computer to directly retrieve unprocessed realtime data.

All the satellite-relayed hydrologic data are being made available on online disk files at the Reston computer. The data from the files can be retrieved using remote terminal-entered jobs that cause the retrieved data to be processed using programs and files of the existing WATSTORE system. Integrating the DCS data with the WATSTORE system provides the user with a powerful set of existing programs, and also provides the data to remote terminal users in a familiar format.

CONCLUSION

The Geological Survey operates a network of hydrologic stations across the United States that include thousands of continuously operating hydrologic sensors. These data on water quantity and quality are operationally retrieved using a manual technique based upon frequent visits to the stations by hydrologic technicians and engineers. Using a system of computer terminals the data are routinely entered into the Reston computer where they are processed and filed using the WATSTORE system. Satellite Data Collection Systems offer a potentially cost-effective system for making the field instrument data available to its WATSTORE system in realtime.

The automatic collection of data in realtime offers two benefits to the Geological Survey and to the water-resources management community. The first benefit is that the realtime-processed hydrologic data can be used by the Survey to monitor the performance of its hydrologic instrument network. Instead of routinely visiting the stations on a fixed-time schedule, it may be possible to visit the stations only when instruments fail or hydrologic conditions warrant the collection of supplementary data; that is, when water quality or discharge are outside the normal range. The second benefit is that the Survey can offer a realtime data service to the water-resources managment community. Growing pressure of municipal and industrial use, and concern for environmental protection, are generating a need for realtime data for more effective water-resources management.

Satellite DCS's offer the opportunity to automatically collect hydrologic data. It is likely that the increasing cost of manpower, the decreasing cost of electronics, and the cost-effectiveness of satellite telemetry will result in eventual automation of the collection of hydrologic data.

OPERATIONAL HYDROMETEOROLOGICAL DATA COLLECTION SYSTEM FOR THE COLUMBIA RIVER

By Nicholas A. Kallio

ABSTRACT

The Columbia River is a valuable source of energy and water supply to the Northwest region of the United States and the Southwest region of Canada. Operation of its complex water-management system requires reliable and timely information on the amount of water received by, flowing through, and stored in all parts of the basin. To provide this information, an interagency hydrometeorological date collection system is being developed, utilizing latest telemetry and processing devices. The experience gained in developing this system may be helpful to planners of other similar systems. Pertinent considerations are: (1) A telemetry system should be chosen with care so as to avoid early obsolescence and costly maintenance. Satellite and meteor-burst systems seem to have greatest potential. (2) Data verification is very important in a realtime system. (3) The cost of operating a realtime system is dependent on data-accuracy requirements, but generally will be more than operation for collection of historical records.

INTRODUCTION

The Columbia River Operational Hydromet Management System (CROHMS) is a comprehensive hydrometeorological data collection-and-data-management system designed and operated cooperatively by several governmental agencies in the Pacific Northwest region of the United States. This system, when fully implemented, will automatically provide realtime data on streamflow, storage, weather, and snow accumulation as needed for forecasting and management of waters in the Columbia River basin.

The Columbia River basin covers 102,300 km^2 in British Columbia and 565,900 km^2 in the United States, encompassing all of Idaho, most of Oregon and Washington, and parts of Montana, Wyoming, and Nevada. The river drains mostly rugged mountain areas where altitudes range to higher than 4,000 m (meters) and precipitation ranges from 150 to more than 4,000 mm (millimeters) per year. The precipitation varies seasonally and orographically and in the higher elevations occurs mostly as snow during the wet winter months. Accumulation of water as snow during the wet season serves as natural storage and carryover to the dry summer months, but presents a serious flood hazard when the accumulation is heavy and weather conditions produce a fast rate of melt.

The objective of water managers, of course, is to capture as much water as possible in available impoundments during the wet season, yet allow storage space to control floods. This presents a challenging task in snow-storage areas where the major part of the runoff occurs over a short period in the spring. Effective water control requires judicious forecasting of the amount and potential rate of snowmelt runoff and delicate coordination of reservoir operation by several organizations.

The water-control system of the Columbia River basin includes nearly 80 major reservoir projects, integrated hydraulically or electrically for joint operation by public and private organizations in the United States and Canada. The system is designed for multipurpose benefits; primarily electric power, flood control, irrigation, recreation, and navigation. Of the major projects, 29 are U.S. Army Corps of Engineers multipurpose reservoirs, 20 are U.S. Bureau of Reclamation multipurpose reservoirs, 23 are non-Federal multipurpose or hydroelectric reservoirs, and 5 are Canadian multipurpose or hydroelectric reservoirs. The basin is nearly fully developed for water regulation, and the 20.9 million kW (kilowatts) of installed hydroelectric capacity (27.8 million in the next few years) represents the most highly developed hydropower resource of any major river basin in the world. Reportedly, annual benefits attributable to this development average in excess of $100 million from prevention of flood damage and $600 million from irrigated crops (Columbia River Water Management Reports, 1973–75). Revenues from power sales in 1974 exceeded $900 million (Statistical Year Book, 1974, Edison Electric Institute).

Management of water by several organizations with different interests and responsibilities requires utmost cooperation and coordination. Although the reservoirs in the United States are operated by several organizations, the U.S. Army Corps of Engineers has primary responsibility for flood control and navigation, Bonneville Power Administration for power scheduling, and the U.S. Bureau of Reclamation for irrigation. These three agencies carry out their responsibilities in coordination and cooperation with their Canadian counterparts (United States–Canadian Treaty agreements) as well as with various United States public and private water-management organizations.

Operation of this complex water-control system is accomplished with the aid of computerized subsystems for forecasting runoff, optimizing reservoir storage, and scheduling power generation. The success of the whole operation is totally dependent on timely and reliable hydrometeorological data.

PRESENT STATUS OF CROHMS

Although agency missions vary, there is in common the need for hydrometeorological data and runoff forecasting. This mutual need was recognized years ago; hence, the development of data collection, communication, and forecasting systems has been a cooperative achievement among data collection as well as water management agencies. A Columbia River Teletype network, operated by the Corps of Engineers, serves as the main communication link among many agency offices and projects, and a microwave system, installed by Bonneville Power Administration, aids in power scheduling and data communication.

CROHMS provides the data collection and data-handling functions for the agency missions. The system is by no means complete, but the course of its past and future development has been well planned to serve the needs of all participant agencies. Telemetry devices for obtaining timely information from data collection stations have been installed by individual agencies at more than 200 data stations, about 100 of which are designed for automatic polling at hourly, or more frequent, intervals. Choice of telemetry instrumentation is entirely the option of individual agencies, but is being coordinated by an interagency group to ensure compatibility with future CROHMS development. Data are presently processed by individual agencies and then made available to others by way of the Columbia Basin Teletype and other Teletype networks. As explained in the following section, it is planned that CROHMS will include a central facility where all data will be processed and stored for interagency use.

A Columbia River forecasting service is operated cooperatively through resources of National Weather Service, Corps of Engineers, and Bonneville Power Administration. National Weather Service prepares and releases the forecasts for private as well as government use. Soil Conservation Service and other agencies collect snow data for use in snowmelt forecasting by the Columbia River Forecast Service.

The U.S. Geological Survey provides river-gaging facilities, some telemetry services, and current stage-discharge ratings for converting stage data to discharge. These ratings are distributed to all offices that receive current stage data and need to convert them to discharge. In addition, the Geological Survey provides a data-processing service for computing daily discharges and reservoir contents for a large number of current-reporting stations and for releasing those data by weekly, monthly, and annual reports to public and private water-data users.

PLANNED DEVELOPMENT OF CROHMS

The goals in the development of CROHMS are not only to provide necessary water data as needed, but also to (1) prevent unnecessary duplication of work and services, (2) provide maximum utility and uniformity in collection and use of water data, (3) ensure the highest degree of reliability at a minimum cost, and (4) gain the economies of multiple use of existing and proposed facilities consistent with individual agency responsibilities. Eight agencies (U.S. Corps of Engineers, Bonneville Power Administration, U.S. Geological Survey, U.S. Bureau of Reclamation, National Weather Service, U.S. Forest Service, Environmental Protection Agency, and the Washington State Department of Natural Resources) signed a Memorandum of Understanding committing their efforts to the achievement of the above goal. Soil Conservation Service and perhaps other Federal and State agencies, although presently not signatories to the Memorandum, plan to intertie with CROHMS for mutual benefit.

The design objectives of CROHMS are:

1. To instrument hydrometeorological data collection stations whereby data will be automatically transmitted to a central station at desired intervals without manual intervention. Nearly 100 data stations are now instrumented for automatic operation, and it is planned that more than 400 additional stations will be automated. Field stations are automated by individual agencies, based on their needs for realtime data.
2. To install a central facility for polling, processing, verifying and storing hydrometeorological data. The Corps of Engineers is in the process of acquiring a computer system dedicated to serve this function. All agencies are invited to participate in the use of the central facility for their data-processing and storage needs. This facility will eliminate the need for each agency to own and operate polling, processing, and storage facilities, and will output processed data through terminals in various formats suitable to individual agency needs.
3. To provide for online and periodic streamflow evaluations and simulations as required for hour-to-hour and day-to-day forecasting, for reservoir regulation, and for power scheduling in accordance with individual agency responsibilities. This will be accomplished either by built-in capability of the central facility, or by intertie with agency computers.

FUTURE OPERATION OF CROHMS

It is the responsibility of individual agencies to install, operate, and maintain field instrumentation. The central facility will be maintained by the Corps of Engineers and operated jointly by the participating agencies as appropriate to their function and expertise. For example, by interactive terminals the Geological Survey will direct the processing and verification of streamflow and storage data, and National Weather Service will perform a similar function for weather data. Various flow simulations will be conducted online or periodically by agencies to serve their individual or joint needs.

GUIDELINES FOR ESTABLISHING A REALTIME SYSTEM

The remaining part of this paper presents the writer's views on pertinent factors involved in planning, designing, implementing, and operating a realtime, hydrometeorological data collection network. These views are based on experience gained in observing the devèlopment of CROHMS, and are limited mostly to collection of realtime streamflow records.

The develoment of a network as an interagency activity, as with CROHMS, is slow and seemingly inefficient because of differences in agency needs, policies, and priorities. However, planning and development must be conducted in a deliberate manner in order to meet the data needs of all agencies, to avoid duplication of services and facilities, and to comply with agency missions and constraints. CROHMS development is directed by an interagency group (Columbia River Water Management Group) and by committees thereof. Although slow and deliberate, development has kept pace with the evolution of telemetry and computer processing techniques. CROHMS has been a pioneering effort, and the development of similar interagency systems in the future may well benefit from CROHMS experience. Following are considerations that may be helpful in implementing similar systems:

PLANNING AND DESIGNING AN AUTOMATED DATA COLLECTION SYSTEM

Determine the optimum size of the system (number of stations, functions, and so forth) based on data and processing needs, and the cost-effectiveness to each participant organization. From the standpoint of conceptual design, it would be desirable to project these needs far into the future, approaching a conception of the ultimate system. From the standpoint of material design, however, it may not be economical to design beyond about ten years because of rapid improvements in the art of data communications and processing.

Experienced leadership during initial planning would be very helpful, and expert help in the design of the system is essential. Leadership in interagency coordination and planning would most appropriately be supplied from within the participant agencies. Commercial assistance in design is available from private firms that specialize in this type of service. If a specialist is hired to perform the material design, his task should be well specified and all information necessary to perform the task should be known and prepared in advance. Individuals from the private sector usually are not familiar with agency data needs and functions, therefore could not be expected to advise on data-acquisition rates, processing requirements, duration of data storage, output formats, etc. This information should be provided as input to the design task.

TELEMETRY INSTRUMENTATION

Telemetry instrumentation for the CROHMS system has been costly and at times, unsatisfactory. The policy of having each participant procure, install, and maintain telemetry equipment of his individual choice results in an assorment of instrument designs and maintenance problems, but it was practically a necessity in CROHMS development because not all participants were prepared to start field automation at the same time, and available instrumentation had not been tried and tested. Some of the first radiotelemetry instruments had to be replaced within a few years, and subsequent acquisistions from other vendors have not fared much better. Some of the instruments, even those that have functioned fairly well, are now difficult to maintain because the vendor is no longer in business or has discontinued the manufacture of replacement parts. Also, the diversity in instrument design makes it costly to keep an adequate stock of replacment parts.

