Chapter 19

Database Management Model for SCADA Systems

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Water quality and hydrologic/hydraulic monitoring historically has been accomplished through manual techniques and recently with standalone computerized dataloggers. Supervisory Control And Data Acquisition (SCADA) systems are currently being used with graphic software packages to retrieve data from computerized meters and samplers, display the information in real-time, and log the data to disk. However, most of these packages do not come standard with a historical database that can be used to store all incoming information at intervals typically needed to access water quality and/or hydrologic impacts. This chapter presents an information model which uses a relational database to store all historical data from a SCADA system necessary to complete a water quality monitoring program. An example of a water quality monitoring and control system that is to be installed at a Combined Sewer Overflow (CSO) control facility in a large municipality is presented. The database model, as it is applicable to several other monitoring scenarios, is also presented.

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19.1 Introduction

The purpose of most water quality monitoring programs is to examine water quality in the environment, and through a succession of steps (collection and analysis), gain an understanding of water quality conditions. This objective seems intuitive at the onset of a monitoring scheme; however, if proper design principles are not enacted at the beginning of the project, the result could be inadequate data to meet the project objectives. In order to design an effective water quality monitoring program, the following components should be identified:

- time the monitoring system will be in use,
- types of measurements that will be made, and
- type of water quality management tool to be maintained.

The time-line for a monitoring effort can consist of long-term (or fixed station), short-term (or special study), or a combination of the two (usually consisting of intensive efforts within the first couple of years with reduced efforts over the remainder of the project life). The measurements used to quantify water quality usually consist of physical, chemical, and biological samples (i.e. flow, phosphorus, and fecal coliform, respectively). The last component of the monitoring system, the management tool, plays a critical role in how the results will ultimately be interpreted (Orlob, 1992). This tool - *or information system* - should provide the framework of the monitoring program. Typical monitoring programs include:

- compliance monitoring,
- enforcement monitoring,
- trend monitoring, and
- background monitoring.

The *information system* should be modeled in such a way as to *not only* act as a data receptacle, but also provide for the necessary interfaces by which all other mechanisms within the monitoring program can openly exchange, manipulate, check, and report information. Figure 19.1 illustrates the flow of information for a water quality monitoring system (adapted from Ward, Loftis and McBride, 1990).

With the advent of microcomputer *workstation* technology, and the increase in useability of software due to Graphical User Interfaces (GUI's), computerized information systems for water quality monitoring can be designed as an *open system* by which all data becomes available for each aspect of the program. This chapter will concentrate on a *computerized*

Figure 19.1
Information flow in water quality monitoring system.

information system that is part of a large-scale water quality monitoring program (consisting of five or more metering devices) occurring over an extended period of time (greater than one month).

19.2 Computerized Monitoring Devices

Computerized monitoring devices used to measure hydrologic and pollution parameters have been used in water quality monitoring efforts for several years. These units typically consist of a microprocessor interfaced to a specialized probe or mechanism by which flows, levels, rainfall, and/or priority pollutants are measured. These units are usually packaged as either portable, or as permanently-mounted devices (Whitfield and Wade, 1992). Examples of these devices are flow meters, level sensors, rain gages, automated samplers, and direct-read water quality meters. As part of the package, these devices usually come with proprietary software for setup and downloading data to a laptop PC. Depending upon manufacturers, some of the software also contains cursory analysis

modules usually consisting of simple statistics and graphing capabilities. Another feature of some of the software packages includes capabilities to export the collected data to either ASCII or flat-file spreadsheets.

A portable monitoring device works very well for small or short-term monitoring projects. However, these meters can fall short for large or long-term monitoring efforts. Permanent monitoring devices work similarly to their portable counterparts except that they may provide more memory for logging data, and usually come with an external port to connect into either a chart recorder or another computerized device. Although these metering devices do very well at collecting raw data, they lack the ability to provide an *information system*. If a water quality monitoring study is constructed on the premise that the computerized metering devices (with associated software - including spreadsheet packages) will fulfill all information system needs for the project, the end result will usually fall short of expected goals.

