# THE HYDROLOGIC INSTRUMENTATION FACILITY

# OF THE U.S. GEOLOGICAL SURVEY

By C. Russell Wagner and Sharon Jeffers

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## ABSTRACT

The U.S. Geological Survey is the principal Federal agency responsible for the collection of hydrologic data needed for the planning, development, use, and management of the Nation's water resources. The reliability of data, however, is only as good as the instruments and supporting equipment used to collect them. The Hydrologic Instrumentation Facility (HIF) was established in 1980 to improve the instrumentation of the Water Resources Division.

The consolidation at the HIF of instrumentation functions has provided the mechanism for efficient and effective management of previously scattered support elements. Performance standards have been established as a basis for acceptance of various instrumentation to support data collection that will meet Water Resources Division requirements. Instrument development is oriented towards increased flexibility and reliability through the system-engineering concept using interchangeable modules which may be configured to meet specific needs. A Quality-Assurance program provides a means of monitoring the efficiency of all internal HIF functions toward providing highly reliable field instruments. Consolidated procurement, warehousing, and distribution of both sales and rental items provides a cost-effective way of providing support to all field users within the Water Resources Division. Centralized repair and calibration services reduces the need for field offices to have trained repair technicians, and ensures uniform calibration procedures. The HIF staff strives to maintain communication and technology transfer with Water Resources Division personnel, both to provide information on new products, application, and operation instructions and to gain input regarding field instrumentation needs.

## HISTORY AND BACKGROUND

Throughout its history, the U.S. Geological Survey has used a variety of instruments for water-resources investigations. Equipment initially was required to assist in the manual collection of water-level and streamflow data, and included current meters, staff gages, cranes, reels, stopwatches, and cable cars. As mechanical technology developed in the early part of the twentieth century, more automated instrumentation was utilized by the Geological Survey, principally to measure water levels. During the late 1950's and early 1960's, the Geological Survey deployed an electromechanical hydrologic data recording system, principally for water levels, but also for the collection of water-quality and precipitation data.

Often instruments and equipment were procured from the private sector, but at times it was necessary to adapt these commercially available systems to meet the Geological Survey's unique requirements. When this was not possible, the Geological Survey would sponsor the development of specialized equipment, either by contract or through the efforts of Geological Survey employees and laboratories. As a result, most of the stream-gaging equipment used in North America has been developed through Geological Survey initiative.

Much of the instrumentation-development work in the early 1970's was accomplished by the National Research Program of the Geological Survey's Water Resources Division. Logistical support for the procurement, warehousing, and repair of instrumentation and equipment was provided by the Geological Survey's Administrative Division. Other groups within the Water Resources Division provided liaison between Geological Survey field offices and these support functions. Thus, the several entities responsible for the development, procurement, repair, and modification of instrumentation and equipment were scattered organizationally and geographically.

By the mid-1970's, technological advances offered new opportunities for improvements in hydrologic data-collection activities. It became clear that a closely integrated support program would be essential to take advantage of these technologies. It also was apparent that organizational efficiencies could be realized if the function of identifying instrumentation requirements, as well as the development, procurement, repair, and supply of equipment were organizationally consolidated and collocated in one geographical location.

In 1977, the Survey decided to develop a hydrologic instrumentation program that would be responsible for a broad range of instrumentation support for field offices. The program was placed in the Office of the Assistant Chief Hydrologist for Operations within the Water Resources Division. A position of Instrumentation Coordinator was established in that office with responsibility for coordination of the development and operational use of real-time, satellite-based telemetry systems, and technical oversight of the Instrumentation Program.

During 1977-1979, the Geological Survey selected a site, modified building and laboratory space, recruited staff, and consolidated the previously scattered support functions at the new location, known as the Hydrologic Instrumentation Facility (HIF). A program-planning effort was conducted to reassess Geological Survey requirements for an improved data collection system, to examine technologies that were available to address these requirements, and to develop options for research and development.

An Instrumentation Committee was formed to provide guidance to the instrumentation program. The Committee meets periodically with Instrumenation Program staff to review operations and to help define requirements for new equipment. The committee membership includes a District Chief from each WRD region, representative of Surface-Water, Quality of Water, and Ground-Water Branches, Assistant Chief Hydrologist for Scientific Publications and Data Management, Assistant Chief Hydrologist for Research and Technical Coordination, the Instrumentation Coordinator and Chief, Hydrologic Instrumentation Facility.