From this experience, it appears that a telemetry system must be chosen with great care, and, if at all possible, the selection should be coordinated within the entire group. All participants might then procure the same types of instruments, thus simplifying maintenance and stocking of spare parts. It would be well to have some assurance that the supplier will stay in the business and continue supplying parts as needed.

CROHMS participants presently are delaying the procurement of additional terrestrial telemetry equipment in view of potential advantages of satellite and meteor-burst telemetry systems. The greatest advantage of these systems is that they do not require terrestrial repeaters to relay telemetry signals from river valleys and canyons. Repeaters are generally costly to maintain because they are often located on exposed sites at high altitudes. Moreover, because of esthetic objections, land-use permits for repeater installations may be difficult to obtain.

Of the satellite systems, the geostationary satellite seems to present the greatest potential at this time for a realtime telemetry system. In addition to the Geostationary Operational Environmental Satellite, which is a government-owned system, there is at least one commercial firm that can provide a telemetry service using a commercial geostationary satellite. A polar-orbiting satellite has been demonstrated to function very reliably, but the frequency at which data can be relayed is limited (from one to several times daily, depending on latitude of stations). The meteor-burst system utilizes meteor trails as repeaters (reflectors) and, therefore, does not require terrestrial nor satellite relay stations. Meteor-burst equipment can be purchased directly or leased as part of a commercial telemetry service.

ACCURACY OF REALTIME STREAMFLOW DATA

The accuracy of realtime streamflow (discharge) data is dependent on (1) the quality of sensing and telemetry equipment, (2) the stability of the stage-discharge relationship (rating) or the frequency at which the rating is checked by discharge measurements, and (3) the effectiveness of error-detection techniques (data verification). Realtime data are information sensed and reported shortly after occurrence and, presumably, are used for decisionmaking shortly after being reported. This allows very little time for verification; to provide reasonable reliability for decisionmaking, it is imperative that at least large errors (20 percent and greater) be detected and flagged. Although large errors in data may not occur very frequently, the fact that they can occur at any time affects confidence in the use of the data for hour-to-hour water management decisions.

A study of 109 gaging stations in the Columbia River basin by the U.S. Geological Survey (Lystrom, 1972), showed that a 20-percent error in daily mean discharges can be expected to occur at a station on the average of 15 days per year, and a 50-percent error on an average of 5 days per year. Change in the stage-discharge relation (shifting control) was the most frequent source of error and can occur at any time, but most seriously during high flow. Errors caused by sensing and recording equipment (not including telemetry) were second most frequent, and backwater from ice was third.

Errors caused by backwater from ice are the most difficult to detect but, fortunately, occur only during a period of the year when accuracy is generally less critical.

Data verification appears essential in any realtime system, and to be performed effectively and expediently, it must be conducted as part of the realtime processing system. Techniques are being developed for CROHMS by which verification of streamflow and storage data will be performed by computer.

In a realtime system, stage-discharge ratings should be corrected as soon as possible after a change is detected by discharge measurement. Measurement computations must be completed in the field; if a significant change in rating is indicated, the measurement results should be reported from the field by telephone or by other expedient means. Ratings prepared for computation of historical records usually reflect past conditions, based on discharge measurements made during the period of record to be computed. Ratings for realtime use, on the other hand, represent a projection of conditions into the future. Any subsequent shift that occurs, if not detected by verification, would not be known until the next discharge measurement is made, and all the realtime data generated since the shift occurred will have been in error. For this reason, and because of limited time for verification, a realtime system cannot be expected to produce discharge data comparable in accuracy to data obtained by a conventional system (historical data) for an equivalent number of discharge measurements. Accuracy can be improved only by checking the rating more frequently by discharge measurements, or by applying effective data-verification techniques.

COST OF REALTIME DATA COLLECTION

Telemetry equipment costs vary considerably, depending mostly on type. Costs are increasing, but following are estimates of present costs of telemetry instrumentation per gaging station:

VHF radio (terrestrial)	$15,000
Meteor burst	20,000
Satellite (GOES)	5,000

Associated with these costs are costs of equipment for repeating, receiving, polling, and so forth, which depend on the size of a network or the number of users. A recent commercial quotation for telemetry service, utilizing the meteor-burst system, is $150 per month per field station, and $1,600 per month for a master station. One master station will accommodate at least 50 field stations at an hourly transmission rate.

The cost of operating a realtime streamflow network will depend on data-accuracy requirements, but will add to the cost of operating a conventional data collection system if both historical and realtime data are collected. In the collection of historical records, the Geological Survey generally visits gaging stations at a frequency ranging from once every four weeks to once every eight weeks. These visits are scheduled primarily to check the stage-discharge rating by discharge measurement and secondarily to check and maintain the equipment. Adding telemetry will make it possible to know when equipment failures occur, but field trips as needed to fix equipment will generally be in addition to scheduled measurement trips. Telemetry, in these cases, is an asset to improving the completeness of the record but at the extra cost of additional field trips. Great savings would be realized through telemetry if the frequency of field trips for both discharge measurements and equipment repair could be limited to an "as needed" basis. This would require data verification that is sensitive enough to detect errors that are near the limit of acceptable data accuracy. The reduction of field effort to an "as-needed" basis may be possible for some stations, depending on the stability of the stage-discharge rating, the sensitivity of data verification, and the limit of acceptable data accuracy.

If the need for accuracy is not the same for all stations, it would seem economical to design and operate the system to accommodate more than one level of data accuracy. In this way, field work for stations with lower accuracy requirements might be limited to measurements and maintenance only as needed. Also, the cost of sensors is generally proportional to their quality and precision; therefore, it might be economical to install a sensor suitable to the desired level of data accuracy. For example, the most precise water-level sensor is the stilling-well and float, but this may be very costly to install at some locations. A pressure transducer is less costly and less precise, but would be adequate for flood-warning stations.

STORAGE AND RETRIEVAL OF WATER-RESOURCES DATA

By Charles R. Showen

ABSTRACT

The U.S. Geological Survey investigates the occurrence, quantity, quality, distribution, and movement of the surface and underground waters that comprise the water resources of the United States. It is the principal Federal water-data agency and, as such, collects and disseminates about 70 percent of the water data currently being used by numerous State, local, private, and other Federal agencies to develop and manage the Nation's water resources. As part of the Geological Survey's program of releasing water data to the public, a large-scale computerized system has been developed for the processing, storage, and retrieval of water data collected through its activities.

The U.S. Geological Survey's National Water Data Storage and Retrieval System (WATSTORE) was established in November 1971 to modernize water-data processing procedures and techniques and to provide for more effective and efficient management of data-releasing activites. The system is operated and maintained on the central computer facilities of the Survey at its National Center in Reston, Va.

INTRODUCTION

The Geological Survey currently (1976) collects data at approximately 10,000 stream-gaging stations, 1,300 lakes and reservoirs, 4,300 surface water-quality stations, 4,100 water-temperature stations, 880 sediment stations, 2,500 water-level observation wells, and 5,800 ground-water-quality wells. Each year, many water-data collection sites are added and others are discontinued; thus, large amounts of diversified data, both current and historical, are amassed by the Survey's data collection activities. A large-scale computerized storage and retrieval system is used by the Geological Survey to store and disseminate water data acquired through its many activities.

The National Water Data Storage and Retrieval System (WATSTORE) was established in November 1971 to provide for more effective and efficient management of the Survey's data-releasing activities. The WATSTORE system provides for the processing, storage, and retrieval of water data pertaining to surface water, quality of water, and ground water. At present, there are 50 Geological Survey remote job-entry sites (fig. 5), located in various offices throughout the country, that are equipped with high-speed computer terminals for remote access to the system.

GENERAL SYSTEM DESCRIPTION

The WATSTORE system consists of several files (fig. 6) in which data are grouped and stored by common characteristics and data collection frequencies. The system is also designed to allow for the inclusion of additional data files if the need should arise in future years. Currently, the following files are maintained: (1) Daily Values File, which is composed of surface-water, quality-of-water, and ground-water data measured on a daily or continuous basis; (2) Peak Flow File, which is composed of annual peak values for streamflow stations; (3) Water-Quality File, which is composed of chemical and biological analyses for surface- and ground-water sites; and (4) Ground-Water Site-Inventory File, which is composed of hydrologic, geologic, and well-inventory data for ground-water sites. In addition, a Station Header File, an index file of sites for which data are stored in the system, is also maintained.

Most of the computer programs used in the system are written in Programming Language/1 (PL/1) for the IBM 360 or 370 series computers[2] and were developed internally to satisfy the data-processing requirements of the Geological Survey. The WATSTORE system is directly accessible by computer terminals which are maintained by the Geological Survey and other Federal and State agencies.

DETAILED SYSTEM DESCRIPTION

The WATSTORE system is designed to use magnetic disk to store current data and magnetic tape to store historical data. This technique is used because of the high cost involved in maintaining online disk files. Approximately 15 per-

[2]The use of trade names does not constitute endorsement by the U.S. Geological Survey.

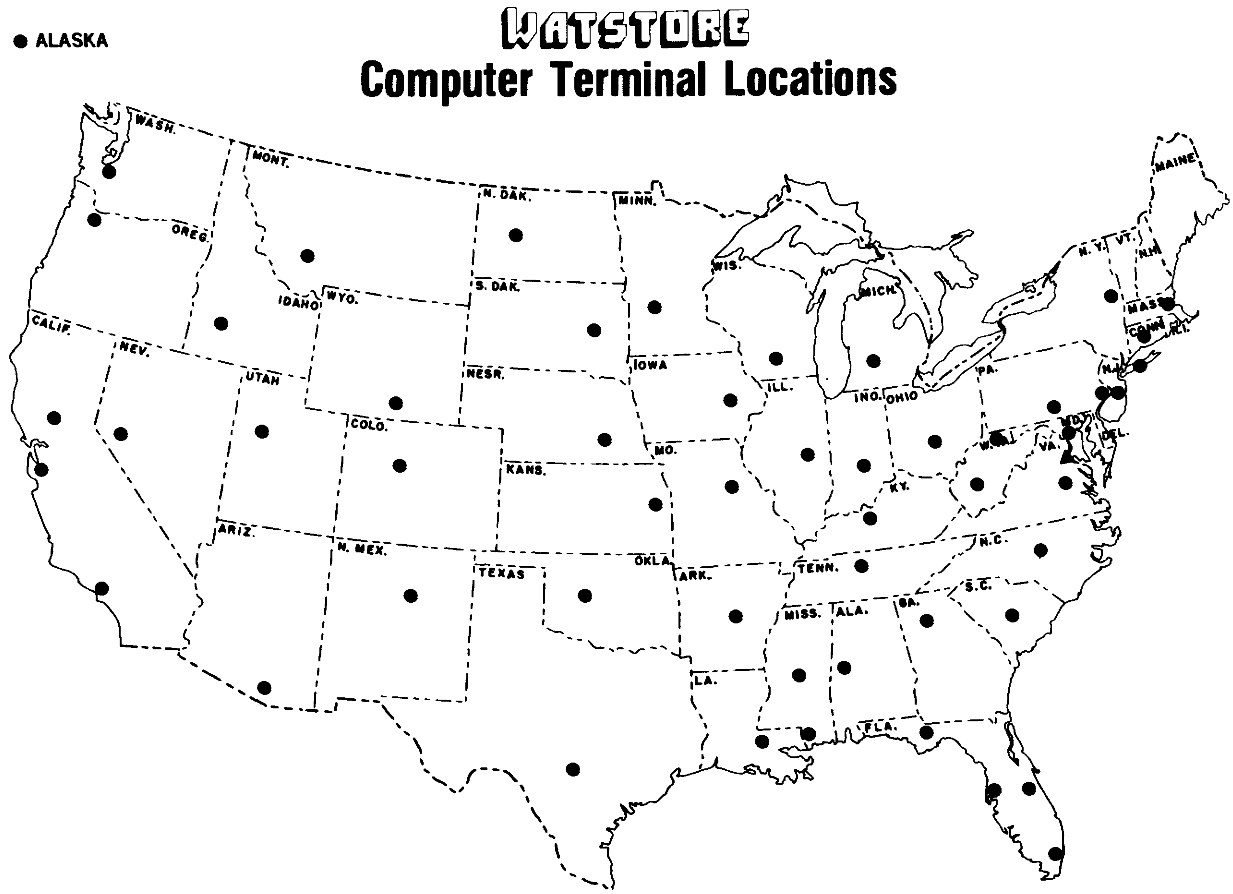

FIGURE 5.—Map indicating location of WATSTORE computer terminals.

cent of the data is stored on magnetic disk and the remainder on magnetic tape. "Current data" is defined as data for the current year and the year immediately preceding. Data failing to meet this criterion are removed periodically from disk and merged with data in the historical file, which is maintained in a sequential manner on magnetic tape by station identification number and date. The retrieval computer programs permit data to be retrieved from the current file, the historical file, or both files.

