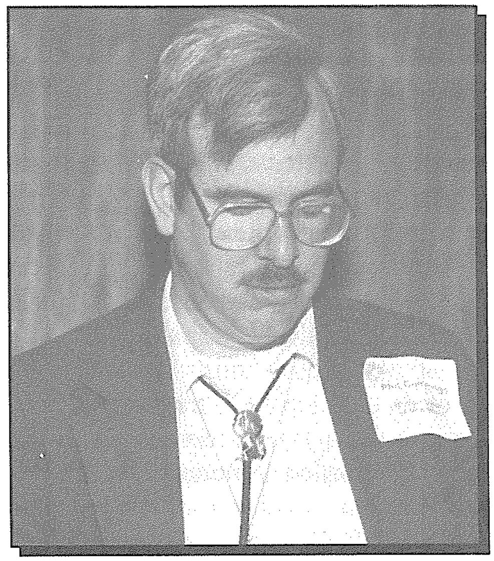
Phil Cummings is President and Senior Technical Consultant with Compu/Quest™ of New Mexico. Having lived in Albuquerque since the age of three, he left in 1973 for duty in the U.S. Navy as a Submarine Reactor Operator and Instructor, and following employment as a nuclear power engineer and computer systems programmer, he returned in 1991 accepting employment as the Manager, Information Systems at the Middle Rio Grande Conservancy District. He designed and developed the Middle Rio Grande Information System, an integrated geographic information system that will allow MRGCD to effect a more equitable rate structure in 1995. Phil is now concentrating on system design and development. Recent projects have included development of a proposed water resource information system for the native Hawaiian people.



WATER RESOURCE INFORMATION MANAGEMENT

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INTRODUCTION

This Report and Associated Resources

This report is not so much what we said at the 39th annual water conference as it is what we said and why we said it. It contains all the salient points of the presentation, with supporting references.

The presentation was video taped by WRRI staff. After the presentation, we distributed computer disks with a geographical information system (GIS) demonstration using ArcView™ Version 2, a product of Environmental Science Research Institute, Inc. (ESRI™). Copies of the video tape and computer disk are available from WRRI.

Information Management Defined

For many people, information management is an oxymoron. A working definition of Information Management is the effective application of information technology. We can define information technology as the technology associated with processed data used for decision making (O'Brien 1994). Management information is that information used by professionals to make decisions. Information management is the effective use of technology to enable this information to become meaningful to decision makers (Emery 1987; Meltzer 1981).

Water Resource Information Management

Every day, more and more decisions confront water resource professionals. Increasing amounts of information constantly bombard them. Even the rate of change of information increases at an exponential rate. Until recently, New Mexico water resource professionals have had only very limited meaningful measurements of hydrological resources, irrigation, or consumption. Even basic elements of inflow and outflow have consisted of literally tons of paper records with almost no organization, correlation, or data reduction capability.

Technology exists today to take massive amounts of data and relate it meaningfully so that managers can make good decisions. In particular, geographic information systems make the spatial relation of this data possible as a 'living map' (Ben-Salem et al. 1994). Here information can be accessed using a tool familiar to most hydrology professionals: the map. Technology collapses the time required for the information system's development cycle, but the cycle remains (Athey 1982; O'Brien 1994; Smith and Reinertsen 1991).

A SURVEY OF WATER RESOURCE INFORMATION MANAGEMENT IN NEW MEXICO

Water resource information management in New Mexico has run the range from hand-drawn maps and filled-out forms to complex computerized geographic information systems.

Then . . .

The oldest water resource information system in New Mexico is the Mayordomo. The Mayordomo directs the operation of his acequia (a term describing both the waterway and its operating association). He knows what resources are available, who needs what, and usually retains detailed records of acequia operations (Crawford 1988). Though the acequia system has potentially major flaws (what if the Mayordomo really does not like you?), its information system is excellent. It is integrated (all data in one place), object-oriented (based on real objects with definable characteristics and inheritance), and uses memory and inference (natural intelligence) (Emery 1987; Heckel 1984; O'Brien 1994; Crawford 1988).

