INFORMATION TECHNOLOGY TODAY AND TOMORROW FOR MANAGING WATER RESOURCES

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INTRODUCTION

From wireless communication to the Internet, the information age with advanced digital electronics and sophisticated software offers a plethora of tools for water resources managers. Let us review "state of the art" technology now available, problems and priorities for equipment suppliers, and speculate where future developments may take us.

During this past winter and spring, the deficient snowpack in the Northwest generally, and in Northern Utah more locally, received plenty of attention in the news. The Utah State Department of Water Resources has responded with increased attention and support for policy changes in water districts and municipalities that encourage the conservation of water resources. A recent news broadcast reported that rates for water use in the Salt Lake area would be increasing substantially, that measures were being considered to charge a premium for excessive use, and that landscape ordinances should be reconsidered to encourage native vegetation. My mind caught hold of the thought of native landscaping. The kids are grown so my family doesn't need as much lawn. If I planted sagebrush in the yard, I wouldn't have to water it, I wouldn't have to mow it, and I might even find that it is socially acceptable with the neighbors as a native landscape! Now I just have to convince my wife.

A water-short year like the one we are having affects more than just how we water our lawns or the rates charged for water use. The snowpack is always watched by local farmers who use runoff for irrigation, and this year we are seeing dramatic affects on a tight energy market in the western United States with a reduction in available hydroelectric power. It is times like these when we should be asking, "Is the right information available in a timely manner to the decision makers?" That's what all the investment in information technology is about.

THE DECISIONMAKERS

My first experience with water resource decision makers came at an early age. When I was a teenager, water from a local canal was turned into a ditch by opening a headgate and then routed to irrigate my parents' lawn and vegetable garden. My father assigned me the responsibility of weekly irrigation. I was to check with the water master to confirm a designated time. This routine was interrupted one summer by the city carrying out repairs on a sewer line in the area, and to be sure there would be no disruption of their work by inadvertent flooding, they put a padlock on the headgate at the canal. Dad was upset and saw no reason, with appropriate precaution, why the ditch near their construction site couldn't be dammed off and irrigation resumed, but the Mayor didn't agree. After a heated phone conversation including the threat of arrest if the padlock were removed, Dad loaded the cutting torch into the back of the pickup and headed for the canal. He later told me that he changed his mind before he got there because he thought his arrest would not be respectable for the family. I don't suppose in the annals of history it would have been the first arrest over a water dispute. Who are the decision makers affecting our use of water?

They are the end users with a specific requirement. At the retail or residential level, they usually open a valve and expect water to be there. Often, we don't think about using water directly when we start the dishwasher or clothes washer. The information required for these decision makers usually relates to a direct need at hand, and the availability of water is almost taken for granted, at least in much of the United States.

Other decision makers are those who are in the supply chain of daily water delivery. They regulate flows and pressures. They monitor water quality and make treatment decisions. They work to assure supply to their customers. The information required for these decision

makers usually relates to immediate need based on use by customers served, and immediate availability is usually provided through long-term investment in delivery and treatment systems.
Another level of decision makers is those who allocate, regulate, and approve water use in the executive branch of government. They carry out policy under the law by issuing (or denying) permits for use. Their need for information relates to allocation over years, or indefinitely, so long as use is consistent with the permit. They also require information on quality and quantity to verify that use is consistent with the law. They interface with other executive government bodies to form agreements, and to be effective they need specific information regarding water resources.

The last level or group of decision makers I will mention are those who make laws and policies governing water resources and adjudicate claims when there is conflict. They are usually in the legislative and judicial branches of government. The information they need relates to their accountability to those who elected them – the end users.

Each of these respective levels of decision makers use information technology (IT), and some have made and will make considerable investments. When I refer to IT in this paper, I refer to electronic measurements of water level, pressure, flow, water content in soil or snowpack, and water quality and temperature measurements; automated communication and storage of measurement values; the computer based analysis, reporting, and archival of data; and finally, the human/machine interface and machine functions of carrying out decisions or control of treatment or use, particularly automated controls. I refer to the many computer models that predict the availability and use of water resources. I also refer to the means of monitoring flood events and dam safety and warning the affected public.

VISION & OBJECTIVE

Modern democracy is based on some level of empowerment of the individual. A broader base of decision-making in modern society depends on people being well educated and well informed. The development of IT has been driven by market demand for more people to know more.