A technology that has been used for years in plant automation is now being applied to water and wastewater monitoring programs. Supervisory Control And Data Acquisition (SCADA) systems have provided distributed processing capabilities to monitor and control centralized and remote locations. Until recently, SCADA systems usually consisted of Programmable Logic Controllers (PLC) which were used to monitor water quality devices and control appurtenances. PLCs are small and powerful microprocessors (usually networked to UNIX workstations, mini, or mainframe computer systems) by which all data is logged and control schemes regulated. These monitoring systems were usually difficult to setup and program - a systems integrator was necessary to program the units in *ladder logic* and configure the PLCs to interact with the high-end computers. Thus, these systems were limited to large municipalities that had large budgets and could afford to hire highly specialized technicians (WEF, 1993).

Within the last couple of years, SCADA technology has given birth to more modular, powerful, and easily programmable units. These units, referred to as either a smart PLC or Remote Telemetry Unit (RTU), have made constructing a more holistic monitoring program a reality for municipalities and engineers alike. For example, a single RTU, consisting of a multitasking microprocessor and a terminal strip, can log data from many different monitoring devices, while at the same time using that information to control selected appurtenances. Many of these units are constructed in a modular fashion (other metering devices can be added or

subtracted by simply plugging-in or removing input/output (I/O) modules in the RTU enclosures). These units can also provide the flexibility to easily add modems, battery backup, and alarm capabilities entirely in one compact enclosure. Another feature of these RTUs is the device-independent graphical software packages that can be purchased to provide all datalogging capabilities and control algorithms (Jentgen and Wehmeyer, 1993). These graphical software packages are typically referred to as *Man-Machine Interface (MMI)* software, and provide all necessary tools to graphically program, log data and control the RTU devices.

19.3 Man-Machine Interface Software

Typical MMI software, usually purchased separately from the SCADA devices, not only provides graphical (user-friendly) datalogging and control routines, it also allows for integration with other features necessary for a computerized information system. The MMI software can reside on either a stand-alone PC or a network. It can be used to program the SCADA units, log data to either memory or hard-disk, and control devices (e.g. sluice gates). Components provided in a typical MMI software package usually include the following:

- process database
- graphics
- data logging / data collection
- trending / reporting, and
- other features (alarms, security, schedulers)

The process database consists of files which relate processes to information retrieval and display. This database *is not* a historical database, but includes information such as data addresses, point (or meter) names, point characteristics, scaling information, polling frequency, and priorities to name a few. The graphics module or GUI, is what makes the MMI program so easy to use. This module provides the link between the water quality monitoring instruments, the process database, and the user. By providing drawing and screen development tools, the GUI can display information in real-time through pictorial displays and text. The GUI also provides for the user a means of initiating different processes or events (e.g. switching over to a backup automated sampler if the primary sampler fails - all of which can be done at a computer in an office, rather than in the field).

The data logging/data collection module is used to define and

control the storage of monitored data for future analysis. This module allows for the direct recording of data or the averaging of data over a selected time interval. The historical data can then be stored either in memory (depending on time interval and number of metering devices), or can be written to a disk in either binary or ASCII format. The trending/reporting modules allow the user to display graphical charts to the screen or send tabular data to a printer (Intellution, 1993). A shortcoming of the reporting capabilities of typical MMI software packages is its inability to construct a non-proprietary historical data file. Although historical data files can be created, they are written to disk in a proprietary binary format. This *does not* allow for easy exchange of large amounts of data to other programs, which is necessary to complete a computerized information system for the water quality monitoring program.

19.4 Open Database Model

In order for the collected information to be of use for decision making, the data must be available to users in a common, open format, by which they can easily access the most up-to-the-minute information (Brueck and Gerstberger, 1993). To accomplish this, the historical data logged by the SCADA system (by MMI software specifically) must be in a *non-proprietary* format that allows for easy exchange between any off-the-shelf database, spreadsheet, statistics program, or word processor. To facilitate the processing of the voluminous amounts of data typically generated by a long-term (or large scale) water quality monitoring program, the data should be easily exchanged through an open architecture format. This linked exchange *cannot* be accomplished through typical import/export of ASCII files or through proprietary binary data files.