Mayordomos are today relatively rare, primarily serving the small acequias of northern New Mexico. The logical successor to the Mayordomo, today's irrigation system operator (ditchrider), receives only a modicum of training, knows the assigned area, but may be assigned to others, works harder and is paid less per year than a mail carrier.

Often, due to the design and complexity of the water system, they are busy opening and shutting valves, gates, and checks around the clock during an irrigation season. In most cases electrical or mechanical assistance is unavailable. In some operations, these people are used as little more than remote valve actuators. Often the job fatigues and stresses the worker. Need we wonder why they often experience substance abuse problems?

. . . and Now

Water resource information management systems in New Mexico encompass everything from meters, water bills and ditchrider logs to computerized mapping systems and satellite remote imagery. By statute, the State Engineer Office oversees all water use in the state, but even this office has not yet reached effective automation.

An example exists in the recent history of the Middle Rio Grande Conservancy District (MRGCD) where ditchrider logs recorded a certain farmer irrigating his land at 1:00 p.m. on March 15, *three years in a row!* What are the odds of this occurring? Comparing that data with the climatology would be interesting. Was it raining? Did it happen? Told to come up with data, the workers do what they know how to do: let it flow.

MRGCD, faced with using a legislatively mandated water service-charge based revenue structure, is in the midst of a 5-year $1.2 million project to develop an accurate computer GIS. The system is designed to meet needs identified into the next century. Recent Information Management turnover has been such that whether the 1995 mandate will be achieved is problematic. Leaping a canyon in two bounds is difficult, if not impossible! The project is funded for performance only once (Ben-Salem et al. 1994). It will be expensive to lose focus (Peters 1994). Counting on additional funding from state or federal sources is risky at best, since they can guarantee neither (Athey 1982; Ben-Salem et al. 1994; Gabor 1990; Smith and Reinertsen 1991).

LIMITATIONS OF CONVENTIONAL INFORMATION MANAGEMENT METHODOLOGY

In order to understand the limitations of the Information Management methodologies, we must review the major aspects of those methodologies and their inherent natures.

Systems Development Life Cycle (SDLC)

The basis for systems development education in recent years has been a process called the Systems Development Life Cycle. It consists of five phases with their products listed below:

Investigation	Feasibility Study
Analysis	Functional Requirements
Design	System Specifications
Implementation	Operational System
Maintenance	Improved System

This cycle comprises the entire operation of the Information Systems department in most instances, and often these steps, while necessary, consume vast amounts of time (Emery 1987; Meltzer 1981). In even the briefest of projects, the steps exist, though they may be abbreviated (Athey 1982; Emery 1987; O'Brien 1994; Smith and Reinertsen 1991). In the continued complexification of systems, we discern the science of surprise (Casti 1994). Often we are solving the wrong problem (Emery 1987; Gabor 1990; Labovitz 1993; Peters 1994). Systems often indicate their ultimate successors by failing in one or more areas (Emery 1987; Gabor 1990; Labovitz 1993; Meltzer 1981; Peters 1994) one of which may be the best information 'currency' of an organization, for example, maps (Ben-Salem et al. 1994). The solution to the most unsolvable dilemma posed by the problem is often the solution to the *entire* problem (Casti 1994).

Recent refinements in SDLC Application

The SDLC can become less time-consuming by:

A. Minimizing Writing
B. Simplifying Evaluation of Alternatives
C. Combining Systems Simulation Charts with the Systems Utility Determination
D. Limiting the Scope of Analysis
E. Eliminating System Utility Determination
F. Eliminating Preference Charts (especially if more than one Critical Decision Maker exists)
G. Limiting Study to Major Alternatives
H. Limiting Alternatives Considered
I. Not 'Selling the Solution' to Management
J. Limiting Talks with Critical Decision Maker

This order is based on time saved in analysis vs. adverse effect on the final decision, though we would have lumped C and E together in effectiveness since both hinge on a detailed analysis of features and functions within the system, often an early sacrifice to project schedule demands (Smith and Reinertsen 1991).

