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Quality Assurance Plan for the Data Acquisition and Management System for Monitoring the Fuel Oil Spill at the Sandia National Laboratories Installation in Livermore, California

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QUALITY ASSURANCE PLAN FOR THE DATA ACQUISITION AND MANAGEMENT SYSTEM FOR MONITORING THE FUEL OIL SPILL AT THE SANDIA NATIONAL LABORATORIES INSTALLATION IN LIVERMORE, CALIFORNIA

by

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ABSTRACT

This report describes the formal quality assurance plan that will be used for the data acquisition and management system developed to monitor a bioremediation pilot study by Argonne National Laboratory in association with Sandia National Laboratories. The data acquisition and management system will record the site data during the bioremediation effort and assist users in site analysis. The designs of the three major subsystems of this system are described in this report. Quality assurance criteria are defined for the management, performance, and assessment of the system. Finally, the roles and responsibilities for configuration management of this system are defined for the entire life cycle of the project.

1 INTRODUCTION

1.1 PURPOSE

The purpose of this quality assurance (QA) plan is to establish the QA practices and procedures for the data acquisition and management system that will be used to collect, manage, archive, retrieve, and analyze data from the field instrumentation that will monitor activities at the fuel oil spill (FOS) site at the Sandia National Laboratories (SNL) installation in Livermore, California. This plan considers all hardware, software, and documentation associated with the monitoring activities — including the design, implementation, testing, installation, and operation of the end-to-end system — from a total quality management perspective. It also establishes the roles and responsibilities for configuration management during the development, release, and maintenance of all computer software and supporting documentation.

This QA plan is a comprehensive guide; it consolidates and discusses issues traditionally addressed in separate documents, such as configuration management, validation and verification, and life-cycle support. To the extent possible, the practices and procedures described herein have been streamlined to meet the requirements of the FOS monitoring project. Because of the dynamic nature of this project, this QA plan will be updated as necessary to address new technical, administrative, and programmatic issues as they arise.

1.2 BACKGROUND

In February 1975, the accidental puncture of an underground transfer line buried about 1.2 m (4 ft) below the ground surface at the SNL installation in Livermore, California, resulted in the release of approximately 225.5 m^3 of No. 2 diesel fuel. The FOS is located at a 670-m^3 (179,000-gal) aboveground fuel reserve storage tank near the center of the SNL Livermore installation. Some of the diesel fuel infiltrated the soil underlying the spill site. The remainder migrated laterally in a shallow (less than 0.6 m [2 ft]) light pole trench adjacent to the spill and then migrated vertically and laterally below the trench into the unconsolidated soil column. Although a small amount of fuel was recovered from the light pole trench near the puncture, most of the oil remains in the unsaturated zone beneath the site. A detailed evaluation of the release indicated that 162 m^3 (43,000 gal) of diesel fuel, or about 72% of the initial volume spilled, remains in the unsaturated zone (DOE 1989).

Extensive site characterization studies and a feasibility study of the FOS were conducted by the U.S. Department of Energy (DOE) between 1984 and 1990 (DOE 1989, 1990). In addition, laboratory and numeric studies of bioremediation were conducted by Argonne National Laboratory (ANL), SNL, Los Alamos National Laboratory, and the University of Notre Dame (ANL 1992). On the basis of the results of these studies, bioremediation was selected as the preferred remedial alternative to treat the diesel fuel spill. A Remedial Action Plan was prepared for the California Regional Water Quality Control Board (ANL 1992). It described the proposed restoration of the FOS by means of in situ bioremediation in conjunction with a groundwater injection and withdrawal system. The system circulates oxygen and nutrients and maintains hydraulic control so that not even minimal contamination will spread beyond the existing affected area. A work plan describes the monitoring system, which is designed to provide information regarding the pressure distribution within the unsaturated zone, movement of the nutrients, movement of tracer chemicals, and thermal reaction of the unsaturated zone to the injected fluids and remediation process (ANL 1993b). The data acquisition and management system discussed in this QA plan will collect, manage, archive, and analyze this information.