## ORGANIZATION

The HIF has 36,000 square feet of office, laboratory, and warehouse space (fig. 1), located at the National Space Technology Laboratories (NSTL), a 13,480 acre installation on the Mississippi Gulf Coast, northeast of New Orleans, Louisiana. With the National Aeronautics and Space Administration serving as the host agency, 17 other State and Federal agencies located at NSTL benefit from contractor-supplied technical and facility support services as well as technology exchange opportunities at this unique multiagency scientific community.

Approximately 50 professional, technical, and clerical personnel at the HIF are organized in six sections: Administrative; Field Service and Supply; Repair and Calibration; Instrument Development Laboratory; Technical Services; and Test and Evaluation. To ensure that the HIF maintains responsiveness to field needs, most management positions have been staffed with personnel having previous Geological Survey field experience.

## INSTRUMENTATION PERFORMANCE STANDARDS

The Geological Survey's scientific credibility depends on the unbiased accuracy of the hydrologic data that the agency collects. One critical factor in the selection of a field instrument for the collection of data is the refinement or resolution at which the instrument is capable of sensing and recording. The HIF works closely with other organizational units within Water Resources Division and with instrumentation counterparts in other agencies to define and document the required refinement that field instrumentation must achieve. These requirements then set the benchmarks against which commercial products are evaluated before being purchased. They also set design criteria that HIF-developed products must meet.