The Station Header File and the Daily Values File have the option to "password" protect data stored in these files for one or more specified sites. The use of password protection prohibits unauthorized updates and (or) retrieval from the files. These files also provide for the identification of data by an agency code which permits data to be stored for agencies outside the Geological Survey.

A brief description of each of the WATSTORE files is given below:

STATION HEADER FILE

The Station Header File contains information pertinent to the identification, location, and physical description of over 130,000 sites for which data are stored in the WATSTORE files. The file serves as an automated index from which a retrieval list of stations may be obtained without searching massive data files. The information items stored in this file are listed below:

- Agency code
- Station identification number
- Station locator (latitude–longitude)
- State code
- District code
- County code
- Drainage area
- Contributing drainage area
- Site code
- Station name
- Hydrologic unit code

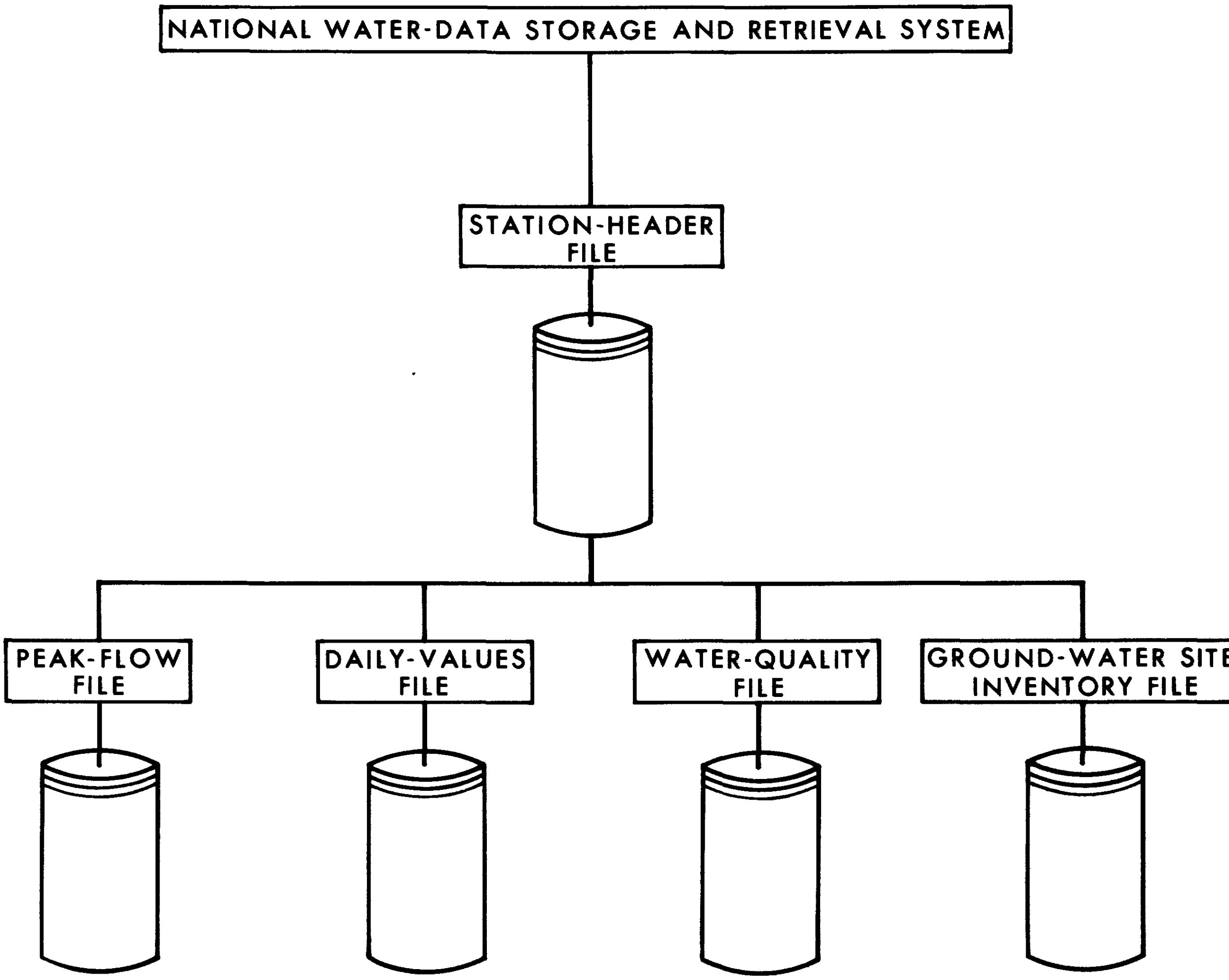

FIGURE 6.—Schematic representation of WATSTORE files.

- Gage or land surface datum
- Geologic unit code
- Well depth
- Aquifer type
- Password

The eight underlined items are mandatory items for each station, and data are not permitted to be stored in the data files without this information. The mandatory fields were so designated because of retrieval purposes, for example, the capability of being able to retrieve all stations in a particular county in a particular State.

A typical example of the use of this file would be to select a group of data satisfying a defined set of criteria, such as to provide a list of stations that have surface-water data in the files and are located in Fairfax County, State of Virginia, that have a drainage area of less than 20 square miles. Computer programs are available that will permit the retrieval stations to be plotted on a line printer using various scales suitable for use as a map overlay, as well as to print selected data only for the retrieval stations. The retrieval stations list also may be used as input to retrieval programs for other WATSTORE files.

DAILY VALUES FILE

The Daily Values File contains water-data parameters measured or observed either on a daily or on a continuous basis and numerically reduced to daily values. Instantaneous measurements at fixed-time intervals, daily mean values, and statistics such as daily maximum and minimum values also may be stored. This file currently contains over 120 million daily values including data for streamflow values, river stages, reservoir contents, water temperatures, specific conductance values, sediment concentrations, sediment discharges, and ground water levels.

The data in this file are identified in the following manner:

- State code
- Agency code
- Station identification number
- Cross section locator (Distance in feet from left bank)
- Sampling depth (Depth at which observation was made)
- Parameter code (Five-digit numeric code to identify the parameter measured)
- Water year (The 12-month period, October 1 through September 30)
- Statistic code (Five-digit numeric code to identify the frequency of measurement or numeric reduction of the data)

Each record in this file contains daily values for a water year (October 1 through September 30). Since most retrievals from the file are made on a State basis, the records in storage are grouped by States to minimize retrieval costs.

Data may be retrieved from the Daily Values File in the following formats: (1) in the form of a computer printout (listing), (2) in punched card form, (3) in a monthly character format on a magnetic device (usable on almost any type computer), and (4) in the standard daily values record format on a magnetic device.

This file also has password protection to protect records against unauthorized updating and (or) retrieval.

A generalized retrieval program retrieves records from this file in machine-readable form and passes the retrieved records to computer application programs. Examples of the application programs are:

- Publication tables
- Data inventory of selected portions of the file
- Preparation of X–Y plots on the Calcomp plotter
- Preparation of monthly and annual statistics
- Preparation of duration tables, low- and high-value sequence summaries, and log-Pearson frequency distributions

WATER-QUALITY FILE

The Water-Quality File contains information pertaining to the chemical, physical, biological, and radiochemical composition of both surface and ground water. The data stored in this file are primarily obtained through the analytical techniques performed by the three central water-quality laboratories operated by the Geological Survey. At present, this file contains the results of over 850,000 analyses of water samples, and the analyses may contain data for more than 570 different constituents.

The data in this file are identified as follows:

- Station identification number
- Collection date
- Time of collection
- Parameter code (Five-digit numeric code to identify the parameter measured)

Data may be retrieved from the Water-Quality File in the form of a computer printout (listing), in punch-card form or as punch-card images on a magnetic device, and in the standard water-quality record format on a magnetic device.

A generalized retrieval program retrieves records from this file in machine-readable form and passes the retrieved records to computer application programs. Examples of the application programs are:

- Publication tables
- Frequency analyses
- Stiff diagrams
- Piper diagrams
- Collins diagrams
- Ropes diagrams
- Irrigation classification
- Ratio tables
- Map plots
- Interface with statistical programs for plotting and contouring on Calcomp plotters

PEAK FLOW FILE

The Peak Flow File contains the annual maximum (peak) streamflow (discharge) and the annual maximum gage height (stage) values obtained at surface-water sites. It currently contains more than 350,000 annual maximum observations.

Data may be retrieved from the file in the form of tables, card images, or records on a magnetic device. The primary application program for this file is a program that computes log-Pearson Type III frequency distribution. This program produces a table of basic statistics, theoretical values, and a frequency distribution plot of both actual and theoretical values.

GROUND-WATER SITE-INVENTORY FILE

The Ground-Water Site-Inventory File contains inventory data about wells, springs, and other sources of ground water. The data included are site location and identification, geohydrologic characteristics, well-construction history, and one-time field measurements such as water temperature.

The Ground-Water Site-Inventory File is managed and maintained through a generalized Data-Base Management System called SYSTEM 2000. This system is marketed by MRI Systems Corp., Austin, Tex. SYSTEM 2000 is oriented to the collection, maintenance, and manipulation of data en masse, and it provides a report-generation capability, a data-base loading facility, a teleprocessing interface, and a query language. The Ground-Water Site-Inventory File is designed to accommodate 209 data elements. At present, the file contains data for 140,000 sites. This file is currently being built and the number of sites is anticipated to increase to 1 million within a year.

Using the retrieval language which is available as a part of SYSTEM 2000, data can be retrieved selectively and listed in a variety of ways. A program to retrieve selected data and prepare publication tables has been written, and programs to interface the file with plotter and statistical routines are under development.

SYSTEM OPERATION

All data files of the WATSTORE system are maintained and managed on the central computer facilities of the Geological Survey at its National Center in Reston, Va. However, data may be entered into or retrieved from WATSTORE through a number of locations that are part of a nationwide telecommunication network.

At present, there are 50 Geological Survey remote job-entry sites, located in various offices throughout the country, that are equipped with high-speed computer terminals for remote access to the WATSTORE system. These terminals provide rapid and efficient access to the system and allow each site to enter data or retrieve data from the system within several minutes to overnight, depending upon the priority placed on the request.

The Geological Survey operates more than 9,000 data collection stations that remotely collect water data on punched-paper tape. To provide for current and timely processing and reporting of these data, a transmission network provides for the local translation of data to a computer-compatible form and transmits the translated data over telephone circuits to the central computer facility. These data are then processed by the central computer via a computer terminal located at the transmission site. The results obtained by this procedure are simultaneously stored in the WATSTORE files and printed at the transmission site.

Data are also entered into the files which are obtained from the LANDSAT and GOES (Geostationary Operational Environmental Satellite) satellite systems. At present data from 150 sites are being collected in this manner.

Three central water-quality laboratories that analyze more than 60,000 water samples per year also contribute data to the system. The laboratories are highly automated and perform chemical analyses that range from determinations of simple inorganic compounds such as chlorides to complex organic compounds such as pesticides. As each analysis is completed, the results are verified by laboratory personnel and then transmitted via a computer terminal and stored in the WATSTORE system.