The core of the computerized information system model is the Relational Database Management System (RDMS). An RDMS is more powerful and efficient than typical *flat-file* databases (Ogorek, 1993). The RDMS is the central location for data storage, however it is also the *conduit* by which all other external programs will exchange data. The movement of data, and ultimately information, is critical to the success of a water quality monitoring program. Within any database system, there are many layers of data exchange, so for simplicity, this discussion will be limited to data exchange pathways from the meters to the MMI software, and from the MMI software to the historical database. Initially a parameter is sensed from a quantity or quality probe. This signal is then converted

to an electrical current by which the MMI software senses and scales the output to a numerical value (e.g. 10 ft. of head). This numerical value can then be displayed on the computer screen, written to a printer, or most importantly, sent to a historical database file. In order for the data to be sent to an RDMS (historical database), a link must be established. Many RDMSs come with a mechanism to link programs together; this link is the Structured Query Language (SQL).

SQL is the typical mechanism by which data can be transferred from MMI software to the RDMS (Kok, 1993). Once this link is established, real-time data is passed directly from the meters to the SCADA system (and MMI software) and to the RDMS. Figure 19.2 graphically illustrates this process.

The real-time data can be saved in the RDMS at any time interval; disk space is the limiting factor. Once the data is sequentially logged to an RDMS, it is then available in an *open format*. Other links can then be established to other programs. Possible software links to the RDMS include:

- hydrologic/water quality models (i.e. EPA, HEC, SCS)
- statistical analysis/graphing software
- quality control/quality assurance software
- real-time control algorithms
- Geographic Information Systems (GIS)
- Automated Mapping/Facilities Management (AM/FM)
- compliance reporting software
- manual calibration/verification and sampling data input

If an operating system such as Windows or OS/2 is used, mechanisms (other than SQL) can be used (Potratz, 1994). Once the data is in a Windows database program (i.e. Dbase, Paradox, Access), most other Windows software can access the data through copying/pasting, Dynamic Data Exchange (DDE), and/or Object Linking and Embedding (OLE). Not only can off-the-shelf software be used, but any custom programs written in Windows (i.e. Quick Basic, C++, or database application languages) have instant access to all data fields and records. Information transfer within this open database model is not limited to just the application and the database, but information transfers from one application to another are possible by using the database as the transfer mechanism (or conduit). *This differs from typical linking methodologies in that custom programs are not written to interface one program to another, but the data (both input and output) from one program can be accessed by another application by simply calling on the central database.* Even DOS-based

Figure 19.2
Structured query language (SQL) link.

programs can be included in the information system by having programs or scripts written to pass input from the database to the application and then read the applications output and pass it back to database. A schematic of the *open information model* is given in Figure 19.3.

19.5 Case Study

This open system model is being applied to a computerized information system to monitor water quality and control operations at a pilot CSO facility for a large municipality. The pilot CSO facility will test the removal efficiencies of three vortex concentrator units over a variety of rainfall and flow conditions. In order to accurately monitor the three units for inflow, overflow, and underflow, many flow meters, level sensors, and automated samplers will be placed systematically around the

Figure 19.3
Schematic of open information system model.

units. Data acquisition and control will be facilitated by a SCADA system to be used with a standalone PC workstation. The PC workstation will have modem capabilities for remote data transfer and alarm handling. Up to 60 analog and 30 digital inputs will be interfaced to a single SCADA unit housed within the control room at the facility.

Flows, velocities, levels, sample times, pump and sluice gate operations, along with alarm conditions will be logged to a central RDMS residing on the SCADA computer. An MMI will be constructed to control the facility and also to exchange information from the remote location to other offices. Custom database programs will also be written to allow laboratory data to be entered into the database once the analysis is performed for certain key constituents (TSS, BOD, Fecal Coliform, and floatables). Quality Assurance/Quality Control (QA/QC) procedures will be implemented throughout the datalogging cycle. The information gained from this study may ultimately be used for hydraulic modeling and

real-time control of the facility after the initial two-year sampling program is complete. With the computerized information system, high quality data from the facility will be available in an open systems format for use in any Windows-based analysis software.

19.6 Conclusions

As presented above, the *open information system model* can be applied to many aspects of a water quality monitoring program. The model methodology is not limited to water quality monitoring programs. Other applications include hydrologic/hydraulic analyses, Sewer System Evaluation Surveys (SSES), air quality monitoring studies, large scale GIS programs, etc. By placing all pertinent time series, geographical, and point data in one relational database, common data can be *united* to any model, GIS, or real-time SCADA system. The *information system model* is not an end in itself but a methodology by which data can be accessed, checked, and transferred with minimum manipulation and maximum benefit.

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