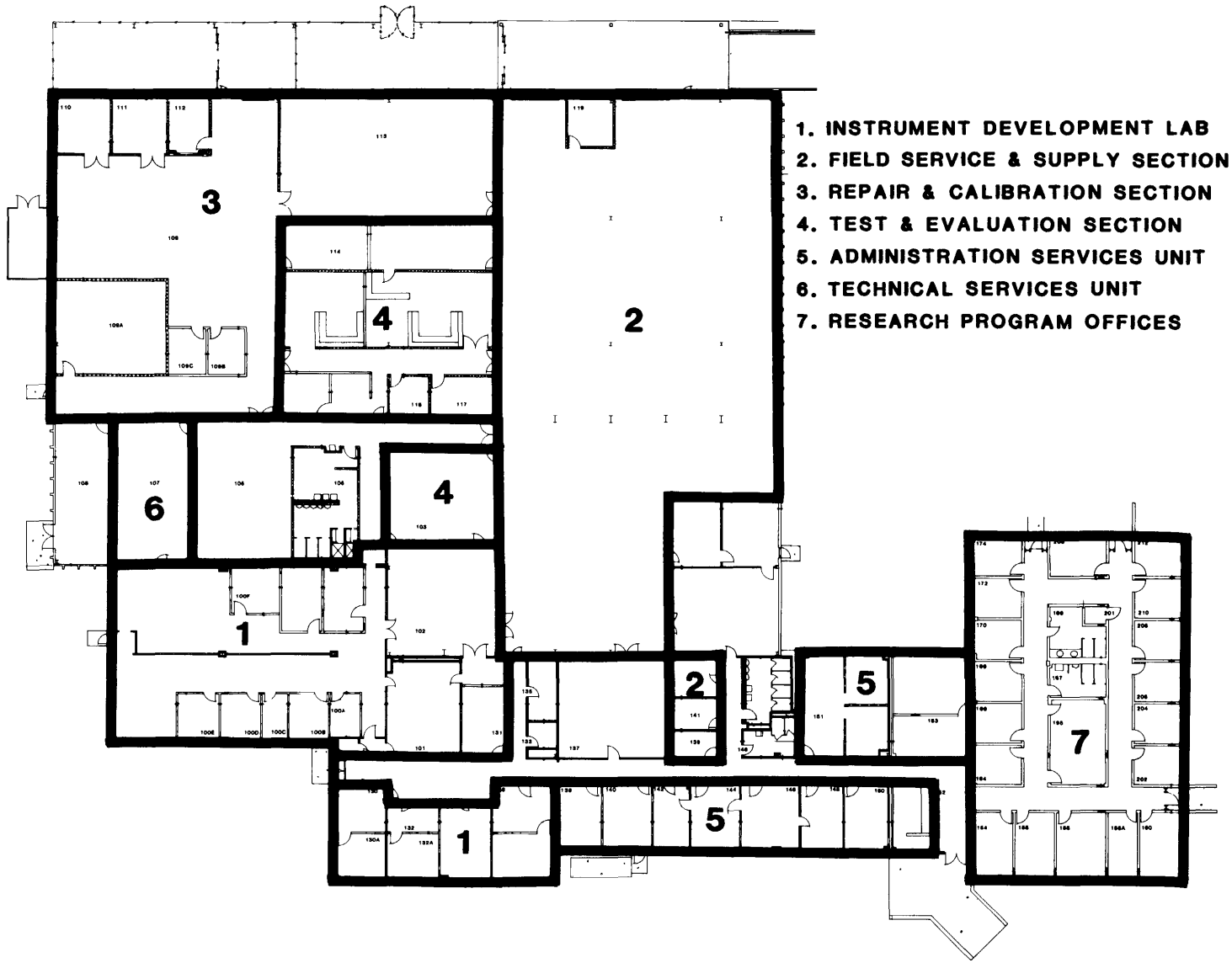


Figure 1. -- The Hydrologic Instrumentation Facility.

Many new technologies offer exciting possibilities for unique field instrumentation, but some do not meet performance requirements or are too expensive. It may be desirable to develop instruments with several levels of sophistication with corresponding levels of accuracy and overall performance capability. The tradeoff between cost, accuracy, and performance needs to be closely monitored to ensure that the Geological Survey's credibility is maintained.

The HIF has developed, and will continue to update, a comprehensive set of environmental specifications to ensure reliable field performance of instrumentation. These specifications define the field operating conditions that equipment must meet, including temperature, humidity, wind, dust, sunlight, vibration, electric power fluctuation, electromagnetic interferance, among other factors. These considerations are included along with other product design critera.

## INSTRUMENT DEVELOPMENT

The HIF responds to both the long-range needs of upgrading the Geological Survey's hydrologic field-data-acquisition capability and high-priority special projects for unique data-acquisition devices. The Instrument Development Laboratory (IDL) serves as HIF's principal research and development resource for hydrologic instrumentation by:

1. Updating and modifying existing instrumentation to take advantage of improved materials or technology;
2. continuing development of instrumentation compatible with equipment owned by the Survey at the existing level of technology; and
3. performing research and design of totally new instrumentation that will anticipate the state of the art for future instrument packages.

Research, design, and development are conducted in-house (fig. 2) as well as by contract. Survey personnel have responsibility for developing performance criteria, statements of work, and monitoring contracts for outside development.

IDL staff is exploring advanced technologies that include:

- Measurement of fluid flow by electromagnetics and acoustics;
- noncontact means of recording water levels, including measuring distance by lasers and ultrasonics;
- pressure transducers for water-level sensing;
- water-quality sensing devices;
- suspended-sediment measurements using ultrasonic, infrared, and X-ray technologies.

The demand for hydrologic instrumentation usually is not large enough for the private sector to invest development funds for complete systems that meet Geological Survey requirements; therefore, it has frequently been necessary to modify commercially available components, or to develop custom interface units to adapt these components to

Figure 2. -- Fabrication of prototype electronic circuit board.

Geological Survey needs. In the past, problems have been encountered that include:

- nonstandard power supplies;
- limited component interchangeability;
- lack of well-defined performance standards;
- frequent loss of sources of supply of major components.

To improve this, the HIF is taking the systems-engineering approach so that future instruments will be interchangeable and compatible. Compatibility with the Geological Survey's new interactive data processing computer systems also will be a required design criterion.

The Adaptable Hydrologic Data Acquistion System (AHDAS) currently is being developed to serve as the recorder of the future. It is a modular microprocessor-controlled solid-state recorder that can easily be modified to accept various input sensors and output devices (fig. 3). The microprocessor will enable the unit to control sensors and peripheral equipment and perform internal data compaction routines. Future activities will enhance and expand this suite of instruments.