1.3 REFERENCES

The specific practices and procedures described in this QA plan are based in part on the formal standards and practices defined in the documents listed below. DOE Orders 1330.1C and 5700.6C and the *ANL Quality Assurance Program Plan* (ANL 1993a) are particularly relevant source documents.

- ANL 1992, *Remedial Action Plan for the Fuel Oil Spill at Sandia National Laboratories, Livermore*, Argonne National Laboratory, Argonne, Ill., July.

- ANL 1993a, *Argonne National Laboratory Quality Assurance Program Plan*, Argonne National Laboratory, Argonne, Ill., Feb. 17.

- ANL 1993b, *Work Plan for the Fuel Oil Spill at Sandia National Laboratories, Livermore*, draft report, Argonne National Laboratory, Argonne, Ill., June 4.

- ANL 1993c, *Development of Preliminary Remediation Goals for the Sandia National Laboratories Fuel Oil Spill Based on Human Health Risks and ARARs*, Argonne National Laboratory, Argonne, Ill., June.

- ANSI/IEEE Std 730-1984, *IEEE Standard for Software Quality Assurance Plans*, American National Standards Institute and the Institute of Electrical and Electronic Engineers, Inc., New York, N.Y., Dec. 17.

- ANSI/IEEE Std 828-1983, *IEEE Standard for Software Configuration Management Plans*, American National Standards Institute and the Institute of Electrical and Electronic Engineers, Inc., New York, N. Y., June 24.

- DOE 1360.2A, *Unclassified Computer Security Program*, U.S. Department of Energy, Washington, D.C. (May 1988).

- DOE 1989, *Remedial Investigation Report, Sandia National Laboratories, Livermore, Fuel Oil Spill*, U.S. Department of Energy, Albuquerque Operations Office, Environment and Health Division, ER Programs Project Group.

- DOE 1990, *Sandia National Laboratories, Livermore Fuel Oil Spill Feasibility Study Report*, U.S. Department of Energy, Albuquerque Operations Office, Environmental Restoration Technical Support Office.

- DOE 1330.1C, *Computer Software Management*, U.S. Department of Energy, Office of ADP Management, Washington, D.C. (Jan. 12, 1990).

- DOE 5700.6C (Attachment 1), *Quality Assurance Program Implementation Guide*, U.S. Department of Energy, Office of Nuclear Energy and Office of Environment, Safety, and Health, Washington, D.C. (Aug. 21, 1991).

- DOE/AD-0028, *Software Management Guide*, U.S. Department of Energy, Office of Administration and Human Resources, Washington, D.C. (June 1992).

- DOE-ER-STD-6001-92, *Implementation Guide for Quality Assurance Programs for Basic and Applied Research* (June 1992).

- DOE 1324.2A, *Records Disposition*, U.S. Department of Energy, Washington, D.C. (Sept. 1988).

1.4 ORGANIZATION

The remainder of this QA plan is organized as follows. Section 2 provides a detailed description of the data acquisition and management system and its three major subsystems. All hardware and software components are described. Section 3 discusses the overall management structure for the FOS subsurface biorestoration project, including specific roles and responsibilities. Section 4 addresses QA criteria. These criteria are organized into three categories: management, performance, and assessment. Software configuration management is described in Section 5. Section 6 discusses security management as it relates to physical security, personnel security, information security, disaster recovery and contingency planning, and virus prevention and detection. Finally, Section 7 discusses records collection, maintenance, and retention.

2 SYSTEM DESCRIPTION

The data acquisition and management system is designed to accurately and reliably collect, manage, archive, retrieve, and analyze data from the field instrumentation that will monitor activities at the FOS site. Information from the chemical data analysis and the chemical tracer studies will also be managed and analyzed by the system.