As a supplier of IT, my vision is to make available appropriate technology so that decision makers have the information they need about water resources and demands, when they need it, to make the right decision. Our objective in serving the decision maker is to gather information about resources and demands, with appropriate accuracy, reliability, and timeliness, so that the decision maker is well informed. Inform the decision maker. That's the objective.

SUMMARY OF PRESENT INFORMATION TECHNOLOGY

Benefits of modern IT not only include information on available water to meet demands, but also information about the resources. Figure 1 is an overview of IT organized into functional partitions of field data acquisition, communications, and computer systems. The logical sequence of these functional partitions is from a larger scale systems perspective, and may not fit certain cases of IT such as stand alone measurement and control. It is, nonetheless, useful for our general discussion of technologies as they fall into these respective partitions.

FIELD DATA ACQUISITION

There is an expanding frontier of wireless products affecting field data acquisition. Notice the wireless connection between GPS satellites and the field PC. We are also beginning to see small radios replacing sensor lead wiring. As the cost and size comes down, there will be more wireless sensors that will make it easier for field data acquisition -- both for those using field PCs as well as those using stationary data loggers. The future use of wireless sensor local area networks (LANs) will improve field measurements by allowing more flexibility for measurement siting and the number of sites measured. For highly variable parameters like soil moisture, this will be a nice step forward.

Innovations in data loggers in recent years allow greater amounts of data storage, as well as more flexibility for network communications. More choices abound, both for those whose work demands more sophisticated on-site processing, as well as for those more interested in saving raw time series values for subsequent processing.

Figure 1. Field data acquisition.

Figure 2

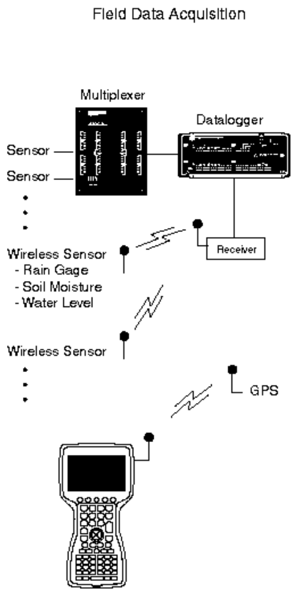


Figure 2. Field data acquisition. Field instrumentation involves sensors to measure quantity (level, flow, precipitation, content) and quality (temperature, conductivity, turbidity, etc.) of water. Depending on the number of different measurements, there may be accessory multiplexers to expand channels. The data logger with power supply and accessories are housed in a suitable enclosure or shelter. In addition to the data logger, I have included in this figure a field PC (personal computer) with GPS (global position sensor). The modern hydrographer is able to enter manual readings and notes with an integrated GPS data stream, and is also able to record boundary locations with area calculations. These notes and related data can subsequently be transferred to more sophisticated GIS databases and used in models and reports. The field PC is distinguished from related IT digital devices such as handheld or pocket computers by its robustness and design specifically for GIS applications.

Communications

Figure 3.

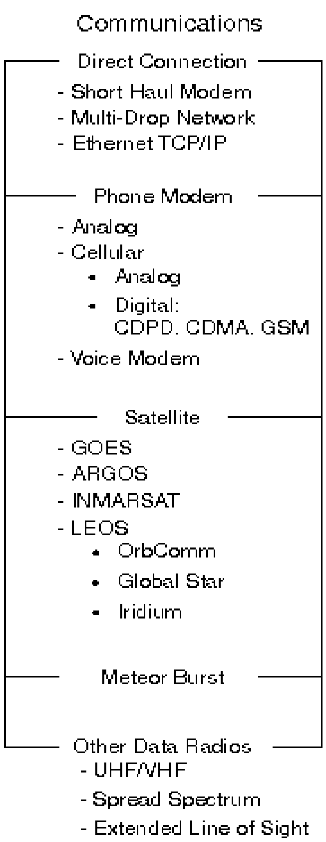


Figure 3. A summary of communications means used in today's data acquisition networks. In many systems, the investment in communications is the largest part. There may be a number of choices depending on the distances and topography of network requirements. If the network is compact, it may be served by short-haul modem, or by cabled multi-drop modems. Ethernet TCP/IP networks are now planned in most new buildings including water treatment plants.