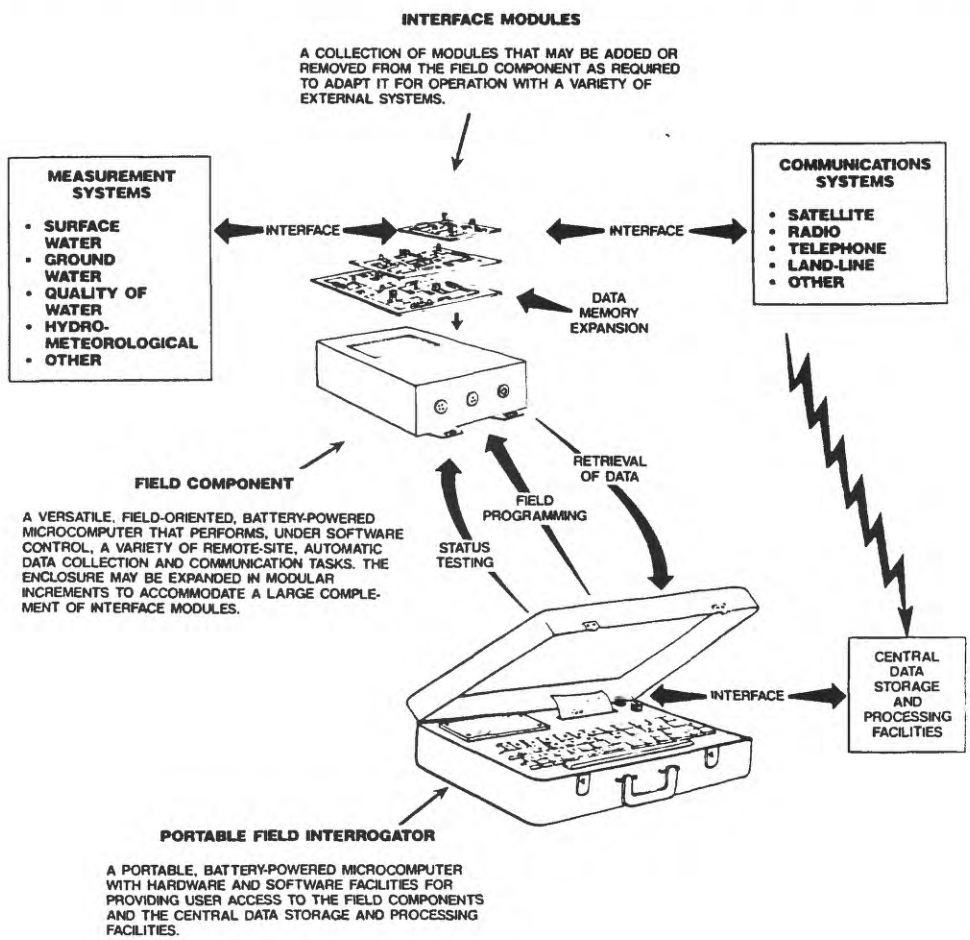


Figure 3. -- Adaptable Hydrologic Data Acquisition System provides a systems approach to the next generation of instruments.

HIF personnel set drafting standards and develop drawings of all new and modified instrumentation, and update old drawings and specifications when changes are required (fig. 4). Drawings are microfilmed for ease of reference and storage and as a safety measure should a catastrophic accident destroy the original line drawings. Also, written specifications are developed, primarily for procurement purposes.

Fully equipped electronics and machine shops allow prototype fabrication of in-house developed instrumentation. Custom fabrication or modification of standard instrumentation for a particular field application can be accomplished in these shops. Engineering design services for these custom applications are provided by HIF personnel or fabrication can be accomplished from drawings or sketches submitted by field personnel.

Figure 4. -- Drafting work fulfills an important supporting role in all Hydrologic Instrumentation Facility activities.

## QUALITY ASSURANCE

Laboratory and field tests of prototype instrumentation are a major part of HIF development activities. Cooperative field testing by Geological Survey offices as well as the HIF is critical to the successful integration of new instruments and technologies into the Geological Survey's hydrologic-data-acquisition program.