As illustrated in Figure 2.1, the data acquisition and management system is composed of three major subsystems, each consisting of hardware and software components. These subsystems contain the (1) monitoring and logging instrumentation for the pressure transducers, temperature probes (thermistors), tensiometers, and neutron and gamma and electromagnetic (EM) induction logging tools; (2) data acquisition computer for uploading data recorded by the data loggers and recording results of laboratory sample analysis from the air-lift samplers and lysimeters; and (3) data analysis computer for archiving data, performing statistical analyses, and modeling the FOS.

2.1 MONITORING AND LOGGING INSTRUMENTATION SUBSYSTEM

The monitoring and logging instrumentation subsystem consists of three Campbell Scientific Model CR10 data loggers with associated input sensors, multiplexers, and interface devices, suction cup lysimeters, air-lift samplers, and geophysical logging equipment. Data input to the CR10 data loggers are collected directly from electronic instrumentation located in the boreholes. These data are directly uploaded into the data acquisition computer, as illustrated in Figure 2.2. In contrast, analytical data from the water samples collected from the suction cup lysimeters and air-lift samplers must be manually input into the data acquisition computer. The multiplexers and data loggers associated with this subsystem will be housed in an uphole equipment building to be located adjacent to the main pilot study area.

As detailed in Figure 2.3, 50 Geokon Model 4500S vibrating-wire pressure transducers will be multiplexed by four Campbell Scientific Model AM416 multiplexers, whose outputs are connected to data logger No. 1 through a Campbell Scientific Model AVW4 interface unit. In operation, the pressure transducers will be connected and accessed one at a time by (1) enabling the appropriate multiplexer via its reset input, (2) measuring the pressure by executing an instruction sequence in the data logger, and (3) sending one clock pulse to the multiplexer. This procedure will connect the next pressure transducer for measurement. The process will be repeated until all 50 pressure transducers have been measured in the normal monitoring sequence. Also, one additional Geokon Model 4500AL pressure transducer (labeled transducer No.1 in Figure 2.3) will provide barometric pressure values for adjusting pressure readings for barometric fluctuations.

