In ancient Egypt, water managers trekked arduous miles to collect data from the Nile using only crude staff gauges. Today’s water resource managers receive real-time water data from far away without leaving their air-conditioned offices. They are beneficiaries of four modern telemetry options: phone modems, cellular modems, line-of-site (LOS) radios, and satellites.

Phone modems, cellular modems, LOS radio, and some satellites provide two-way communication links between the user’s office location and remote data-collection sites. Two-way communication allows users to “poll” Data Collection Platforms (DCPs) remotely for real-time information at one site or many. Control signals can also be sent to the stations.

**Phone Modems**

Phone modems have two primary advantages: They are readily available and very affordable, between $400 and $900. A recent system developed for a county government included ten river gauging stations equipped with telephone modems. The telephone modems added only about $700 to the cost of each station. Telephone service was about $50 per station per month.

With only a PC, an operator can connect to each station to download its log, view live data, or access the station set-up. More powerful software enhances system functions. With it, remote sites can be polled automatically 24 hours a day on a specific schedule. All station data can be automatically stored in a relational database for real-time viewing, Web posting, or future study and processing. Alarms can be sent from the site to a pager or phone as well as to a PC, where they can automatically trigger a control task at the site. Additionally, stations can be configured to accept telephone calls and report — “speak” with pre-recorded voice messages — the exact sensor values at the time of the call.

A primary disadvantage of phone modems is the lack of telephone service to sites. Also, phone modems have not proven as reliable as other forms of telemetry. This is because phone service in rural areas is sometimes unreliable and DCPs connected to long telephone cable runs are more susceptible to lightning damage.

**Cellular Modems**

Cellular modems provide the same features and advantages as phone modems, but cellular service is available in many places where wire-line telephone service is not. Both the hardware and the cellular service have proven very dependable in most cases, but care must be taken to ensure adequate signal availability at the DCP location. Also, cellular carriers sometimes make system changes that enhance system coverage overall but may actually decrease coverage in a specific location.

Disadvantages include recurring cellular phone bills and the fact that cellular modems use significantly more current to transmit voice and data than do phone modems; this must be taken into account when configuring solar and battery components that power most sites. Changing cellular technology is also an issue. Migration to digital cellular and the lack of a single nationwide digital cellular protocol requires that users be careful about the equipment they buy and be knowledgeable about the cellular services available in their area.
Southeast Mexico. Soon, hydrologic monitoring by the USGS thus provides opportunities for understanding the hydrology of the heavily suburbanized Temecula basin immediately upstream, and Santa Margarita River, as it enters the reserve, derives from the streamflow gauging stations above and below the reserve. The USGS has long-term oxygen at one central location, and the USGS has long-term data-transmission capabilities at SMER to obtain real-time access to their research projects and to test wireless methods for use elsewhere. While much of the research at SMER has an ecological focus, researchers in other disciplines are finding the site’s protected, undeveloped setting and wireless communication facilities well-suited to their needs. A group that includes researchers from Scripps Institution of Oceanography at the University of California San Diego (Scripps), the U.S. Geological Survey (USGS), and the San Diego Supercomputer Center (SDSC) worked at SMER to develop a program to answer questions about the water balance and variability of weather and water in the Southern California landscape. In addition, they are monitoring airflow and other meteorological properties related to airborne pollutant loadings and sources of water and air pollution.

Precipitation, wind speed and direction, air temperature, relative humidity, barometric pressure, and solar radiation are currently being collected at SMER, with additional parameters on the drawing board. To date, 20 meteorological towers have been installed and are presently being outfitted with sensors, specially designed data loggers, and spread-spectrum radios. This array should provide some of the highest-density information yet collected over a coastal Southern California watershed.

The SMER staff is currently measuring stream pressure (to calculate stage), temperature, conductivity, and dissolved oxygen at one central location, and the USGS has long-term streamflow gauging stations above and below the reserve. The Santa Margarita River, as it enters the reserve, derives from the heavily suburbanized Temecula basin immediately upstream, and thus provides opportunities for understanding the hydrology of a suburban-rural interface. Soon, hydrologic monitoring by the Scripps-USGS researchers will include stream stages (to calculate stream discharge), water temperature, and conductivity (to estimate total dissolved solids) at several locations along the main stem of the river and in some of its tributaries, including Stone Creek, an unregulated drainage that is relatively unaffected by development. The tributary observations are intended to characterize the near-natural variations of Southern California runoff.

The network of hydrometeorological stations is currently connected to the wireless Internet through three TC sites. These sites receive radio signals from data logger stations as short-range spread-spectrum signals and convert the dataflow into a wireless Internet protocol. The TCs then transmit the information into the intra-SMER wireless network, which, in turn, is connected to HPWREN, the noncommercial High Performance Wireless Research and Education Network (see page 16) that provides Internet access to the SMER data.