SYSTEM PRODUCTS

Water data compiled by the Geological Survey are used in many ways by decision makers for the management, development, and monitoring of water resources. Thus, in addition to its data processing, storage, and retrieval capabilities, WATSTORE can provide a variety of useful products to meet diverse needs. These products range from simple retrieval of data in tabular form to complex statistical analyses. A wide variety of retrieval options for the system are available, such as,

- Individual station
- Polygon of latitude–longitude
- State
- County
- Aquifer code (for ground-water sites)

- Dates
- Individual parameters
- Greater than or less than specified parameter values

A typical retrieval request might be for a list of all the dissolved-oxygen values of less than 5.0 mg/l (milligrams per liter) for a particular county in a particular State.

A summary of the products available is as follows:

1. Computer-Printed Tables: Users most often request data from WATSTORE in the form of tables printed by the computer. These tables may contain lists of actual data or condensed indexes that indicate the availability of data stored in the files. A variety of formats is available to display the many types of data.
2. Computer-Printed Graphs: Another capability of WATSTORE is to computer-print graphs for the rapid analysis or display of data. Computer programs are available to produce bar graphs (histograms), line graphs, frequency-distribution curves, X–Y point plots, site-location map plots, and similar items by means of line printers.
3. Statistical Analyses: WATSTORE uses the Geological Survey's collection of computer programs known as STATPAC (Statistical Package) to provide extensive analyses of data such as regression analyses, the analysis of variance, transformations, and correlations.
4. Digital Plotting: WATSTORE also makes use of software systems that prepare data for digital plotting on peripheral, offline Calcomp plotters available at the central computer site. Plots that can be obtained include hydrographs, frequency-distribution curves, X–Y point plots, contour plots, and three-dimensional plots.
5. Data in Machine-Readable Form: Data stored in WATSTORE also can be obtained in machine-readable form for use on other computers or for use as input to user-written computer programs. These data are available in the standard storage formats of the WATSTORE system or in the form of punch cards or punch-card images on magnetic tape.

PUBLICATION OF WATER-RESOURCES DATA

By S. M. Lang and C. B. Ham

ABSTRACT

Water data are the raw materials used by scientists and engineers for determining the availability and accessibility of water resources and for the design, development, and management of major water facilities. The principal responsibility of a hydrologic service is to furnish the scientists and engineers the data they need in a consistent and timely manner. The medium most frequently used for release of water data is the data report. It is the principal product of the major hydrologic services, even in this era of big computers with their massive automated data storage and dissemination capabilities. Data publications meet the requirements of a widespread audience; they also provide archival capability that has not yet been equaled by automation techniques.

Most water-resources data are numeric in character and comprise information about the rate of flow (or discharge) of streams, the volume of water in lakes and reservoirs, the fluctuations of water levels in wells tapping principal aquifers, and the quality of surface and ground waters as determined by analyses of chemical constituents, analyses of biological and biochemical constituents, measurements of temperature (changes), and measurements of sediment loads transported.

These data are used for many purposes by many people with varied backgrounds and interests. Probably the data are used most extensively by engineers and scientists who are responsible for the planning, development, and management of the Nation's resources. However, the data are also needed by public administrators who must apportion resources among contending claimants, by the users of water (utility managers, irrigators, industrial managers), by developers interested in availability of water, by conservationists, by environmentalists, by recreationists, and by those guardians of public safety who must contend with major disasters such as floods and massive pollution.

As the number of data-collection sites has increased, as the variety of types of data collected has expanded, and as the availability of people to do routine calculations and listing of figures has decreased, the need for electronic computers and data banks has arisen. C. R. Showen discusses the development and use of computers in the section on "Storage and Retrieval of Water-Resources Data." Computers, however, have not yet eliminated the need for water-resources data reports in book form. Most users of water-resources data are capable of obtaining needed information from a book by looking in the index and reading the station description and numbers. However, only a limited number of users have access to the specific terminal connected to the appropriate data bank and even fewer users know how to interrogate the computer to learn what data are in storage and how to retrieve the part they need of those data which are available.

It is one of the responsibilities of a hydrologic service to see that reliable water data are available to the investigators of that resource. One of the earliest methods of making data available was the publication of reports and the placing of those reports in conveniently located repositories such as public and university libraries throughout the country. The method is still worthwhile and is still in use.

Publication of reports actually serves another purpose in that the printed copy provides an archival capability that has not yet been matched by computers even though computer data banks are becoming more and more the mainstay of data storage and data dissemination. Accidents in the handling of computer files do happen and many people doubt that computer storage can serve as an archiving tool without multiple duplicate files in geographically separate locations. Moreover, magnetic tapes have not been used long enough to assure that they have a useful life of many years (40 or 50 or more). The need for data publications is as strong today as it was several decades ago, and will continue into the foreseeable future.

In addition to the archival factor, the ability to release large quantities of data to a broad audience and at a relatively low cost is still a principal plus factor for a publication program. A request for a relatively few pieces of data can be handled much more conveniently, quickly, and economically by referral to a publication than to treat the request through our presently available computer equipment. However, a computer and its data bank are much better able to furnish a user large volumes of data covering a long period of years than are the many published books containing the same data. Therefore, the computer and published reports virtually go hand in hand in meeting the total needs of the hydrologic community.

Water resources publications have been major products of the U.S. Geological Survey since before the turn of the century. The streamflow measurements in the Water-Supply Paper series of the Geological Survey constitute an invaluable record of the history and flow of the rivers and streams in the United States. They represent a multibillion dollar investment in equipment and manpower resources that have permitted the Nation to develop and use its resources in a wise and efficient manner. The program as initially constituted was to develop a basic understanding of the quantity, quality, and availability of both surface water and ground water, but it also provided the background data for the principal developments of the resources throughout the Nation. The data reports resulting from the program of data collection of the Geological Survey are used extensively by the engineering community for the background support in the design of facilities to develop the Nation's water resources. In more recent years the emphasis has been on conservation of resources and environmental protection; the availability of data in published form plays a vital role in these areas.

The publication of basic data in reports of the U.S. Geological Survey usually falls into one of two types of presentations. The first type is as supporting evidence in a special analytical or project report. In such a report the data are specifically selected to support the technical findings of the investigation and to permit the reader an insight to the background leading to the decision, recommendation, or conclusion in the technical report. The second type of presentation, and the one with which this paper is concerned, is specifically designed to make available to every user all information collected and processed, without interpretation, recommendation, or conclusion. Examples of such reports are the series entitled "Surface Water Supply of the United States" (1900–1970) "Quality of Surface Waters of the United States" (1941–70) and "Ground Water Levels in the United States" (1940–74). These reports contain tabulations of discharge (streamflow), reservoir storage, chemical and biological analyses, sediment determinations, water temperatures, well levels, and other related information.

By publishing data reports, the U.S. Geological Survey makes available to all interested and concerned parties reliable information on water resources. The information should be as nearly complete as the investigations warrant, and should be presented in such a manner that it can be understood by as many as possible of those people who need to use the information. The report should be made available while the need and desire for it are still fresh. The reports should also be in such form that they will be usable whenever needed as historical records for use in comparing currently collected data with those collected in the past and those which may be collected in the future.

The method of presenting data is to give as much of the information as possible in tabular form using printouts from computer storage as photo-offset copy. See figures 7 and 8. Aside from the obvious advantages of displaying maximum information in minimum space and elimination of much tedious, repetitive typing, this method provides an opportunity for visual check of figures stored in the computer data bank.

Tabulated streamflow data usually are daily mean discharges with monthly and yearly summaries of minimum, mean, and maximum daily values, total volumes, and sometimes unit runoff. Reservoir data are often given as daily contents, usually at a specified time. For some sites, streams, and reservoirs, daily stages only are listed. Ground-water levels are usually given at 5 day or less frequent intervals (fig. 9).

Water-quality data include a wide variety of information, such as water temperature, sediment concentration and loads, conductivity, analyses and concentrations for chemical parameters, and analyses and concentrations for biological parameters.

There is a need for supplemental information to accompany the data in tables. First, the site at which the data are collected should be identified. The simplest and briefest location statement is, of course, latitude and longitude. Besides giving information for plotting the site on a map, the re-

OHIO RIVER MAIN STEM

03216600 Ohio River at Greenup Dam, Ky.

LOCATION.--Lat 38°38'48", long 82°51'38", Greenup County, at left end of Greenup Dam, 1.1 mi (1.8 km) upstream from Grays Branch, 4.7 mi (7.6 km) downstream from Little Sandy River, 5.0 mi (8.0 km) north of Greenup, and at mile 341.0 (548.7 km).

DRAINAGE AREA.--62,000 sq mi (161,000 sq km), approximately.

PERIOD OF RECORD.--October 1968 to current year.

GAGE.--Gate-opening and water-stage recorders. Headwater gage 0.4 mi (0.6 km) upstream at datum 502.51 ft (153.165 m) above mean sea level, datum of 1929 or 503.06 ft (503.06 ft (153.333 m) above mean sea level, Ohio River datum. Tailwater gage 0.4 mi (0.6 km) downstream at datum 30.12 ft (9.181 m) lower.

AVERAGE DISCHARGE.--7 years, 95,100 cfs (2,693 cu m/s), 20.83 in/yr (529 mm/yr).

EXTREMES.--Current year: Maximum daily discharge, 400,000 cfs (11,300 cu m/s) Mar. 16; maximum observed headwater gage height, 19.80 ft (6.035 m) Mar. 16; maximum tailwater gage height, 48.78 ft (14.868 m) Mar. 16; minimum daily discharge, 10,700 cfs (303 cu m/s) Aug. 3.
Period of record: Maximum daily discharge, 540,000 cfs (15,300 cu m/s) Jan. 12, 1974; maximum observed headwater gage height, 26.2 ft (7.99 m) Jan. 13, 1974; maximum tailwater gage height, 55.11 ft (16.798 m) Jan. 13, 1974; minimum daily discharge, 8,100 cfs (229 cu m/s) Sept. 3, 1973.

REMARKS.--Records good. Daily discharge computed from head, gage openings, and lockages. Flow regulated by Ohio River system of locks, dams, and reservoirs upstream from station.

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1974 TO SEPTEMBER 1975

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	27,400	26,600	134,000	177,000	255,000	274,000	305,000	259,000	93,200	50,700	24,200	113,000
2	21,100	30,000	154,000	221,000	292,000	169,000	257,000	235,000	101,000	37,000	14,600	131,000
3	30,300	23,400	149,000	221,000	283,000	161,000	200,000	210,000	125,000	30,600	10,700	95,600
4	31,000	23,300	150,000	203,000	276,000	151,000	180,000	205,000	118,000	16,300	19,600	70,100
5	25,900	32,200	132,000	175,000	211,000	141,000	173,000	220,000	81,800	37,400	12,900	48,900
6	31,400	47,400	108,000	158,000	235,000	126,000	158,000	215,000	100,000	27,400	23,500	46,700
7	19,800	52,500	92,800	137,000	280,000	118,000	133,000	182,000	129,000	27,400	23,600	50,700
8	23,100	50,800	97,300	117,000	265,000	129,000	113,000	147,000	134,000	26,300	29,600	45,600
9	23,400	44,500	163,000	111,000	236,000	159,000	99,200	137,000	120,000	28,900	20,500	33,100
10	23,300	41,000	209,000	113,000	184,000	177,000	95,400	126,000	93,400	40,200	17,300	36,700
11	22,800	39,200	200,000	127,000	147,000	165,000	79,200	121,000	78,400	37,400	18,700	27,000
12	20,100	44,800	167,000	138,000	156,000	204,000	68,800	105,000	80,400	29,400	17,900	42,700
13	21,200	55,200	144,000	134,000	220,000	286,000	76,400	87,300	90,900	24,100	23,000	72,800
14	17,700	55,500	135,000	136,000	219,000	334,000	57,400	83,900	98,400	25,300	31,800	70,100
15	25,000	66,000	128,000	140,000	181,000	393,000	55,200	84,500	101,000	21,500	36,800	54,000
16	24,100	60,800	126,000	125,000	145,000	400,000	58,900	106,000	85,500	31,200	68,600	33,000
17	45,800	62,400	143,000	114,000	126,000	332,000	53,300	109,000	79,700	21,900	97,800	36,600
18	54,300	57,800	159,000	108,000	125,000	277,000	55,000	127,000	85,500	24,400	88,100	42,700
19	54,000	50,000	156,000	141,000	141,000	251,000	46,500	132,000	76,400	26,500	39,100	49,700
20	32,000	54,300	139,000	195,000	163,000	260,000	63,400	119,000	68,600	24,100	30,500	69,100
21	33,800	85,900	122,000	219,000	159,000	338,000	67,200	117,000	54,600	25,100	19,900	78,100
22	25,400	107,000	111,000	201,000	144,000	365,000	67,300	79,700	55,100	27,700	25,100	69,600
23	26,900	109,000	104,000	154,000	148,000	355,000	61,400	84,900	46,200	22,900	20,300	67,300
24	34,000	106,000	93,900	130,000	211,000	304,000	81,700	103,000	38,700	17,600	18,100	132,000
25	29,400	103,000	97,600	131,000	282,000	310,000	246,000	116,000	34,600	38,400	23,500	225,000
26	30,800	102,000	140,000	186,000	317,000	325,000	330,000	94,000	43,400	12,800	17,700	211,000
27	28,500	118,000	178,000	225,000	340,000	281,000	354,000	92,200	78,600	28,300	20,000	136,000
28	23,200	125,000	201,000	216,000	324,000	204,000	319,000	91,000	72,200	26,800	18,300	107,000
29	29,700	119,000	199,000	182,000	------	239,000	275,000	74,200	79,200	14,400	24,200	93,600
30	24,200	104,000	195,000	183,000	------	287,000	270,000	79,200	74,900	13,100	22,600	76,300
31	31,900	------	177,000	215,000	------	314,000	------	109,000	------	11,500	56,700	------
TOTAL	891,500	1,996.6M	4,504.6M	5,033.0M	6,065.0M	7,829.0M	4,399.3M	4,050.9M	2,517.7M	826,600	915,200	2,365.0M
MEAN	28,760	66,550	145,300	162,400	216,600	252,500	146,600	130,700	83,920	26,660	29,520	78,830
MAX	54,300	125,000	209,000	225,000	340,000	400,000	354,000	259,000	134,000	50,700	97,800	225,000
MIN	17,700	23,300	92,800	108,000	125,000	118,000	46,500	74,200	34,600	11,500	10,700	27,000