To ensure satisfaction of Geological Survey performance requirements, HIF personnel test and evaluate a wide range of commercial products, as well as newly-designed Water Resources Division instrumentation, under carefully controlled laboratory conditions. The HIF operates several environmental test chambers that can simulate temperature and humidity typically encountered in the field. HIF also operates an open-channel facility on the nearby Pearl River, where instrumentation is tested under field-operating conditions (fig. 5). The complete range of test equipment that supports the HIF Quality-Assurance program includes Rockwell metal hardness testers, X-ray equipment, chemical composition test equipment, oscilloscopes, frequency counters, and logic analyzers, as well as standard reference measuring tapes, thermometers, timers, and other equipment traceable to the National Bureau of Standards.

Many pieces of hydrologic instrumentation, particularly water-level instrumentation, and water-quality meters, are bought directly from private vendors by Survey field offices. In the past there was insufficient independent technical information available to guide procurement of these systems; the HIF has instituted a Qualified Products program to alleviate this problem. Operational and performance specifications have been developed which vendors can match against their products and submit them for critical testing against these specifications. Those that meet or exceed the standards, are added to the Qualified Products List. Survey offices can order any item on the list and be certain of quality instrumentation. This program meets all requirements of the Federal Procurement Regulations. The HIF is cognizant of the importance of Quality Assurance, and is presently planning a comprehensive program that will impact on all aspects of HIF operations.

Figure 5. -- Instrument test facility located on the Pearl River, NSTL, Mississippi.

Prototype instruments are commonly placed in field locations selected because of specific program needs or environmental conditions. This allows field personnel to lend their technical expertise to the evaluation of the effectiveness of a new instrument before it is included in the HIF inventory.

The combination of testing in the environmental chambers, where extremes of field conditions can be simulated, and operation at the HIF field station and in various locations throughout the country, has proven effective in providing reliable products to users.

## PROCUREMENT, WAREHOUSING, AND DISTRIBUTION

The HIF operated warehouse is a nationwide facility for the distribution of hydrologic instruments and allied equipment to Geological Survey field offices (fig. 6). The HIF is the only source of supply for many instruments and, therefore, serves as a supplier of these products to state and local Geological Survey cooperators and to Federal agencies throughout the United States. Equipment also is furnished on a reimbursible basis to various countries through the United Nations and programs of the Agency for International Development.

Currently, there are over 700 different types of instruments, components, and allied equipment stocked in the warehouse (fig. 7). Items are built to Geological Survey plans and specifications or require tight quality-control procedures to ensure that data-collection standards of the Geological Survey are met.

A purchasing unit provides support for the replenishment of warehouse stock, as well as for all the internal procurement needs of the HIF. Many procurement requests involve state-of-the-art components, or items that are not easily located or readily available. In 1983, 1300 individual purchases were made at a cost of $3,000,000.

The HIF shops build specialty items for the HIF warehouse. Usually, products fabricated in-house are made in very small quantities or the specifications are not suitable for competitive procurement.

Quality-control inspections are performed before stock is accepted and placed in the warehouse. The scope of the quality-control effort varies with the complexity of the product. Quality-control inspections are conducted according to procedures recognized by the National Bureau of Standards, by the American Society of Testing and Materials, and by other professional organizations.

The warehouse activity is supported by an interactive computer network that allows Geological Survey offices to check equipment price and availability, place orders, and verify resulting accounting transactions and property transfers via computer terminals. This computerized support includes data on inventory and property control, contract monitoring, rental program equipment tracking, as well as the automation of many of the accounting functions associated with the HIF.