The weather elements are sampled once per second and averaged each minute. Data are stored at SDSC and eventually will be available from the Western Regional Climate Center. The data are available to the public through the ROADNet Web site, at roadnet.ucsd.edu/.

The Scripps researchers and their partners plan to use weather and stream data to investigate microclimates, temporal and spatial variations of storms, sea breezes and Santa Ana winds, and water balances as the basis for water and air quality studies. The effects of evapotranspiration on the discharge of the Santa Margarita River and its tributaries will be studied, and the water budgets of the Santa Margarita River, regulated through substantial injections of fresh water upstream of SMER, and of unregulated Stone Creek will be compared.

**Future Plans**

This fall, the research team plans to install additional meteorological towers within SMER, and in the longer term, they hope to extend the network beyond the boundaries of SMER into upper and lower parts of the river’s watershed. Eventually, they plan to couple these hydrometeorological observations into a watershed model to synthesize the water balances and other hydrometeorological aspects. With their SDSU partners, the researchers are discussing an expansion of their emphasis from the physical aspects of weather, climate, and the water balance to studies of air and water quality and to fire-protection networks. The weather towers, data loggers, and communications structures are also available to support other kinds of sensors, so it is hoped that new experimental efforts will take hold as this project evolves.

For more information, contact Dan Cayan at dceyan@ucsd.edu, Mark VanScy at mvanascoy@sciences.sdsu.edu, Michael Dettinger at mddettin@usgs.gov, or John Helly at hellyj@sdsc.edu. The Scripps-USGS-SDSC hydrometeorological research at SMER is supported by the National Science Foundation through the ROADNet Project, the California Institute for Telecommunications and Information Technology (CalIT2), the NOAA Office of Global Programs through the California Applications Program, and the California Energy Commission through the California Climate Change Center at Scripps Institution of Oceanography.
LOS Radio Systems

LOS radio systems require investment in infrastructure beyond the radio module inside the DCP. A base station, appropriate software, and repeater stations to provide a radio frequency path from the base station to the DCPs can add significant cost to such a system. Therefore, LOS radio systems are often larger systems where the number of DCPs justifies the fixed infrastructure investment. LOS is often used for flood-warning systems where immediate communication of hazardous conditions is critical. A simple LOS radio system (including automatic polling software) where all DCPs are line-of-site from the base station can add $500 to $2,000 to the cost for each DCP. A base station, including software, usually costs from $5,000 to $10,000. More complex systems involving additional repeater sites are, of course, more expensive.

Traditionally, LOS radio systems communicate on a dedicated network. Irrigation systems, river control systems, and groundwater pumping and diversion systems exist with more than 100 DCPs sending water data and receiving control signals to manage water movement. Infrastructure costs for some of these systems exceed $100,000.

Several frequencies and technologies exist for use in an LOS radio system. Factors contributing to a decision on whether to purchase an LOS system include regulations specific to a user’s agency or industry; terrain; distance to remotes; and electrical environment at the DCP and base station sites. In general, lower frequencies cover greater distances, but can be subject to interference from other communications in the area. Spread-spectrum technology is generally less prone to interference because alternate communication channels are available. However, selection of the best approach is best left to consulting engineers who specialize in the design of radio frequency systems.

Once installed, LOS radio systems do not have the recurring expenses of cellular or phone systems.

Satellites

Commercial and government satellites are available for transmission of environmental telemetry. The most commonly used satellite telemetry for hydrographic data is a one-way communications link, although two-way satellite service is available commercially.

The National Oceanic and Atmospheric Administration (NOAA) operates two Geostationary Orbiting Environmental Satellites (GOES) in a Data Collection System (DCS). Use of the GOES DCS is regulated, by law, to the collection of environmental data by federal, state, and local government agencies, and by international government agencies and research organizations with a U.S. government sponsor. More information on becoming a GOES user is available at the agency’s Web site at noaasis.noaa.gov/DCS/htmlfiles/howto.html.

Available virtually everywhere, including locations where phone and cellular service is nonexistent, GOES satellites offer numerous advantages for data collection applications meeting NOAA’s criteria. Users can download their data from NOAA’s site. Large system users frequently use commercial software to download their data automatically, receive and respond to alarms, and automatically store all station data in a relational database for viewing, Web posting, and future study and processing. Other users invest in base station equipment that can receive a rebroadcast of the GOES data. Operators of mission-critical systems may want their own equipment to receive their data directly from the GOES satellite.

GOES has no recurring costs and is free for those who qualify. The new High Data Rate GOES transmitters range in price from about $2,300 to $2,600. As of July 2003, at least one transmitter also has data-logging capabilities and can operate as a fully functional DCP.

Although the GOES DCS is currently a one-way system, it has proven to be very reliable and the most cost-effective data-collection solution for a majority of water resource managers. More than 22,000 actively transmitting DCPs use the system.