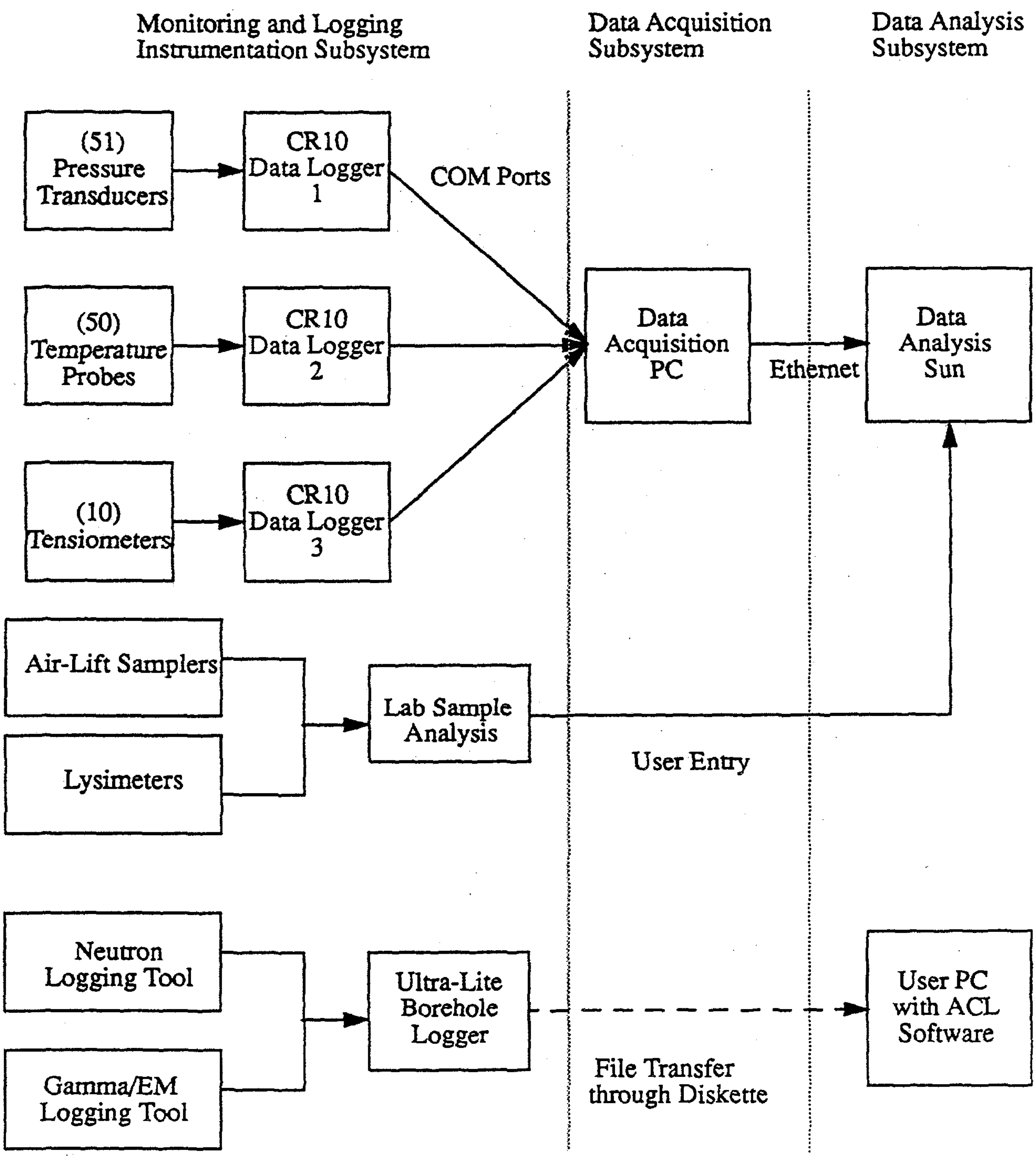

FIGURE 2.1 Overview of Data Acquisition and Analysis System