COMMUNICATIONS

Data transfer over telephone continues to be one of the most common communication means. A modern glossary of digital broadband terms still includes POTS (plain old telephone service). For systems specifiers, suppliers, and IT managers, there is some increasing difficulty of maintaining compatibility with emerging digital IT. Phone modems designed for analog phone lines don't work on digital phone lines. New services from local exchange carriers (LECs provide end user dial tone) may include both analog and digital phone lines. Many cellular phone service networks support analog modems for data transfer. Some new cellular networks no longer support analog modems. Digital cellular networks are using different standards in the U.S., which means that when a data acquisition network is specified that uses a cellular phone for data transfer, questions must be resolved with the cellular service provider about whether or not analog modems are supported, or which digital standard is supported. Common digital cellular phone standards include CDPD, CDMA, and GSM. As a representative of industry, I'm sorry this has gotten so complicated for you. It is an example of the difficulties of moving into the future as new technology becomes available. Sometimes standards compete, and sometimes there are limits to backward compatibility.

There are additional digital cellular phone products on the horizon, although adoption varies in the U.S. by region and by carrier. These products are based on GPRS, billed as a next generation GSM standard and i-MODE based on an advanced standard used in Japan. The CDMA2000 and W-CDMA standards support third generation cellular systems not yet deployed. These advancing digital standards allow higher bandwidth communications and will allow greater capacity on cellular systems giving users fewer busy signals during periods of peak usage.

One other phone based communication product I would like to mention is the voice modem. A caller over POTS can receive information from a synthesized voice about conditions local to a data logger. Based on set-up, the conditions can be historical or current. I mention this because of the automated means now available of distributing information over the established and familiar telephone.

Satellites have been used for many years for data communication involving weather and water. Most users in the federal government have access to GOES (geostationary orbiting earth satellite). Other international satellite services commonly used are ARGOS and INMARSAT. Considerable investment has been made over the last decade in low earth orbiting satellite (LEOS) systems. It was hoped that the lower altitude of LEOS would improve radio signal strength. However, with as much as 15 years in their business investment cycle between design and profitability, LEOS systems are struggling and their future is uncertain.

Meteor Burst (MB) technology has been available for many years, and the USDA NRCS' SnoTel network is based on this technology. It is fascinating that we can bounce radio waves off ionization trails as sand sized meteorites burn up in the upper atmosphere. Though the bounce is limited in duration to about ¼ to ½ second, it is enough to sustain an exchange of data packets with two-way communication. Recent investment by the manufacturer now has MB service available for the continental U.S. and parts of Canada. Bandwidth is limited to 32 bytes every five minutes 95% of the time. Most remote hydro-meteorological measurement requirements can be met by this data transfer rate. Range is typically up to 1000 miles from a base station. As with most satellite services, a user purchases a transceiver or data modem and pays a monthly subscription based on amount of use.

Ground-based RF networks have been available for remote data access for many years. These networks have typically used VHF or UHF radios on a licensed frequency over distances of up to 25 miles line of sight. As the transfer of data without voice has driven the market, products have emerged with the integration of digital communication interfaces built into the radio. Extended line of sight (ELOS) high output (100 W) RF modems at lower frequencies (40 to 50 MHz) are available that are capable of data transfer over distances up to 50 miles, depending on topography and antenna configuration. Spread spectrum technology has made data radios more widely used without the bother of licensing. However, the higher frequencies at which spread spectrum operates don't propagate as well as lower frequency radio waves, so they are more sensitive to having a clear path free of vegetation.

As consumer markets have increased the volume of wireless devices such as pagers, and now wireless personal digital assistants (PDAs), the semiconductor industry has increased the sophistication of features available for designers of data acquisition systems. At the same time, price and size are decreasing. For short distance line of sight, the future will bring more spread spectrum data radio products in smaller sizes and at lower prices. Successful networks that use wireless communications usually have a good RF consultant