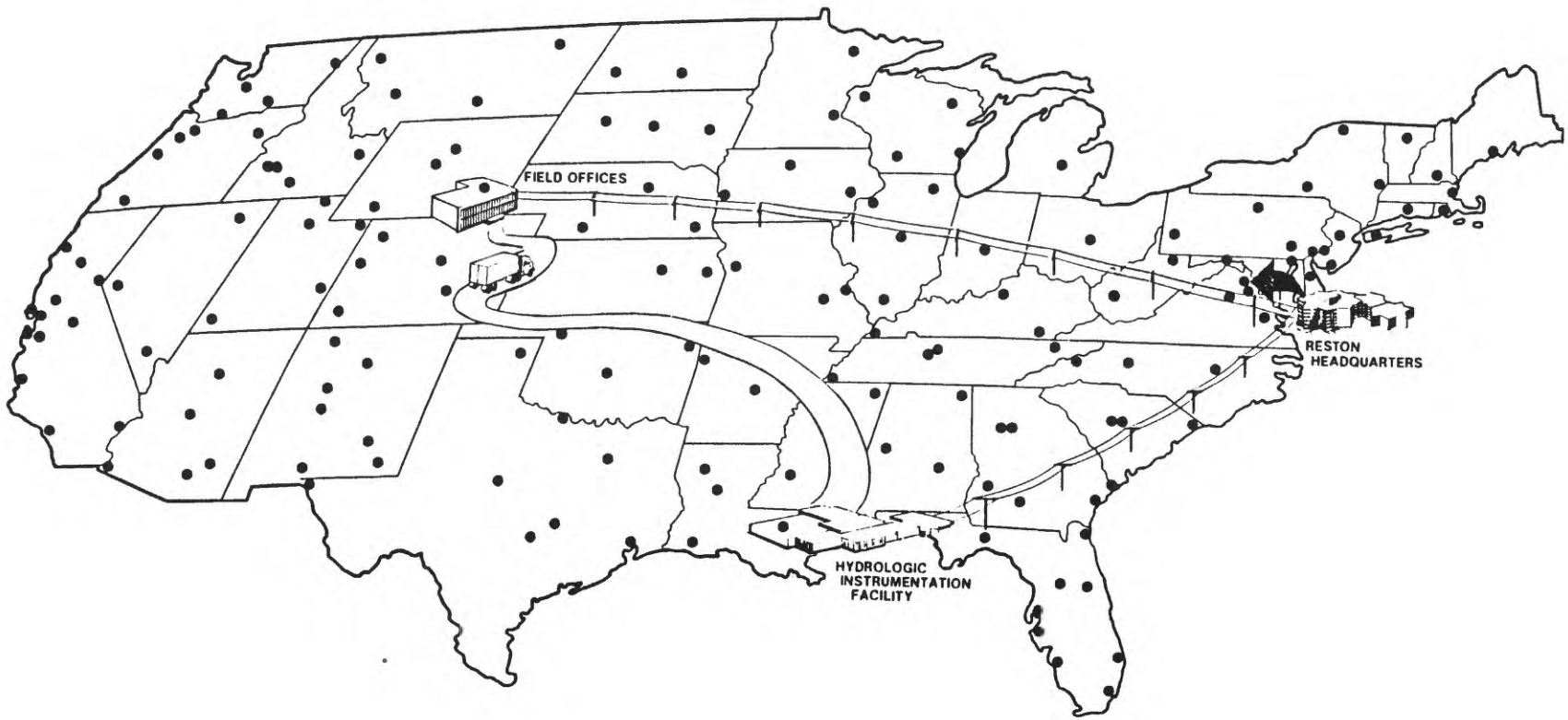


Figure 6. -- Location of U.S. Geological Survey field offices.

Figure 7. -- The Hydrologic Instrumentation Facility warehouse.

## Equipment Rental Program

In most cases, HIF warehouse equipment is sold to field offices; however, the HIF maintains a rental program for some hydrologic instrumentation. The equipment-rental program includes responsibility for procurement, distribution, and maintenance of equipment. The program offers flexibility by allowing field offices to rent equipment in response to immediate needs. It allows program expansion without large capital outlays and shifts unneeded equipment away from a declining or completed program. The rental program includes selected items that are not routinely used or are too expensive to purchase for short-term projects, as well as recorders and water-quality monitors, as described below.

### Analog Digital Recorders

The Analog Digital Recorder (ADR) has been the primary instrument for water-level data collection in the Water Resources Division for two decades. Approximately 14,000 ADRs are in field service. The ADR is a battery-operated electromechanical recorder designed for float or manometer drive (fig. 8). Output capabilities are available for remote telemetry of data by telephone or satellite. The main-

Figure 8. -- U.S. Geological Survey minimonitor attached to an Analog Digital Recorder.

tenance of such a large quantity of recorder units requires a considerable inventory of spare parts and peripheral accessories. Approximately 1500 units are rebuilt or repaired by the HIF each year (fig. 9).