The Importance of Integration

Designing for system integration, operation with a high degree of coordination between subsets, is critical to the successful development of information systems. Database integration (often implemented at the machine level) helps attain system integration. Other means of ensuring system integrity (security controls, separation of processing duties, etc.) are also vital (Emery 1987; O'Brien 1994).

INNOVATIVE APPROACHES

Innovative approaches to information management and information systems development do not always involve new or different methods. They more often require imagination in the application of existing tools (Casti 1994; Peters 1994; Smith and Reinertsen 1991).

Innovation - A Key to Success

Imagination and insight breeds innovation. Without these, system analysis is dead on arrival (Athey 1982; Emery 1987; Heckel 1984; Meltzer 1981; Peters 1994; Smith and Reinertsen 1991). Insight enables the developer to meet existing business needs. Imagination enables us to envision system requirements that may develop long after system delivery. Innovation is imagination in action. If imagination exists in the design process, it will be evident, often directly measurable by innovations in the product (Gabor 1990; Heckel 1984; Peters 1994). It begs the question to say that innovation is required for successful systems design. Successful design cannot occur without innovation (Casti

1994; Emery 1987; Gabor 1990; Heckel 1984; Labovitz 1993; Meltzer 1981; Peters 1994).

Fostering a Climate for Innovation

Almost everything we do as managers in governmental organizations can have a discernable negative effect on innovation (Crosby 1992; Gabor 1990; Labovitz 1993; Peters 1994). We must empower employees to do what they know is right. Decisions based primarily on cost are almost always wrong (Gabor 1990; Labovitz 1993). Information managers who report directly to their largest end-user (often the Chief Financial Officer) are often forced to decide between other departmental needs and their own employee performance review (Ben-Salem et al. 1994; Gabor 1990; Peters 1994).

An innovative climate is one in which mistakes are made, indeed encouraged, if they lead to better analysis and efficiency. The organization waiting for 'mature' information technology is already failing (Casti 1994; Meltzer 1981; O'Brien 1994; Peters 1994; Smith and Reinertsen 1991).

TOTAL QUALITY MANAGEMENT: A SYSTEMIC SOLUTION

Never a quick fix, Total Quality Management (TQM) involves rethinking traditional management methods. W. Edwards Deming once told the U.S. State Department that it would be wrong to export traditional American management methods to a friendly country (Gabor 1990).

An Introduction to TQM

While disparities exist between the Quality methods and teachings of Philip Crosby, W. Edwards Deming, and Joseph Juran, applications of their techniques are well known worldwide. The commitment of an organization to take actions at every level to 'build in' Quality is TQM.

TQM is more than programs and techniques, it is concept, effort, and completeness. The basics of TQM revolve around planning Quality, doing Quality, measuring Quality, and acting on the measurement. Empowering employees to be and do their best is mission-critical (Crosby 1992; Gabor 1990; Labovitz 1993; Meltzer 1981; Peters 1994; Smith and Reinertsen 1991).

Dr. Deming relates six principles of Quality (Gabor 1990):

1. Quality is defined by the customer. Improvement in products and processes must be aimed at anticipating customers' needs. Quality comes from improving the process, not from "inspecting out" the shoddy results of a poorly run process.
2. Understanding and reducing variations in every process is a must.
3. All significant, long lasting quality improvements must emanate from top management's commitment to improvement, as well as its understanding of the means by which systematic change is to be achieved. Improvement cannot come from middle managers and workers "trying harder." Neither quality improvement nor long-term profitability can be achieved through wishful thinking and arbitrary goals set without consideration for how they are to be achieved within the context of an organization's process capabilities.
4. Change and improvement must be continuous and all-encompassing. It must involve every member in an organization, including outside suppliers.
5. The ongoing education and training of all the employees in a company are a prerequisite for achieving the sort of analysis that is needed for constant improvement.
6. Performance ratings that seek to measure the contribution of individual employees are usually destructive. Given a chance by management, nearly all employees will take pride in their work and strive for improvement. But performance-ranking schemes can impede natural initiative. For one thing, by their very nature they create more "losers" than "winners" and thus better morale. And since they don't take into account natural variation, they are inaccurate and unfair, and are perceived as such by employees (Gabor 1990).