CAL YR 1974 TOTAL 38,037,800 MEAN 104,200 MAX 540,000 MIN 11,200 CFSM 1.68 IN. 22.82
WTR YR 1975 TOTAL 41,394,400 MEAN 113,400 MAX 400,000 MIN 10,700 CFSM 1.83 IN. 24.84

M Expressed in thousands.

FIGURE 7.—Example of streamflow data table as published by U.S. Geological Survey

ports try to give enough information so that a person can find the site in the field using commonly available road maps, street or highway markings, and local landmarks. Political subdivisions (State, county, and distance from town) and an indication of where the site fits into the gen-

03216600 Ohio River at Greenup Dam, Ky.--Continued

(National stream-quality accounting network station)

LOCATION.--Lat 38°38'48", long 82°51'38", Greenup County, at Greenup Dam, 1.1 mi (1.8 km) upstream from Grays Branch, 4.7 mi (7.6 km) downstream from Little Sandy River, 5.0 mi (8.0 km) north of Greenup, and at mile 341.0 (548.7 km).
DRAINAGE AREA.--62,000 sq mi (161,000 sq km), approximately.
PERIOD OF RECORD.--Chemical analyses: October 1974 to September 1975.
Water temperatures: October 1974 to September 1975.
EXTREMES.--1974-75:
Specific conductance: Maximum, 490 micromhos Nov. 13; minimum, 155 micromhos Apr. 1.
Water temperatures: Maximum, 31.0°C Aug. 2.
REMARKS.--Flow regulated by Ohio River system of locks, dams, and reservoirs. Records of conductance and temperature for October and November collected by Corps of Engineers at Greenup Dam. Records of conductance and temperature for December to September collected 1.6 mi (2.6 km) upstream from Greenup Dam.

WATER QUALITY DATA, WATER YEAR OCTOBER 1974 TO SEPTEMBER 1975

DATE	INSTANTANEOUS DISCHARGE (CFS)	DISSOLVED SILICA (SIO2) (MG/L)	DISSOLVED CALCIUM (CA) (MG/L)	DISSOLVED MAGNESIUM (MG) (MG/L)	DISSOLVED SODIUM (NA) (MG/L)	DISSOLVED POTASSIUM (K) (MG/L)	BICARBONATE (HCO3) (MG/L)	ALKALINITY AS CACO3 (MG/L)	DISSOLVED SULFATE (SO4) (MG/L)	DISSOLVED CHLORIDE (CL) (MG/L)	DISSOLVED FLUORIDE (F) (MG/L)
OCT.											
22...	23900	4.4	33	10	30	3.0	57	47	92	34	.2
NOV.											
19...	48000	4.9	46	12	30	3.9	56	46	120	37	.3
DEC.											
17...	127000	6.3	32	8.1	14	2.2	49	40	74	18	.2
JAN.											
17...	110000	6.6	28	8.3	14	2.2	52	43	64	17	.2
FEB.											
20...	163000	6.5	31	9.2	15	1.8	44	36	81	18	.0
MAR.											
18...	295000	6.4	22	6.7	9.8	1.8	36	30	52	13	.1
APR.											
22...	73200	5.9	35	10	17	2.0	50	41	85	21	.3
MAY											
28...	91300	5.0	26	7.9	13	1.9	40	33	68	14	.3
JULY											
08...	24000	3.4	33	9.5	21	2.3	50	41	79	25	.1
AUG.											
20...	29700	1.3	52	14	38	3.8	51	42	160	47	.4
SEP.											
17...	34520	6.1	44	11	23	3.5	61	50	110	27	.3

DATE	TOTAL NITRITE PLUS NITRATE (N) (MG/L)	TOTAL KJELDAHL NITROGEN (N) (MG/L)	TOTAL NITROGEN (N) (MG/L)	TOTAL PHOSPHORUS (P) (MG/L)	DISSOLVED SOLIDS (RESIDUE AT 180 C) (MG/L)	HARDNESS (CA,MG) (MG/L)	NONCARBONATE HARDNESS (MG/L)	SPECIFIC CONDUCTANCE (MICROMHOS)	PH (UNITS)	TEMPERATURE (DEG C)	TURBIDITY (JTU)
OCT.											
22...	1.1	1.4	2.5	.07	244	120	77	460	7.6	19.0	10
NOV.											
19...	1.2	.71	1.9	.04	284	160	120	370	7.1	11.5	8
DEC.											
17...	1.0	.67	1.7	.14	158	110	73	250	7.2	15.0	4
JAN.											
17...	.99	.63	1.6	.10	158	100	61	310	--	4.5	20
FEB.											
20...	.87	.59	1.5	.09	194	120	79	320	7.4	4.5	10
MAR.											
18...	.72	.74	1.5	.12	140	83	53	220	7.5	6.5	60
APR.											
22...	.72	.54	1.3	.01	224	130	88	380	6.8	12.0	20
MAY											
28...	.61	.42	1.0	.06	175	97	65	265	7.1	22.0	35
JULY											
08...	.79	.62	1.4	.03	203	120	81	380	6.8	28.0	4
AUG.											
20...	1.4	1.2	2.6	.05	378	190	150	610	7.2	28.0	4
SEP.											
17...	1.2	.45	1.7	.05	263	160	110	390	7.1	24.0	15

FIGURE 8.—Example of water-quality data table as published by U.S. Geological Survey.

Jefferson County--Continued

381315085502601. National Carbide Corp. Bells Lane. Drilled obaervation water-table well in glacial sand and gravel, diam 6 in (15 cm), dapth 108 ft (33 m), screened. Lsd 448.68 ft (136.76 m) above msl. MP top of caaing, 1.10 ft (0.34 m) above lsd. Highaat water lavel 48.21 ft (14.69 m) below lsd, Mar. 29, 1975; lowest 87.29 ft (26.61 m) balow lsd, Nov. 13, 1964. Recorda available: 1956-75.

Water level at noon, from recorder graph, water year 1974

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
5	64.30	65.38	.....	63.02	59.54	60.39	58.93	58.35	58.62	58.71	59.76	60.67
10	64.35	65.43	.....	62.35	59.58	60.41	58.59	58.64	58.29	58.71	59.97	60.44
15	64.90	65.25	.....	62.05	59.84	60.04	58.04	58.84	58.18	58.84	60.18	60.24
20	65.05	65.42	63.50	61.00	60.07	59.76	57.80	58.90	58.50	59.07	60.33	60.05
25	65.13	e65.10	63.54	60.27	60.26	59.40	57.90	58.69	58.81	59.27	60.45	60.15
Eom	65.21	.....	63.40	59.79	60.20	59.01	58.05	58.60	58.82	59.56	60.61	60.35
						Water year 1975						
5	60.45	60.96	60.70	58.91	56.23	54.25	.....	.....	51.62	53.06	54.85	55.72
10	60.50	61.05	60.78	58.34	56.35	53.78	49.57	.....	51.90	53.40	55.10	55.75
15	60.64	61.16	60.11	58.08	55.85	53.94	.....	.....	51.95	53.74	55.26	55.87
20	60.78	61.04	59.79	57.25	55.58	53.05	e51.75	.....	52.30	53.99	55.48	55.87
25	60.83	61.14	59.40	57.30	55.26	51.95	49.26	51.13	52.48	54.30	55.50	55.83
Eom	60.93	60.98	59.15	56.90	55.02	.....	.....	51.37	52.78	54.64	55.64	55.85

e Estimated.

381157085510201. Rubber Reaerve Co. Schenks Lane (praviously reported Shanks Lane). Drilled observation water-table well in glacial sand and gravel, diam 6 in (15 cm), depth 112 ft (34 m), length of casing unknown. Lsd 446.27 ft (136.02 m) above msl. MP top of coupling, 4.85 ft (1.48 m) above lsd. Highest water level 37.14 ft (11.32 m) below lsd, July 6, 1975; lowest 57.62 ft (17.56 m) below lsd, Feb. 25, 1956. Records available: 1945-75.

Water level at noon, from recorder graph, water year 1974

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
5	42.29	42.59	42.87	42.90	42.90	42.41	41.94	41.23	40.80	40.64	40.78	41.00
10	42.30	42.66	42.92	43.87	42.82	42.36	41.81	41.14	40.77	40.63	40.80	41.05
15	42.33	42.60	42.97	43.03	42.75	42.20	41.70	41.07	40.72	40.62	40.84	41.12
20	42.40	42.70	42.98	42.92	42.75	42.12	41.60	40.98	40.71	40.66	40.85	41.17
25	42.43	42.82	42.99	43.06	42.66	42.10	41.50	40.91	40.70	40.70	40.88	41.18
Eom	42.40	42.86	43.05	43.00	42.48	41.97	41.36	40.86	40.63	40.76	40.92	41.27
						Water year 1975						
5	41.33	41.47	41.65	41.72	41.34	40.80	39.83	38.31	37.42	37.16	37.33	47.80
10	41.34	41.44	41.64	41.55	41.33	40.80	39.52	38.17	37.38	37.18	37.41	47.92
15	41.38	41.54	41.57	41.71	41.27	40.80	39.30	37.98	37.29	37.25	37.46	48.02
20	41.43	41.51	41.67	41.66	41.20	40.51	39.06	37.86	37.28	37.20	47.56	38.10
25	41.39	41.59	41.80	41.48	41.18	40.33	38.76	37.73	37.28	37.25	47.62	38.19
Eom	41.42	41.55	41.66	41.55	40.95	40.04	38.46	37.54	37.22	37.33	47.72	38.31

381443085470602. Brown-Forman Distilleries. 1908 Howard St., Louieville. Drilled unused water-table well in glacial sand and gravel, diem 12 in (30 cm), depth 200 ft (61 m), cased to bottom. Lsd 451.13 ft (137.50 m) above msl. MP top of casing, at lsd. Higheat water level 41.89 ft (12.77 m) below lsd, Sept. 19, 1975; lowest 79.64 ft (24.27 m) below lsd, Apr. 22, 1965. Records available: 1961-75.