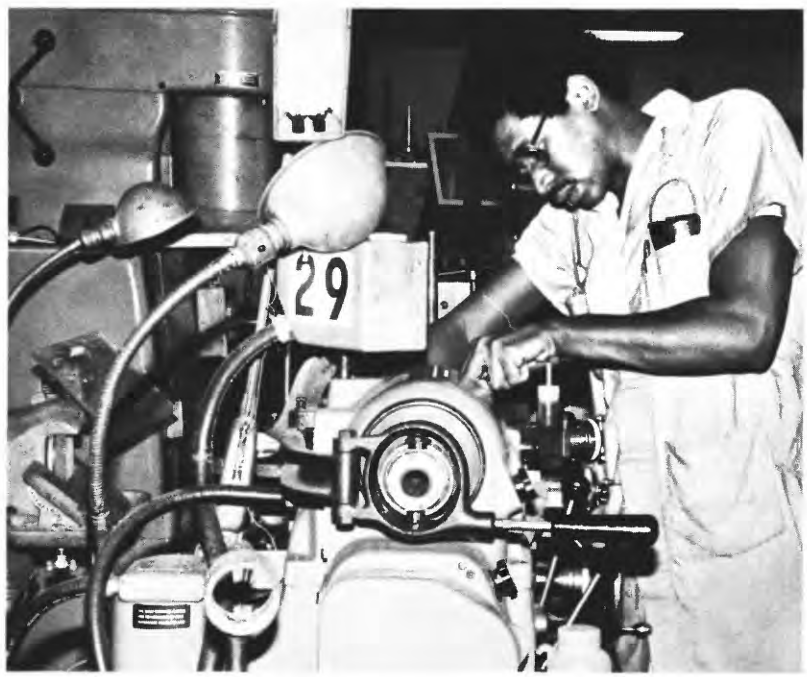

Figure 9. -- Machinist operating a lathe in the Hydrologic Instrumentation Facility repair shop.

## Water Quality Monitors

Nearly 450 water-quality monitors are rented to WRD field offices. Two types of monitors are provided, both of USGS design. One is a flow-through type, which is housed in a building near a stream or lake. Electric power is required to operate the monitor and pump. Water is continuously pumped through the unit which senses and records values on an ADR. The other type is a smaller battery-powered unit, known as the minimonitor, which operates with the sensing probes installed directly in the stream or lake (fig. 8). Both monitors are capable of sensing and recording temperature, conductivity, pH, and dissolved oxygen. Sensors for several additional parameters are available by special request.

## Equipment Redistribution

The HIF operates a redistribution activity for surplus instruments originally purchased by field offices. This equipment is refurbished at the HIF and made available for other field applications. Unrepairable equipment is disassembled and useable parts are retained for future use.

## REPAIR AND CALIBRATION

Repair and calibration services for most types of hydrologic instrumentation can be accomplished in the HIF shops (fig. 9). Repair and calibration services are available to field offices for servicing their equipment on a straight time and materials basis; rental program items are maintained and calibrated with the cost of these services paid from rental program income.

Some repair and calibration services are contracted out by the HIF to shops that have specialized facilities.

## TECHNOLOGY TRANSFER

Communications with field offices is an important element of HIF activity, to provide for integrated hydrologic instrumentation support. In 1982, a full-time position of field coordinator was established, intended to serve as the first point of contact on any instrumentation problem. The field coordinator is responsible for follow-up on all inquiries to the HIF. Technical assistance includes answering requests on availability of instrumentation, field calibration of instruments, and the development of special purpose equipment unique to a single project application.

HIF staff offer briefings and presentations on HIF activities to Geological Survey offices and participate in regional meetings and training programs. Visits of field technicians to the HIF present an opportunity for exposure to the facility's many services and allow technicians to discuss their unique instrumentation problems with discipline and equipment specialists. Conversely, these visits expose HIF staff to instrumentation problems encountered in the field.

The HIF, in cooperation with the Geological Survey's Office of International Hydrology, offers training in hydrologic instrumentation development and applications to foreign hydrologists and engineers.

HIF staff report contributions on improvements to hydrologic instrumentation in Geological Survey report series such as Water-Resources Investigations reports and Techniques of Water-Resources Investigations, and also in various professional and technical journals. Many of the publications prepared by the HIF are designed to serve as a training tool for the field application and operation of hydrologic instruments.