Figure 4

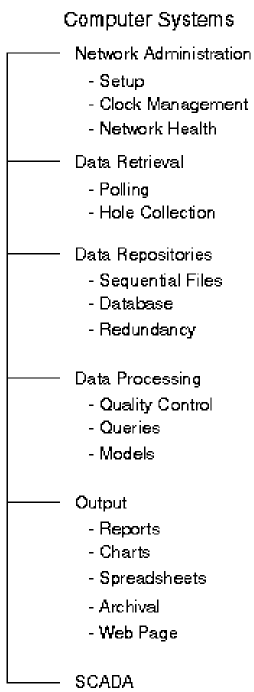
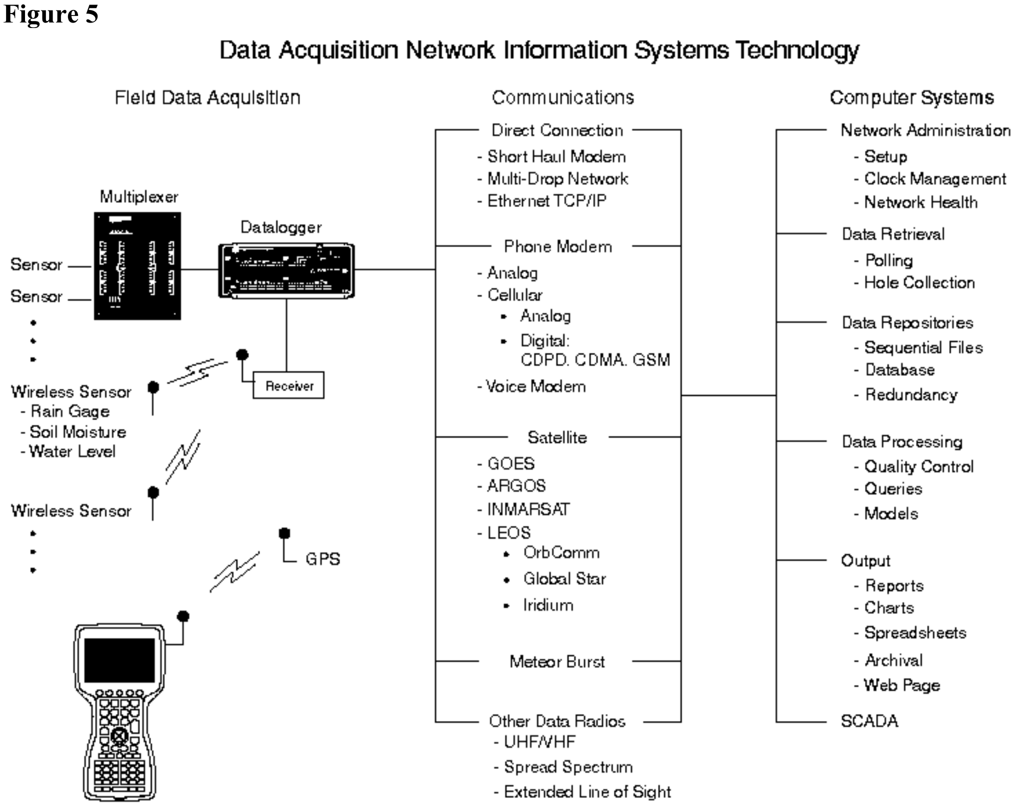


Figure 4. Functions of computer systems used for geographic and hydrologic data collection, storage, analysis, and reporting. Rather than refer to computer systems in terms of memory, processors, and storage media, the functional names refer more to user interaction with applications software, with the exception of data repositories. Most wide area data acquisition networks are built around a computer system with the ability to automatically poll remote sites, or at least as a backup, ingest data from a storage module or file on another computer. *To administer a wide area network, setups are required to specify communication links or packet routing, and a display of network health is very useful for the administrator to quickly identify links or sites having difficulty.*

Figure 5



or staff guru behind them. Problems occur ranging from interference from RF sources outside the network to adequate signal strength within the network. If you are putting in a ground-based system of much complexity, plan some budget for technical support.

For all I have said about telephone and wireless systems, a lot of data is gathered using solid-state storage modules or portable computers with site visits. If there is not a compelling requirement for near real time reporting, the equipment cost is low and site visits are used for maintenance and quality assurance.

COMPUTER SYSTEMS

Clock synchronization over a WAN of data loggers each with its own clock is an important network function. If each communication interaction is real-time and communication is two-way, this it easy. With GOES one-way communication, it may be accomplished with a GPS synchronizer now available in the transmitter. Delays in communication links of two-way WANs pose a compromise in synchronization accuracy. Imagine a data logger clock being synchronized to a computer clock over the Internet, then over an additional RF link. Synchronization of remote sites is limited in accuracy to the latency of a given communication path.

Once configured, a network central computer carries out data retrieval tasks according to the pre-set collection schedule. If a disruption in communication renders a remote site temporarily unavailable, a hole in the normal data stream is created. Hole collection is a lower priority task that allows data to be filled in when communication is restored. Data repositories range from a simple output of sequential computer files to sophisticated databases with redundancy.

Data processing may begin with splitting out certain parameters of interest from a larger table or array. Quality control is an important added value and can vary in complexity from a simple check to see if values fall within upper and lower limits to validation of consistency among measured physical phenomena (e.g. check incoming solar radiation readings against time or precipitation against relative humidity). Queries may be used to compare readings of the same physical parameter measured at the same time at different WAN sites. More common than general queries is the use of sophisticated models that integrate functions of selecting the measurements of interest, performing quality assurance, filling in assumptions if data are missing, applying algorithms, and finally generating output that integrates the information of time, measured values, and geographic location. Let me refer you to the NRCS web site for a fine example of the results of such a process.