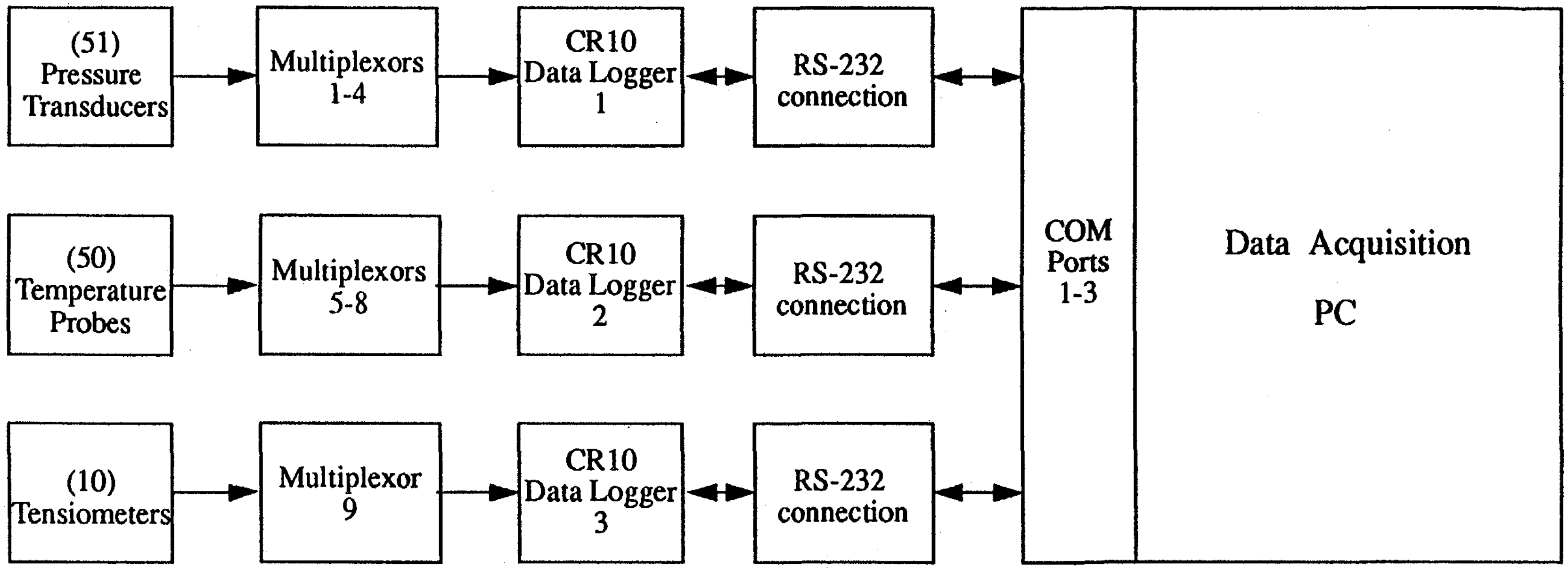

FIGURE 2.2 Electronic Monitoring Instrumentation Interface to Data Acquisition Computer