Dr. Deming's method is often rendered as 14 points:

1. Establish constancy of purpose.
2. Improve constantly and forever every system of production and service.
3. Eliminate numerical goals and quotas, including management by objective.

4. Drive out fear so that everyone may work effectively for the company.
5. Institute leadership.
6. End the practice of awarding business largely on the basis of price.
7. Break down the barriers between departments.
8. Institute training on the job.
9. Eliminate the annual rating or merit system.
10. Institute a vigorous program of education and self-improvement.
11. Eliminate slogans and exhortations.
12. Cease dependence on mass inspection.
13. Adopt the new philosophy.
14. Create a structure in top management to accomplish the transformation.

New Mexico, the Quality State?

Since 1991, New Mexico has made great strides in adopting TQM and related management tools. Much work remains. Elimination of fear is a key to successful employee empowerment. Think about your own organization. Is fear active there? To what extent are decisions made using the CYA (cover your assets) management theorem? Time spent working reactively or putting out fires is much better spent innovating and producing (Casti 1994; Crosby 1992; Gabor 1990; Labovitz 1993; Peters 1994; Smith and Reinertsen1991).

Some are ready to concede defeat in the Quality wars. Often businesses are unable to effectively implement enough of the principles to effectively boost productivity. Usually, these are businesses that have a much less than complete grasp of either the principles, or which of their business processes the principles address. (Gabor 1990; Labovitz 1993; Peters 1994; Smith and Reinertsen 1991).

TQM - One Organization's Experience

In 1991, the Middle Rio Grande Conservancy District Chief Engineer authorized the Information Systems Department to organize the development of the Middle Rio Grande Information System (MRGIS) as a Total Quality Management project. They formed a project team, with representatives from the affected departments. Sandia National Laboratories devoted significant consulting resources to helping us learn to use the principles of W. Edwards Deming, Ph.D. Information Systems was then primarily a financial function with its manager reporting directly to the District Treasurer.

In 1992, Information Systems received the first departmental Quality charter in MRGCD history, empowering it to report to the Chief Engineer directly, and making it responsible for meeting the needs of its information system customers. While the Information Systems Manager still reports to the Chief Engineer, it has since reverted to more traditional operations, with a corresponding effect on system development productivity.

MRGCD's experience with TQM, though brief, is an excellent example of what can be accomplished with behavioral change first, attitudinal change later. Although the hoped for attitudinal change never really occurred (government agencies are self-immunizing against innovation) (Smith and Reinertsen 1991), they obtained many significant results in short order. Voted on by international remote imagery users, MRGIS won second place worldwide for its real-world application of remote imagery (missing first place by one vote) (Ben-Salem et al. 1994).

Cost/performance ratios nineteen times the governmental norm for GIS-related project development were achieved. Cost/performance ratios eight times the norm were achieved for routine operations, with no outsourcing.

QUALITATIVE COMPARISON OF SYSTEMS DEVELOPMENT METHODS

Innovation and the SDLC

When innovative techniques are applied to the SDLC, often the result can be a reduction of 50 percent or more in development time (Athey 1982). Often, the key here is to innovate incrementally, avoiding the "Megaproject Trap," when the solution becomes the problem (Smith and Reinertsen 1991). Sometimes this is unavoidable, as in a major system upgrade, or catastrophic information system failure (Ben-Salem et al. 1994). Systems should be designed for innovation acceptance. They should present some relative advantage over the method(s) they are intended to replace. They should be compatible with the users' equipment. The system should be easy for the users to try out on their own, and they should be highly visible in an organization to promote acceptance (Heckel 1984).