The additional items noted in Figure 4 under "output" are self-explanatory and probably more familiar to most of you in detail than they are to me. I would like to offer some comments on the Internet. As IT goes, the Internet is a tremendous success. I use email more than the telephone because it allows time independent communication with others. Because it is widely available, it is also a great delivery vehicle for information products intended for anyone interested, or selectively through subscription. We are a group with a common interest in water resources. It would be interesting to me to know a little about our use of the Internet in this area. How many of you use the Internet regularly for news, stock market, or other information of general interest? How many of you use the Internet to browse for information on IT products? Now the big question, how many of you regularly access a web site for information about water resources or water use?

The last item on Figure 4 is SCADA (supervisory control and data acquisition). There are a number of sophisticated software packages each with salient features. The lines are blurring somewhat between data loggers, which have control functions, and programmable logic controllers (PLCs) some of which also log data. This is an example of market dynamics as technology progresses and new developments blur lines that used to define a market. Through communication standards such as OLE for Process Control (OPE) (OLE is Microsoft's Object Linking and Embedding)), SCADA software may access a combination of PLCs and data loggers to take advantage of their respective strengths.

Having made comments on features contained within each of the functional partitions of Figure 1, I hope that the overview of the whole is now more meaningful.

GETTING TO THE FUTURE

Improvements to IT come as we are working on specific, fundamental problems and see where a solution is at hand as a result of a fundamental discovery or through the application of technolog already developed. Leonardo da Vinci's discovery that flow is the product of cross sectional area and velocity was fundamental to subsequent developments in hydrology. Today, the use of wireless communication to hydrology is incremental development through the application of technology. It is not easy to look into the future and say what IT we will be using in 20 years or 50 years or 200 years. Most developments are incremental as opposed to revolutionary. We can begin by careful identification of a problem. The solution to one problem often leads to the solution of related ones.

An important dimension of the progress of technology is the emergence of standards. Standards may emerge from professional societies or organizations, or they may result from a more focused collaboration between customer and supplier. Where there is substantial common ground among suppliers, standards often emerge which become industry platforms for products of different suppliers working together. Under ideal conditions, standards ensue from a process of appropriate peer review following prior implementation and testing. Developments in IT often involve passing information between devices or storing information on one device that can be read on another at some later time, so standards are often involved with communication protocols or data storage formats. Perhaps the most successful standard to date has been Internet Protocol (IP). The process of maintaining this standard is well documented. (Brandner, S., Harvard University, Oct. 1996, Internet Standards Process – Revision 3, www.ietf.org/rfc/rfc2026.txt)

The development of standards, whether they are proprietary or public, is an important foundation for building technology, but new developments are driven from something deeper in our imagination. It starts with the ability to contemplate future needs with an understanding of the current problems. Add to that an understanding of current technology. Add to that an understanding of science on which new technology may be built. If these things come together in the right way, a path to the future emerges.

CONCLUSIONS

IT developments in the near term will be dominated by wireless communications and the Internet. The market for these technologies is driven by a broad base of decision makers ranging from policy makers to end users who need the right information in a timely way. Incremental improvements in technology not directly related to water resources management advance the information tools available to water resources decision makers. Suppliers of IT must work cooperatively with their customers to provide longevity of IT investments while adopting new technologies.

AUTHOR

A native of Utah, **Paul Campbell** was born and raised in Cache Valley. He and his wife Paulette have five children. He is active in church and civic affairs. He enjoys being with his family, skiing, and joining in on the family farm at planting and harvest time. Beginning in 1975, Paul's responsibilities with Campbell Scientific, Inc. (CSI), have included service as Vice President, Corporate Treasurer, and President. He has managed corporate finances, manufacturing, and internal resources. Paul also serves as a Director and Chairman of Campbell Scientific, Ltd., a subsidiary located in the UK. He is credited with policies and decisions that have maintained financial independence in the company. Paul attended Utah State University studying chemistry, has served on the Dean's Advisory Council for the College of Business at USU, and in 1988 received the University's Professional Achievement Award, and in 1999 received the University's Distinguished Service Award. As president of the company, Paul has been involved with the expansion in recent years of Campbell Scientific's international marketing. Activities have included the formation of subsidiaries in Australia, South Africa, and Brazil.

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