GOES DCPs transmit their data on pre-assigned channels at specific times, generally every four hours (some stations report hourly). Because GOES DCPs transmit at a specific time on shared channels, problems can occur if timing is not accurate. One GOES DCP may transmit during part of another DCP’s time slot. This can cause missed messages. Fortunately, new GOES DCPs get their timing signals from GPS satellites, so timing problems are quite infrequent. When problems do occur, they can usually be solved very quickly by users working with their vendor’s customer service technicians and the satellite agency. Some GOES DCPs are permitted to transmit alarm information immediately. GOES DCPs cannot be polled and no control signals may be sent to them.
Five sites in the Southwest will participate in the demonstration program. Rimrock, Arizona and Nambe Pueblo, New Mexico will test the granular ferric oxide technology of Adedge Technologies Inc. The water system of Valley Vista, Arizona will test Kinetic’s activated alumina treatment process. In Anthony, New Mexico, Desert Sands Mutual Domestic Water Consumers Association will test Severn Trent’s iron media and the capabilities of U.S. Filter’s iron media will be demonstrated in Reno, Nevada at South Truckee Meadows General Improvement District.

The EPA will not provide direct funding for the demonstration program. Instead, the agency will purchase equipment and engineering services and pay for the installation of the equipment at the sites. EPA will also purchase and provide supplies such as chemicals or media if needed.

Visit www.epa.gov/ORD/NRMRL/arsenic/research.htm for more information.

USGS Reports Record Low 2002 StreamFlows in AZ

A compilation of surface-water, water quality, and groundwater data for water year 2002 (October 2001 to September 2002) was released in May by the U.S. Geological Survey in Tucson, Arizona. The report was prepared in cooperation with other agencies and the State of Arizona. According to the report, annual mean streamflow at 29 of 201 streamflow-gauging stations (14 percent) in Arizona during the 2002 water year was the lowest on record. Three of the stations are on the Verde River in central Arizona and 19 are on tributaries of the Verde, Salt, or Gila rivers. Yearly discharge at five key gauging stations during water year 2002 ranged from 29 to 57 percent of the median of yearly discharges computed for the period 1950 to 2002.

The report contains:
• discharge records for 201 streamflow-gauging stations, 29 crest-stage, partial-record streamflow stations, and 48 miscellaneous sites;
• stage or content-only records for 10 lakes and reservoirs;
• water-quality records for 21 streamflow-gauging stations and 65 wells; and
• water levels for 18 wells.

The report was released in printed form and is also available online at pubs.water.usgs.gov/wdrew02fl.

Telemetry, continued from page 15

Commercial satellite services offer two-way communications to those users who need to “talk” to their DCPs and who are outside the service area of landline and cellular service and for whom an LOS radio system is impractical.

A satellite phone behaves much like a phone modem. Users can dial into their DCP and manually download data or use software to automate this process. Some satellite services provide an Internet protocol (IP) connection to the DCPs using the more expensive phones, allowing the DCP to send data at any time. Basic satellite phone modems communicating at 2,400 to 4,800 bps cost around $1,500 to $4,000. Phones with higher data rates can cost as much as $10,000. Monthly service charges range from $45 to near $100 per month for low-volume data, and can exceed $100 per month if extended periods of station communication occur frequently.

A key advantage of commercial satellite service is two-way communication, which provides the ability to interact with the DCP to change parameters in its setup or to send control signals. Also, technicians have voice communications available to them at the DCP site. Disadvantages are recurring costs and power consumption. Compared to a GOES DCP, some satellite phones require augmentation of the battery and solar panel size by a factor of three or greater, increasing the site cost significantly. Care must also be taken to ensure interoperability of the data logging equipment and the satellite phone. Reliability for systems using geostationary satellites is very high.

Location, terrain, time sensitivity of the data, and budget are primary factors to consider in deciding which telemetry to use. Consulting engineers, equipment vendors, and other water management agencies can provide information to help you in this process.

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ROADNet, continued from page 17

across a network of heterogeneous storage systems. The information discovery system allows users to find data, including data that they might not have known existed, by searching on geographic location or sensor type, and to extract data based upon characteristics rather than location. The data analysis system allows the collection and performance of operations on data and data streams that are stored in different locations as if they were all from a single location. The ability to extract metadata from real-time data flow is anticipated as a future enhancement.

The San Diego Supercomputer Center’s Storage Resource Broker (SRB) provides the interface for ROADNet’s connection of heterogeneous data sources via HPWREN, as well as acquisition of data from other storage locations. In conjunction with the Metadata Catalog (MCAT), the SRB provides users with an efficient means to access data sets and resources based on their attributes rather than their names, disciplines, or physical locations.

Additional information on the HPWREN system is available at hpwren.ucsd.edu.