TQM and the SDLC

TQM, when properly applied to any definable process can result in major increases in productivity. The time formerly spent doing things over, or trying to 'inspect in' quality is now available for product production. The pitfalls here are that the typical large hierarchical organization of a water resource management agency act as self limiters to the points and principles of TQM (Crosby 1992; Gabor 1990; Labovitz 1993; Peters 1994; Smith and Reinertsen 1991).

RE - (TAKE THAT BACK) - ENGINEERING INFORMATION MANAGEMENT

We were going to discuss a current trend in the information management field: that of re-engineering, or reinventing information management. That seems a bit premature, as we are just now seeing some truly engineered approaches to information management in the New Mexico water resource community. The root of the word *engineer* in Latin means to make things work, and efforts to do just that are commendable.

"Crazy Times Demand Crazy Organizations"

After years of studying management techniques that work (and many that don't) the word is out - Chaos is in! Trying to do today's work (not to mention tomorrow's) is impossible using only yesterday's tools. While the organizational changes recommended by this book are not achievable in New Mexico government in the foreseeable future, there is ample guidance on keeping the existing structure, on paper, but performing differently. This is already done in most organizations. Engineers and scientists often know whom they really have to work with to get results. This book ranks as a vital resource (Peters 1994).

Not Just Bean Counting, Anymore - The Mission of Information Systems

Typically a subfunction of the government agency clerk's office or the accounting department, Information Management is probably the most technically complicated function performed by most water resource professionals. Engineers, hydrologists, hydrographers, environmental scientists, cartographers, and technicians are already doing most of the information management work. A favorite example is the programmable calculator, with more computing power than most early computers.

Information Engineers

Logically the information management in an engineering organization is an engineering function, though few people have had the foresight to realize this. It is becoming more evident that information technology, including communications, is a driving force in any major engineering organization (Emery 1987; Meltzer 1981; O'Brien 1994; Peters 1994).

The New Mexico State Engineer Office has recently established its own Information Systems Division, and if past is prologue, this organization will feel the same tensions between the seven last words of government (but we've always done it that way) and the innovation necessary to excel.

RESOURCE-BASED IMPACTS ON INFORMATION MANAGEMENT

Resource-based Requirements for Effective Use of the SDLC

The SDLC requires resources for completion and continuation of systems. It is a certainty that as systems and technology age, costs of maintenance and impacts of obsolescence act to require that new systems replace old. Resources required by SDLC related activities include people, hardware, software, and facilities.

The equipment, financial, and personnel resources for systems development are limited and must be used to best advantage (Meltzer 1981; Peters 1994; Smith and Reinertsen 1991). In a broader sense, it is the limitation of the water resource that is most important. Quantifying this resource, and developing systems for its monitoring and conservation are of an emergency nature in some parts of the state. Water availability is the single largest consideration when discussing New Mexico's future growth. Gold was first used as a monetary resource because of its limited quantity.

It is foreseeable that in time, schedule will be the preeminent design factor in water resource information management systems development, much as cost appears today (Gabor 1990; Peters 1994; Smith and Reinertsen 1991).

Correlation of Cost, Schedule, and Performance

If we view system development cost, schedule, and performance as an equilateral triangle, any SDLC activity will take place at an operating point within that triangle (Crosby 1992; Gabor 1990; Labovitz 1993; Peters 1994). Ideally, if money and time were of no concern, all activity would take place along the performance aspect of this triangle. Usually, however, we are speaking of governmental activities taking place with taxpayer dollars, and the SDLC focus shifts toward either the cost aspect or the schedule aspect (in emergencies).

The advantage to governmental systems development is that if we properly apply an innovation to the SDLC then a corresponding cost savings will usually occur. This money is often still available for the project if budgeted before the innovation. These funds help shift project focus more to favor schedule or performance, as needed.

The true application of TQM to the SDLC (which does not happen until the organization responsible assimilates TQM) results in exponential reductions in development time. True application of TQM to an organization results in tremendous reductions in staff requirements.