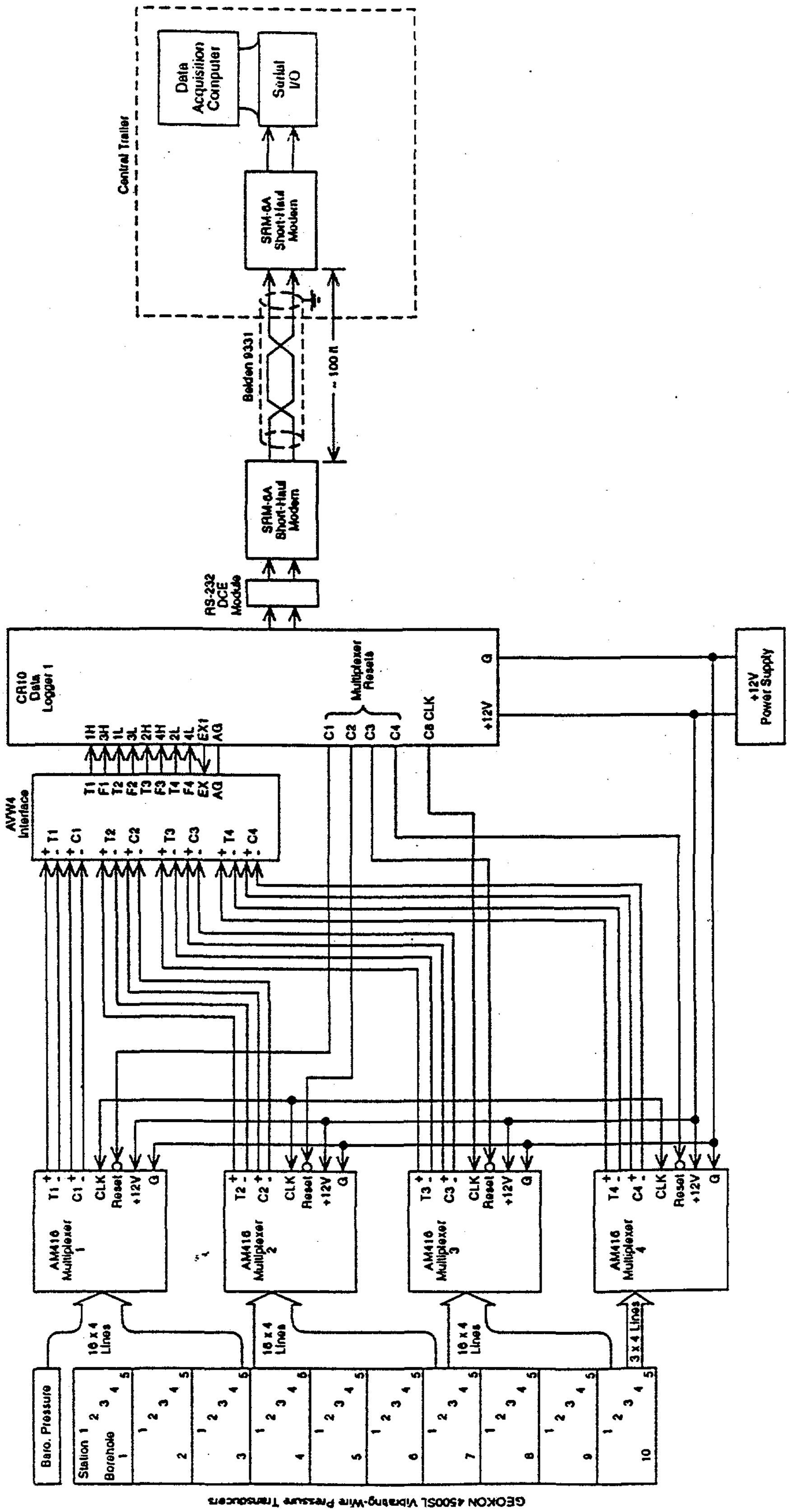

FIGURE 2.3 Conceptual Pressure Sensor Subunit

Temperature of the subsoil water at all of the monitoring well stations is measured by 50 Yellow Springs, Inc., Model 071 thermistor probes. As detailed in Figure 2.4, the two thermistors in each probe are multiplexed one pair at a time by multiplexers No. 5 through 8 into two linearizing range resistors; these provide a differential voltage at data logger No. 2 input that is proportional to temperature. Because all thermistor pairs have matched resistance characteristics, all temperature data obtained will be accurate to within 0.1 °C. In operation, the data logger control of multiplexing is similar to the previously described pressure transducer multiplexing.

The movement of the wetting front created by the influx of water from the infiltration gallery is tracked by 10 Soilmoisture Equipment Corp. Model 2725 Jet Fill tensiometers. The dial vacuum is converted to a value of 4 to 20 mA by attached current transducers for data transfer. As detailed in Figure 2.5, the current from each tensiometer is converted by individual resistors at multiplexer No. 9 to a differential voltage that is accessed by data logger No. 3 and processed to obtain soil suction values.

Fifty Solinst Model 403 Double-Valve Purge/Sample Pumps will act as air-lift samplers, collecting groundwater samples from the monitoring wells to determine the presence of organics, nutrients, and tracers. The air-lift samplers use two stainless steel, one-way check valves and a porous polypropylene filter in a compact, stainless steel housing. A nitrogen-drive system supplies nitrogen to the pump in a teflon-lined polyethylene tube with a 1/4-in. outer diameter (O.D.). The water arrives at the surface in a contiguous undisturbed slug. The control unit allows the timing of the pressure and vent cycles to be easily regulated for purging or sampling.

Fifty Soilmoisture Equipment Corp. Model 1922 "Ultra" Soil Water Samplers act as lysimeters, collecting water samples from the vadose zone. Samples obtained from the FOS site will be analyzed for organic compounds, tracer chemicals, and nutrients. The lysimeters are designed to sample sample moisture at depths to 200 ft. They are fabricated from aluminum high-fire ceramic materials bonded by inert glazes have heavy wall construction for high pressures, and have teflon fittings to provide an ultra-clean sampling environment. An advantage of high-fire ceramic materials over typical lysimeter construction materials is that they allow for the detection of chemicals in the parts per billion range. An electric pressure/vacuum pump will pull a vacuum during sample collection and exert pressure to push the collected water to the surface.