Date	Weter level	Date	Water level	Date	Water level	Date	Watsr level
Oct. 23, 1973	d53.80	Apr. 19, 1974	c53.27	Oct. 21, 1974	d48.23	Apr. 21, 1975	d44.80
Nov. 12	d53.75	May 20	c52.55	Nov. 22	d47.15	May 22	d44.27
Dec. 17	d53.55	June 21	d52.36	Dec. 23	d46.44	June 25	d43.77
Jan. 18, 1974	c53.50	July 22	d50.36	Jan. 23, 1975	d45.91	July 21	d43.24
Feb. 19	c53.03	Aug. 19	d49.22	Feb. 21	d45.52	Aug. 18	d43.56
Mar. 22	c52.98	Sept. 20	d49.13	Mar. 24	d44.79	Sept. 19	d41.89

c Nearby well being pumped.
d Neerby well pumped recently.

Johnson County

374610082453001. Kentucky Water Co. Van Lear. Drilled unused artesian well in Breathitt Formation of Early and Middla Pennsylvenian age, diam 6 in (15 cm), depth 115 ft (35 m), length of casing unknown. Lsd about 630 ft (192 m) above msl. MP bottom of recorder base, 3.42 ft (1.04 m) above lsd. Highest weter level 23.78 ft (7.25 m) balow lsd, Jan. 29, 1972 (revieed); lowest 28.81 ft (8.78 m) below lsd, Oct. 29, 1963. Records available: 1951-75. Measnrement discontinusd Ang. 31, 1975.

FIGURE 9.—Example of ground-water-level data tables as published by U.S. Geological Survey.

eral drainage pattern of the area are also given. Changes in the site during the history of the data collection should also be identified.

Next, there is a need to know what information is available and over what time span each type of information is available. In many instances, there is a fairly long period of one kind of information (usually streamflow or water level) with an even longer period of known extremes such as floods or droughts; and then shorter periods of increasingly varied kinds of information (usually water-quality parameters). A listing of the periods for which each type of data is available serves as a hunting guide to the user of data reports for previous years.

The value of giving the size of the drainage area tributary to a surface-water data site is so universally accepted that it need not be discussed.

Instrumentation at the site is also important in analyzing the completeness and reliability of the data; so it, too, should be stated. Recording instruments usually provide more frequent readings than do personal observations. Conditions at the site and the use to be made of the data determine whether the frequency should be once a year, once a month, once a week, once a day, once an hour, several times an hour, or continuously.

Probably the most commonly asked questions are, "What is the average?", "What is the greatest?", and "What is the least?" The questions may be asked about any parameter and often do not specify a given period, but should probably be interpreted as "What can usually be expected?" and "What are the widest extremes that can be expected?" Average values are given if the record for that parameter is continuous and long enough to be significant. Maximum or minimum or both are given for several parameters if the observations or samples are taken frequently enough so that the true extremes are probably represented. Extremes, if given, are stated for the current year and for the entire period of record for that parameter.

There is no unanimity of opinion about the quantity and nature of additional information that should be given about a site. Some people think that an evaluation of the quality or reliability of the data should be stated; others think that no evaluation is justified; as a compromise, discharge is the only parameter presently rated. Certainly the significant factors affecting the reported parameters should be stated.

The introductory pages of each report follow a standard format which describes the data collection and processing program, identifies cooperating agencies, defines the technical terms used in the report, cites the reports containing data for preceding years, and suggests supplementary information which can be obtained from office files.

There is neither enough money nor enough personnel to collect and process complete discharge data for every day at every site at which information is needed; so an additional network of "partial-record stations" has been established to extend the data coverage by collecting limited information at the extremes of high flow and low flow. The data for extreme high flow are listed in a table entitled "Annual maximum discharge at crest-stage partial-record stations" (fig. 10). The data for low flow are listed in a table entitled "Discharge measurements made at low-flow partial-record stations" (fig. 11). Additional streamflow data are listed as miscellaneous discharge measurements; these data are archived only, since they are not part of the continuing program of a network of basic-data sites.

Similarly, there are water-quality partial-record sites and miscellaneous water-quality analyses made to answer questions for a specific site at a specific time (fig. 12).

As mentioned earlier, the U.S. Geological Survey published water-resources basic-data reports through 1970 in three series of water-supply papers, one each for surface water (quantity), water quality, and ground water (well levels). Each surface-water and water-quality report covered an area bounded by natural drainage divides. As the number of sites (and pages of data) increased, the areas covered by each report were subdivided to keep each book from becoming too cumbersome. Each ground water report covered a section of the country composed of a group of states. The reports were all reviewed, assembled, and published at headquarters (Reston, Va. and Denver, Colo.) from data furnished from field offices throughout the country.

In 1961, as part of a movement to release basic data in preliminary form more rapidly than could be done through publication at headquarters, the streamflow information was issued by the individual districts in virtually the same format as used in the water-supply papers. Each district report, however, contained data only for the area administered by that district (usually one State).

DISCHARGE AT PARTIAL-RECORD STATIONS

Crest-stage partial-record stations

The following table contains annual maximum discharges for crest-stage stations. A crest-stage gage is a device which will register the peak stage occurring between inspections of the gage. At a few of these stations crest stages are determined from continuous water-stage recorder graphs. A stage-discharge relation for each gage is developed from discharge measurements made by indirect measurements of peak flow or by current meter. The date of the maximum discharge is not always certain but is usually determined by comparison with nearby continuous record stations, weather records, or local inquiry. Only the maximum discharge for each water year is given. Information on some lower floods may have been obtained but is not published herein. The years given in the period of record represent water years for which the annual maximum has been determined.

Annual maximum discharge at crest-stage partial-record stations

Station No.	Station name	Location	Drainage area (sq mi) (sq km)	Period of record	Annual maximum		
					Date	Gage height (feet)	Discharge (cfs)
		Cabin Creek basin					
03237895	Indian Run Tributary near Tollesboro, Ky.	Lat 38°34'52", long 83°30'01", Lewis County, at culvert on State Highway 10, 0.1 mi (0.2 km) above mouth, and 4.5 mi (7.2 km) northeast of Tollesboro.	0.23 .60	1975	9-24-75	86.54	76
		Lawrence Creek basin					
03238030	Lawrence Creek near Maysville, Ky.	Lat 38°38'04", long 83°47'32", Mason County, at culvert on U.S. Highway 62 and 68, 0.5 mi (0.8 km) above tributary on left bank, and 1.8 mi (2.9 km) southwest of Maysville.	1.90 4.92	1975	3-29-75	91.63	397
		Licking River basin					
03250150	Indian Creek near Owingsville, Ky.	Lat 38°09'24", long 83°39'05", Bath County, at culvert on Interstate Highway 64, 1.3 mi (2.1 km) above Knox Hill Branch, 1.5 mi (2.4 km) above mouth, and 6.2 mi (10.0 km) east of Owingsville.	2.43 6.29	1975	3-12-75	101.07	1,080
03250243	Rose Run Tributary near Olympia, Ky.	Lat 38°06'46", long 83°42'30", Bath County, at culvert on county road, 1.1 mi (1.78 km) above mouth, and 1.2 mi (1.9 km) northwest of Olympia.	.70 1.81	1975	4-24-75	87.46	210
03250500	Licking River at Blue Lick Springs, Ky.	Lat 38°25'19", long 83°59'57", on bridge on U.S. Highway 68 and State Highway 32, at Blue Lick Springs, 1.2 mi (1.9 km) above Indian Run.	1,785 4,623	1938-59≠ 1960-75	4-25-75	33.48	21,300
03251015	Lees Creek Tributary at Mays Lick, Ky.	Lat 38°31'28", long 83°50'04", Mason County, at culvert on U.S. Highway 68, 0.5 mi (0.8 km) above mouth, and 0.6 mi (1.0 km) northeast of Mays Lick.	.45 1.17	1975	3-29-75	94.51	110
		Pleasant Run Creek basin					
03260010	Pleasant Run Creek at Crescent Springs, Ky.	Lat 39°03'18", long 84°33'59", Kenton County, in trailer court at intersection of Venus Avenue and Mercury Way, about 2.5 mi (4.0 km) above mouth and near village of Crescent Springs.	.68 1.76	1973-75	11-26-73 4-24-75	7.48 7.00	220 205
03260012	Pleasant Run Creek Tributary at Fort Mitchell, Ky.	Lat 39°03'45", long 84°33'45", Kenton County, at culvert on private road, 800 ft (240 m) above the mouth, and about 1.2 mi (1.9 km) east of the village of Crescent Springs.	1.62 4.20	1973-75	11-26-73 3-12-75	4.70 7.65	275 430
		Kentucky River basin					
03277300	North Fork Kentucky River at Whitesburg, Ky.	Lat 37°07'03", long 82°49'29", Letcher County, on brick wall of building at right downstream corner of bridge on State Highway 15, at Whitesburg, 0.6 mi (1.0 km) below Solomon Branch.	66.4 172	1957-75	5-23-75	7.36	2,320
03277400	Leatherwood Creek at Daisy, Ky.	Lat 37°06'48", long 83°05'33", Perry County, on right bank on downstream side of bridge, at mouth of Hicks Branch, at Daisy, 0.6 mi (1.0 km) upstream from Little Leatherwood Creek, and 1.2 mi (1.9 km) upstream from mouth.	40.9 105.9	1964-74≠ 1975	3-13-75	8.47	2,530
03278000	Bear Branch near Noble, Ky.	Lat 37°27'02", long 83°11'43", Breathitt County, on right bank, 800 ft (244 m) upstream from mouth, 0.2 mi (0.3 km) west of Noble, and 3.5 mi (5.6 km) north of Stacy.	2.21 5.72	1954-73≠, 1974-75	3-14-75	2.58	220
03280935	Stamper Fork at Canoe, Ky.	Lat 37°26'24", long 83°26'17", Breathitt County, at culvert on county road, 200 ft (61 m) upstream from mouth, and 0.9 mi (1.4 km) southeast of Canoe.	1.57 4.07	1974-75	3- -75	88.58	345
03281200	South Fork Kentucky River at Oneida, Ky.	Lat 37°16'23", long 83°38'50", Clay County, on bridge at Oneida, 850 ft (259 m) below Bullskin Creek.	486 1,259	1957-75	3-13-75	32.63	33,300

≠ Operated as a continuous-record gaging station.

FIGURE 10.—Example of table of annual maximum discharge at crest-stage partial-record stations as published by U.S. Geological Survey.

DISCHARGE AT PARTIAL-RECORD STATIONS

As the number of streams on which streamflow information is likely to be desired far exceeds the number of stream-gaging stations feasible to operate at one time, the Geological Survey collects limited streamflow data at sites other than stream-gaging stations. When limited streamflow data are collected on a systematic basis over a period of years for use in hydrologic analyses, the site at which the data are collected is called a partial-record station. Data collected at these partial-record stations are usable in low-flow or floodflow analyses, depending on the type of data collected. In addition, discharge measurements are made at other sites not included in the partial-record program. These measurements are generally made in time of drought or flood to give better areal coverage to those events. These measurements and others collected for some special reason are called measurements at miscellaneous sitee.

Records collected at partial-record stations are presented in two tables. The first is a table of discharge measurements at low-flow partial-record stations and the second is a table of annual maximum stage and discharge at crest-stage stations. Discharge measurements made at miscellaneous sites for both low flow and high flow are given in a third table.

Low-flow partial-record stations

Measurements of streamflow in the area covered by this report made at low-flow partial-record stations are given in the following table. Most of these measurements were made during periods of base flow when streamflow is primarily from ground-water storage. These measurements, when correlated with the simultaneous discharge of a nearby stream where continuous records are available, will give a picture of the low-flow potentiality of stream. The column headed "Period of record" shows the water years in which measurements were made at the same, or practically the same site.