The HIF prepares and distributes operating manuals to guide Geological Survey personnel in the operation, maintenance, and field calibration of warehouse-stocked instrumentation. In addition, an internal newsletter is published bimonthly and distributed widely throughout the Division to give status reports on HIF activities, hints on special problems, articles on how field personnel have solved problems, and

other timely notes related to Water Resources Division instrumentation. Field personnel are encouraged to submit articles or comments on HIF activities for inclusion in this newsletter.

## LONG-RANGE INSTRUMENTATION NEEDS

Considerable time and effort are required to research, design, develop, and deploy new instrumentation. The HIF staff, working with the Instrumentation Coordinator and the Instrumentation Committee try to anticipate future Water Resources Division program thrusts and to develop instrumentation support that will meet the data-collection requirements of those programs. Suggestions for new or improved instrumentation are actively solicited from all Water Resources Division personnel. Expected high-priority equipment needs of the Water Resources Division for the remainder of the 1980's include, but are not limited to:

- Reliable water-quality sensors for additional constituents;
- noncontaminating pumps to obtain water-quality samples from small-diameter wells;
- atmospheric deposition instrumentation;
- satellite data-relay systems, with ability to monitor operation of entire field instrumentation package;
- sensors to collect hydrologic and meteorologic data at lake, reservoir, wetland, and estuarine sites;
- sensors to measure ground-water levels in deep, small-diameter wells;
- automated or semiautomated measurements of suspended sediment in streams;
- improved techniques and instrumentation to support water-use studies;
- semiautomated water-quality analyzers for field installation;
- improved sensitivity and reliability of basic sensors in general.

## SUMMARY

The U.S. Geological Survey has made a major commitment to upgrading instrumentation in the 1980's. The Hydrologic Instrumentation Facility was established in 1980 and given nationwide responsibility for research, development, testing, evaluation, procurement, warehousing, distribution, repair, and calibration services for Water Resources Division instrumentation. The reorganization of these activities into a single facility has resulted in improved instrumentation services to the Division.

The HIF staff includes individuals with field experience in surface water, water quality, ground water, and hydrometeorological studies, as well as design engineers with backgrounds in chemical, electronic, electrical, and mechanical engineering.

To ensure reliable performance of instrumentation, standards that have been established and will be continually updated to assure the

Geological Survey's data collection credibility is maintained. These standards set benchmarks against which commercial products are evaluated and new instruments are designed and developed.

Research and development of hydrologic instrumentation addresses three levels of activity:

- Update and modify existing instrumentation to take advantage of improved materials and technology;
- continued development of instrumentation compatible with equipment owned by the U.S. Geological Survey at the existing level of technology;
- research, design, and develop new instruments that will lead the state of the art for instrumentation packaging.

Research and development activities are conducted in-house and by contracts with public and quasi-public research groups, and private companies.

A Quality-Assurance program has been designed to monitor the accuracy and reliability of HIF-supplied equipment. This program is supported by test and evaluation activities under controlled laboratory and actual field conditions.

The HIF warehouse stocks over 700 different types of instrumentation, components, and allied equipment that are built to Geological Survey plans and specifications or meet other strict quality standards.

Over 4,000 orders are placed annually by Geological Survey field offices as well as other Federal agencies needing the specialized hydrologic instrumentation. In addition to equipment available for purchase, the HIF manages a rental program for field recorders, water-quality monitors, and allied equipment.

A purchasing unit provides support for the replenishment of warehouse stock. Purchases in 1983 totalled $3 million.

Some warehouse-supplied equipment is fabricated or adapted for specialized application in the HIF electronics and machine shops. These shops also provide repair and calibration services to field offices of the Water Resources Division throughout the United States.

Discipline and equipment specialists provide technical assistance to field personnel in the operation and application of hydrologic equipment and are responsible for preparation of operations manuals, scientific and technical reports, training programs, briefings, and presentations on Hydrologic Instrumentation Facility activities.

To facilitate an effective program in instrumentation support, long-range planning is of major importance. Based on perceived data collection needs of the future and anticipating technological developments the HIF staff, working with the Instrumentation Committee, has identified those needs it expects to address for the remainder of the 1980's.

Planning for long-range needs and seeking a systems-engineering approach to future instrumentation design is expected to ensure a continued supply of accurate and reliable equipment.

The consolidation at the HIF of instrumentation functions has provided the mechanism for efficient and effective support to the Geological Survey's hydrologic programs.