THE FUTURE OF WATER RESOURCE INFORMATION MANAGEMENT

In viewing the future of information management in the New Mexico hydrology community, we must use two time frames. In the near term, we should look at today (now, in an hour, by the end of the day, week, month, or year). In the far term, we should look at what New Mexico will require by 2005. If we are to believe the population growth estimates (traditionally underestimated) and the measurements of water availability (historically overestimated), we are in trouble.

Under Penalty of . . .

Without efficient use of water resources, we may come to a time when California's recent droughts seem like the 'good old days'. We believe that the key to effective management of the water resources of the state lie in the effective management of the information technology available to decision makers. Historically, most bad decisions from area water boards, conservancy directors, even irrigation systems operators have been traceable to inaccurate information, or *no meaningful information at all.*

Today and Tomorrow

The future begins today. We need not wait until tomorrow to begin to innovate. Psychologists tell us that behavior and attitude go together. In a bureaucratic organization we can spend years attempting to change attitudes. Or we can change behavior today, causing eventual attitudinal change. To paraphrase the athletic footwear advertisement - Just Do It!

To be sure, attitudinal changes may be slow in coming, but eventually they will occur (Gabor 1990; Labovitz 1993; Peters 1994; Smith and Reinertsen 1991). Systems such as the cooperative information system for the Las Cruces area and the Middle Rio Grande Information System are good starting points, but the State Engineer Office needs to be able to get the 'big picture' and that will require an enormous database.

Ten Years From Now

In 2004, in New Mexico's 92nd year of statehood, population approaches 2,500,000. We have mapped and measured the water resources of the state. We know that the state's available water sources total 4,166,667 acre-feet (plus or minus 3 percent), including allocations from the 10-state Underground Pumping Compact.

Recycled water counts for 25 percent of the available resource. The City of Corrales uses a water system operated by Intel Corporation, at rates well below nearby Albuquerque and Rio Rancho.

Arsenic levels in the Town of Bernalillo water supply are less than minimum detectable, since the town installed a state-of-the-art purification plant on the site of the former dairy. The purification system uses a renewable resin preferential ion-exchange process to remove arsenic and other impurities from the water system, and recently this water system was rated one of the top five in the country.

The Middle Rio Grande Conservancy District remotely monitors and schedules its operations at divisional and general office levels. Supervisors can access a map showing the location of each ditchrider. Ditchriders have computerized schedules and up-to-date maps. MRGCD has just issued a Request for Proposal for remote actuation of major facilities for irrigation control, spill isolation, and storm mitigation. Ninety percent of MRGCD's $12 million revenues now come from water service charges.

The New Mexico State Engineer Office has long ago abandoned the earlier practice of dedicating water rights, and is considering condemnation of all private water rights and allocation by engineering review. The turnaround time for an engineering review is a product of the size of request. Engineers approve homeowner allocations in minutes. Intel's expansion for fabrication plant sixteen will take a few days. Plans to intrusively meter all discharges were abandoned in favor of remote imagery mapping and acoustic monitoring.

The Valencia County Arroyo Flood Control Authority recently completed a $15 million construction program of drainage, diversion, and recycling facilities in the Belen, Bosque Farms, and Los Lunas areas, complete with dedicated open space, trails, and bicycle paths. Valencia County, New Mexico's fastest growing metropolitan area (pop. 150,000), was recently rated 60th in the 2004 edition of *Places Rated Almanac*.

Sandia Laboratories no longer seeks to discharge radioactive water into the Albuquerque sewer system, since they are now U.S. Department of Energy Zero Discharge Award winners five years in a row.

If all this sounds unbelievable, remember that all the technology to accomplish these and other scenarios exists today. If we have some idea of where we want to be in ten years we should start going there today. Information management can be an asset. In hydrology, it is the major variable asset, water being a finite commodity. All that remains is for the technology to be effectively applied—the essence of information management.

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