Discharge measurements made at low-flow partial-record stations during water year 1975

Station No.	Station name	Location	Drainage area (sq mi) (sq km)	Period of record	Measurements Date	Measurements Discharge (cfs)
		Big Sandy River basin				
03209460	Shelby Creek at Shelbiana, Ky.	Lat 37°25'24", long 82°29'57", Pike County, at concrete bridge, 0.2 mi (0.3 km) above Dry Creek, 0.3 mi (0.5 km) above mouth, and 0.3 mi (0.5 km) southwest of Shelbiana.	112 290	1965, 1972-75	7-30-75 8-26-75	14.5 11.8
03209600	Right Fork Beaver Creek at Wayland, Ky.	Lat 37°26'35", long 82°48'28", Floyd County, at Chesapeake and Ohio RR bridge at Wayland, 100 ft (30 m) downstream from Steele Creek.	73.9 191.4	1959-64 1967-75	8-26-75	1.59
03214730	Rockcastle Creek at Clifford, Ky.	Lat 38°00'07", long 82°31'12", Lawrence County, at bridge on State Highway 3, at mouth, at Clifford.	121 313	1965, 1972-75	8- 3-75 8-27-75	5.01 3.81
03215410	Blaine Creek near Blaine, Ky.	Lat 38°04'00", long 82°49'38", Lawrence County, at bridge, 0.1 mi (0.2 km) below Cherokee Creek, and 2.7 mi (4.3 km) north of Blaine.	119 308	1972-75	8-27-75	1.42
		Little Sandy River basin				
03216480	Little Fork Little Sandy River near Grayson, Ky.	Lat 38°18'15", long 82°56'23", Carter County, just below old mill site, 0.5 mi (0.8 km) above mouth, 1.6 mi (2.6 km) below Canoe Run and 2.0 mi (3.2 km) south of Grayson.	132 342	1965, 1972-75	8- 3-75 8-26-75	4.24 4.34
03216570	East Fork Little Sandy River near Argillite, Ky.	Lat 38°28'44", long 82°45'46", Greenup County, at bridge on State Highway 747, 1.5 mi (2.4 km) downstream from Pigott Branch, and 3.6 mi (5.8 km) east of Argillite.	138 357	1968-75	8-27-75	6.70
		Tygarts Creek basin				
03216935	Tygarts Creek near Kehoe, Ky.	Lat 38°26'06", long 83°02'04", Carter County, 0.85 mi (1.4 km) below Ross Branch, 0.85 mi (1.4 km) above Shaws Branch, 2.4 mi (3.9 km) southeast of Kehoe, and 4.0 mi (6.4 km) above Buffalo Creek.	125 324	1963-65, 1972-75	7- 6-75 8-27-75	25.5 6.52
		Licking River basin				
03248170	Licking River at Fredville, Ky.	Lat 37°36'13", long 82°58'17", Magoffin County, at private walk bridge, 150 ft (46 m) south of State Highway 7, 0.4 mi (0.6 km) west of Fredville Post Office, 0.7 mi (1.1 km) below Whitley Branch, 1.0 mi (1.6 km) below Trace Fork, and 1.1 mi (1.8 km) above Buck Branch.	40.3 104.4	1973-75	10-10-74 8-25-75	4.82 .51
03248250	Licking River at Royalton, Ky.	Lat 37°40'21", long 83°01'22", Magoffin County, at low-water bridge, 800 ft (244 m) above Gum Creek, 0.2 mi (0.8 km) south of Royalton, 1.8 mi (2.9 km) above Oakley Creek, and 2.0 mi (3.2 km) below Big Half Mountain Creek.	76.7 198.7	1973-75	10-10-74 8-25-75	9.88 1.24
03248540	Middle Fork near Salyersville, Ky.	Lat 37°44'24", long 83°07'48", Magoffin County, at bridge on Mountain Parkway Toll Road, 0.2 mi (0.3 km) above Patton Branch, 0.8 mi (1.3 km) below Right Fork, 1.8 mi (2.9 km) above mouth, and 3.3 mi (5.3 km) west of Salyersville.	45.7 118.4	1973-75	10-10-74 8-25-75	4.92 .30
03248730	Caney Creek near West Liberty, Ky.	Lat 37°56'00", long 83°18'36", Morgan County, at bridge on county road, 0.3 mi (0.5 km) above mouth, 0.9 mi (1.4 km) below Straight Creek, and 2.9 mi (4.7 km) west of West Liberty.	41.4 107.2	1973-75	10-10-74 8-27-75	3.74 .31

FIGURE 11.—Example of table of discharge measurements made at low-flow partial-record stations as published by U.S. Geological Survey.

ANALYSES OF SURFACE-WATER SAMPLES COLLECTED AT MISCELLANEOUS SITES

CHEMICAL ANALYSES IN MILLIGRAMS PER LITER, WATER YEAR OCTOBER 1974 TO SEPTEMBER 1975

DATE	INSTANTANEOUS DISCHARGE (CFS)	DISSOLVED CALCIUM (CA) (MG/L)	DISSOLVED MAGNESIUM (MG) (MG/L)	DISSOLVED SODIUM (NA) (MG/L)	DISSOLVED POTASSIUM (K) (MG/L)	BICARBONATE (HCO3) (MG/L)	CARBONATE (CO3) (MG/L)	ALKALINITY AS CACO3 (MG/L)	DISSOLVED SULFATE (SO4) (MG/L)	DISSOLVED CHLORIDE (CL) (MG/L)
SALT RIVER BASIN										
03295900 - BRASHEARS CR AT TAYLORSVILLE KY (LAT 38 01 49 LONG 085 21 05)										
AUG., 1975 27...	9.8	56	6.0	--	--	173	0	142	24	7.6
03298390 - FLOYDS FORK NR GAP IN KNOB KY (LAT 38 02 04 LONG 085 39 33)										
JULY, 1975 23...	22	64	16	--	--	198	0	162	41	15
03298760 - NORTH ROLLING FORK AT BRADSFORDVILLE (LAT 37 30 22 LONG 085 08 34)										
AUG., 1975 25...	.50	43	12	--	--	154	0	126	32	3.6
03300498 - CARTWRIGHT CR AT FREDRICKTOWN KY (LAT 37 45 45 LONG 085 19 29)										
OCT., 1974 31...	27	63	12	--	--	240	0	197	50	10
SEP., 1975 15...	2.3	59	9.4	--	--	133	16	136	55	12
BLACKFORD CREEK BASIN										
03303450 - BLACKFORD CR NR MACEO KY (LAT 37 53 56 LONG 086 59 11)										
SEP., 1975 16...	.78	39	17	--	--	38	0	31	140	6.2
GREEN RIVER BASIN										
03305660 - GREEN RIVER NR. DONNVILLE, KY. (LAT 37 13 13 LONG 084 59 12)										
AUG., 1975 25...	5.3	26	7.0	--	--	93	0	76	13	4.6
03305865 - CASEY CR AT CASEY CR KY (LAT 37 17 57 LONG 085 09 00)										
AUG., 1975 25...	.42	19	4.7	--	--	68	0	56	11	3.4

DATE	INSTANTANEOUS DISCHARGE (CFS)	TEMPERATURE (DEG C)	TOTAL ARSENIC (AS) (UG/L)	DISSOLVED ARSENIC (AS) (UG/L)	TOTAL ARSENIC IN BOTTOM MATERIAL (UG/G)	TOTAL CADMIUM (CD) (UG/L)	DISSOLVED CADMIUM (CD) (UG/L)	TOTAL CADMIUM IN BOTTOM MATERIAL (UG/G)	TOTAL CHROMIUM (CR) (UG/L)	DISSOLVED CHROMIUM (CR) (UG/L)	TOTAL CHROMIUM IN BOTTOM MATERIAL (UG/G)	TOTAL COBALT (CO) (UG/L)	DISSOLVED COBALT (CO) (UG/L)
03306490 - GREEN R NR GREENSBURG,KY. (LAT 37 14 43 LONG 085 28 47)													
JULY, 1975 18...	119	19.5	0	0	5	0	0	<10	<10	0	<10	0	0
SEP. 10...	121	21.5	1	0	6	12	0	<10	<10	0	<10	0	0
03307295 - BIG PITMAN C NR SUMMERSVILLE KY (LAT 37 18 17 LONG 085 31 39)													
JULY, 1975 16...	12	19.5	1	1	3	3	3	<10	<10	0	<10	0	6
SEP. 10...	4.9	24.0	7	6	8	4	1	<10	<10	0	<10	1	0

FIGURE 12.—Examples of tables of miscellaneous water-quality analyses as published by U.S. Geological Survey.

The response to the district streamflow data reports was so favorable that in 1964 water-quality data were released in similar district reports. The publication of surface-water and water-quality basic data at headquarters in the water-supply paper series was discontinued after 1970. In 1975 the district reports were declared to be the official basic-data reports in a new series called U.S. Geological Survey Water-Data Reports. In the new series, all basic data for an area (usually a State) are in one book; surface-water, water-quality, and ground-water data are combined in the same volume. The data for 1971 through 1974 will be incorporated into the new series to provide continuity.

The water-supply paper series will continue to be used primarily for interpretative reports of national interest and for release of materials describing techniques and methodologies that have transfer value to other sectors of the country. As indicated earlier, data in those interpretative reports will be supporting evidence to the findings and results of the investigations.

The preparation of data reports in the U.S. Geological Survey is highly automated; the principal reason for automation is the large volume of data collected. The data may be handled either manually or by automation; the decision as to what degree of automation is required will depend on the resources, both manpower and funds. In those organizations where labor expenses are high or constraints upon availability of manpower may exist, the interest in automation will be very high.

Potential for money and manpower savings in addition to the need for realtime data are also considerations which are being applied to the evaluation of current experiments with the satellite data programs. The implication in the name "realtime" is that the system is rather sophisticated and incorporates the latest in the way of processing equipment and technology in data transmission. The subject is raised at this time because it is frequently heard that there is an interest in publishing "realtime" data. Realtime data and publication are contradictory because of the inherent delays in preparing material for publication. In general, publications deal with historic data. Even though a site has a direct link with a satellite or telemetering device, data entered into a file require time for dissemination to points of interest. Essentially then, the situation is a historic data system, albeit the data from the satellite program may be much more current than that available from a normal field operation. Printouts from the computer can be assembled for publication; however, at that stage they become historic because of the time delay factor in making the material available. An example of a publication and the computer working together to respond to the needs of the user community is a system incorporating either a satellite relay or a land-line system to provide data indicating conditions taking place at the station at the time of inquiry or interrogation. Data coming into the computer through the satellite program are immediately available for the user through terminal networks, and the same data are also available for future compilation and release in publications.

Recently, increasing recognition has been given in the United States to the role that many governmental agencies at Federal, State and local levels have in water resources planning, development, and management. Each agency collects and (or) uses water data to carry out its mission responsibilities, but very little of these data are published although they may be available in some other form. Because the data are not in published form, other agencies may not be aware of their existence. This lack of awareness has led to another kind of water data—that is, data on data. The expression may sound confusing, but what it boils down to is the development of an index to the data holdings of the many agencies active in the field of water resources.

The nucleus of such an index already exists in the U.S. Geological Survey's Office of Water Data Coordination (OWDC), which is responsible for coordinating Federal water-data acquisition activities in the United States; its authority is based on OMB Circular A–67, which directs Federal agencies to cooperate with the Department of the Interior in eliminating duplicative activities in the acquisition of water data. The Department delegated A–67 responsibilities to the U.S. Geological Survey which, in turn, established the Office of Water Data Coordination in its Water Resources Division.

Every other year, the OWDC issues an updated edition of its Catalog of Information on Water Data, which is a compilation of data activities of about 20 Federal agencies and about 300 non-Federal agencies—mostly State-level organizations—which voluntarily submit information

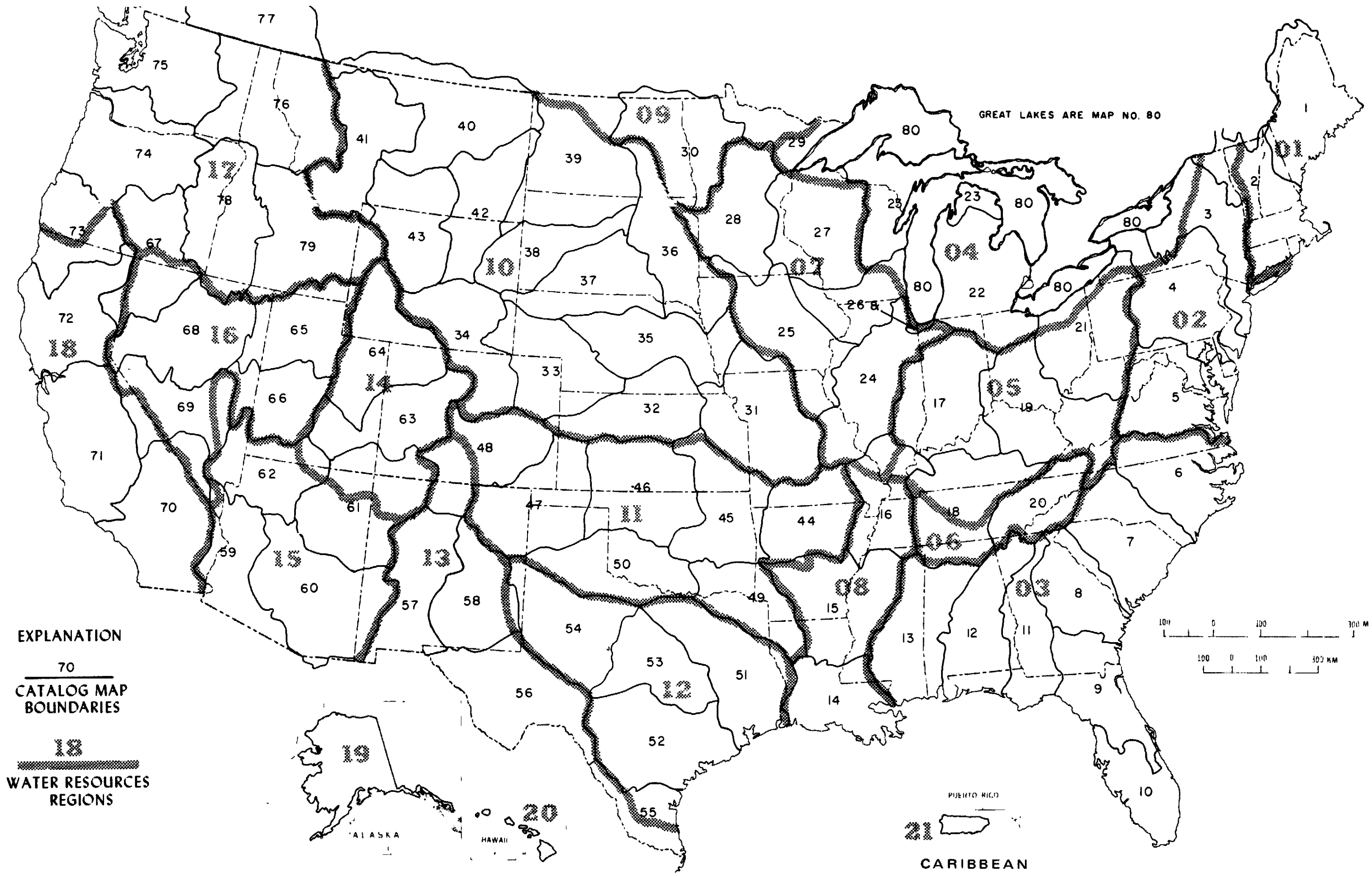

FIGURE 13.—Map of the United States showing OWDC amp numbers and Water Resources Regions.

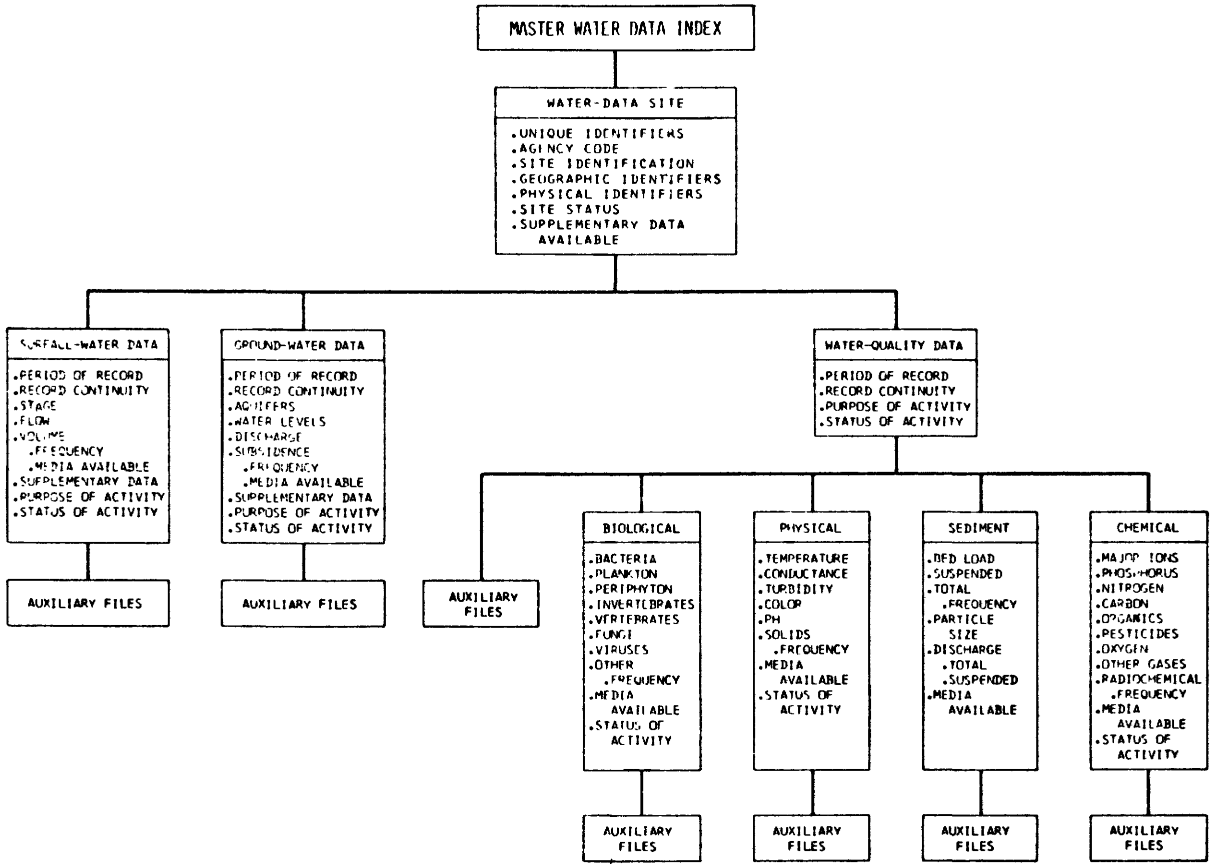

FIGURE 14.—Data elements in the Master Water Data Index of the National Water Data Exchange (NAWDEX).

on their data activities for inclusion in the catalog. The catalog is published in 21 volumes, a separate volume for each of the Water Resources Council Regions (fig. 13) into which the United States is subdivided for water resources planning purposes. The catalog tells the user who is collecting what kinds of data and where; it also gives information as to how the data may be acquired, where it is, who should be contacted, and the media in which the data are available.

The information in the OWDC catalogs has been of great value to the data-user community as far as it goes, but it still leaves a "knowledge" gap in that in provides only summary type information for data stations of the contributing organizations. The catalog does not give the specifics that many users require in order to decide whether or not it is worth the time and cost to acquire the data to meet a particular need. Neither does it give any indication as to other organizations that collect data but do not participate in the catalog. As a result of this awareness of data information deficiencies, a Federal interagency working group was formed under OWDC sponsorship to look into the problems associated with data handling. The work group recommended the development of a National system to improve access to water data. In its report, "Design Characteristics for a National System to Store, Retrieve, and Disseminate Water Data," the work group laid the foundation for the National Water Data Exchange (NAWDEX). A NAWDEX Program Office has been established within the Water Resources Division of the Geological Survey. One of its major functions, as described in the work group report, is "to assemble knowledge as to the locations of all types of water data." This function was further interpreted in the Summary Recommendations as "it will prepare and maintain an index to water-data activities which ultimately will include information on all water data in the files of member units of NAWDEX". Several contracts with private consultants have produced an implementation

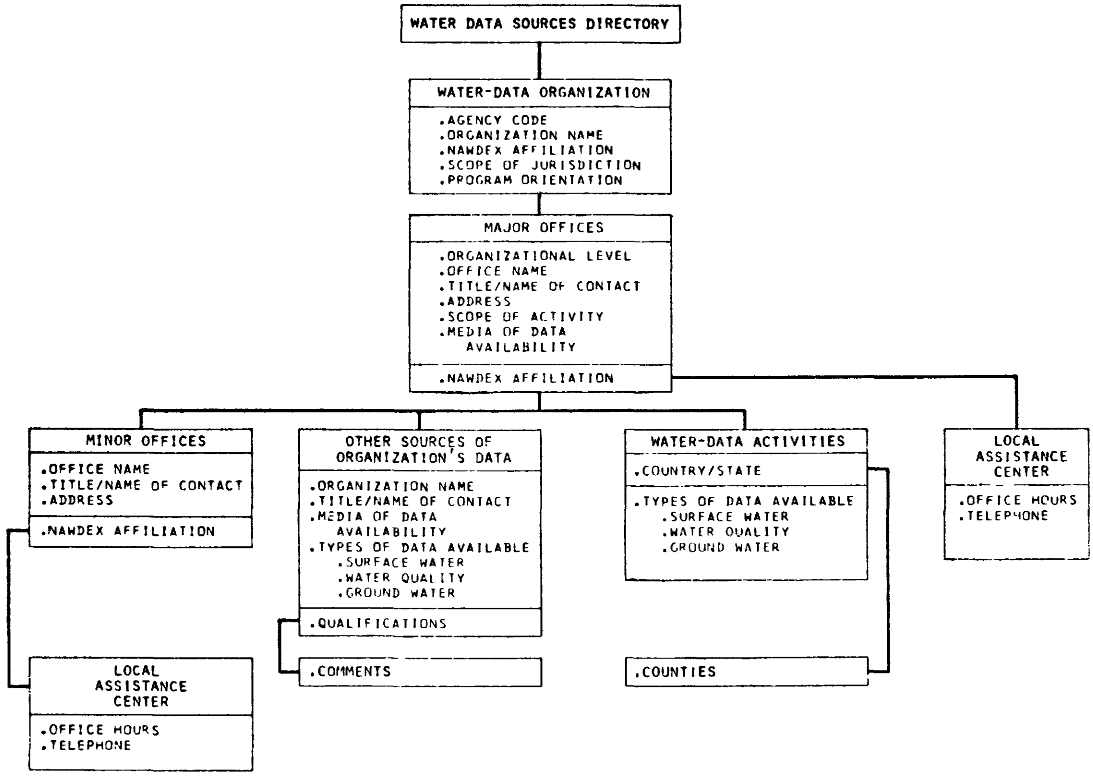

FIGURE 15.—Data elements in the Water Data Sources Directory of NAWDEX.

plan for NAWDEX, part of which has been the establishment of a master index of water-data activities, and to incorporate the OWDC Catalog of Information into the master index in order to activate it as quickly as possible. However, the complete or detailed index will require considerable funds and manpower before it reaches the stage at which it will be effective in responding to information requests on availability of data. These problems have led to the concept for a second file which would complement the index—a Water Data Sources Directory. The Directory will contain information on organizations that have water data, whereas the index will have the specifics on the data characteristics of individual activities. Figure 14 shows the data elements for the master index; figure 15 shows the elements for the Directory. Both will be online files accessible through remote terminals. In addition, the data contained in these files will be published periodically in order that they will be more readily available to the user community.

The Geological Survey recently experimented with the release of index material by publishing the background information on data in the files of the Survey's National Water Data Storage and Retrieval System (WATSTORE). This index may be an indicator of future conditions showing that, as data networks expand, the volume of data increases exponentially. The resources required to make these data available in published form may become so great that media for release other than publication may be required. However, those other media must provide an archiving mechanism that will serve as well as a publication would.

Computer-related techniques for storing massive quantities of data have been developed in recent years, but many people are reluctatnt to rely solely on the computer for official archiving of data. Periodic computer failures in which data files have been wiped out, and occasional "bugs" in software packages which play havoc with data files are examples of the causes of such reluctance. A combination of the computer and the publication has resulted in better responsiveness to most needs of the user community than either one alone. However, the cost of publication continues to rise and the competition for use of available funds becomes more acute; a reevaluation of the data publication program may be required in the near future.

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