The geophysical logging equipment consists of a neutron logging tool and a natural gamma/electromagnetic induction logging tool attached to a data logger. The neutron logging probe is part of the multiprobe Century Geophysical 9050 Logging Tool. Neutron logging will measure moisture changes at the monitoring stations that result from the injection of water through the injection zones. Gamma logging and EM logging will be performed by using the multiprobe Century Geophysical 9510 Logging Tool. The gamma logs will be correlated with the electromagnetic

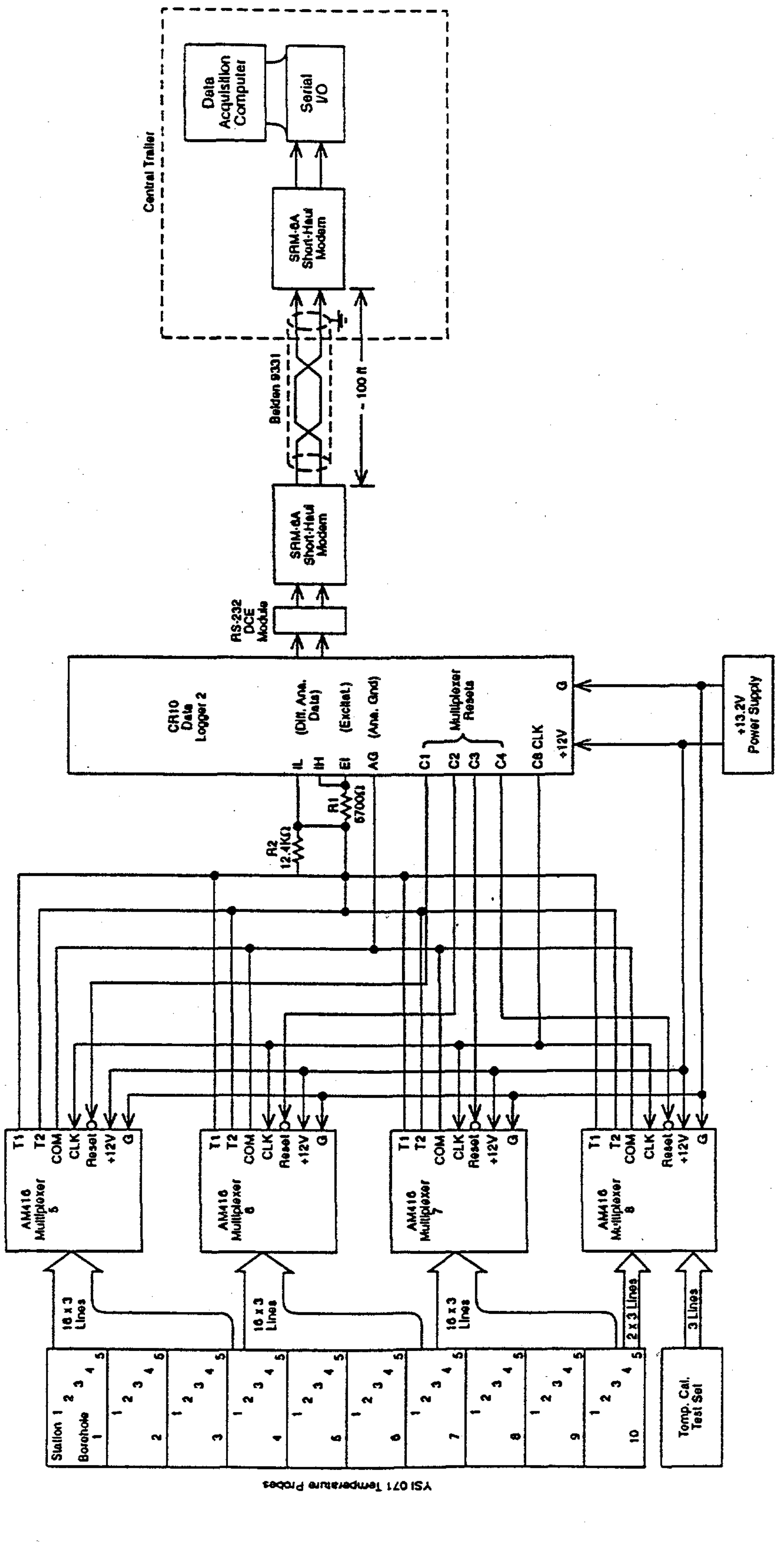

FIGURE 2.4 Conceptual Temperature Probe Subunit

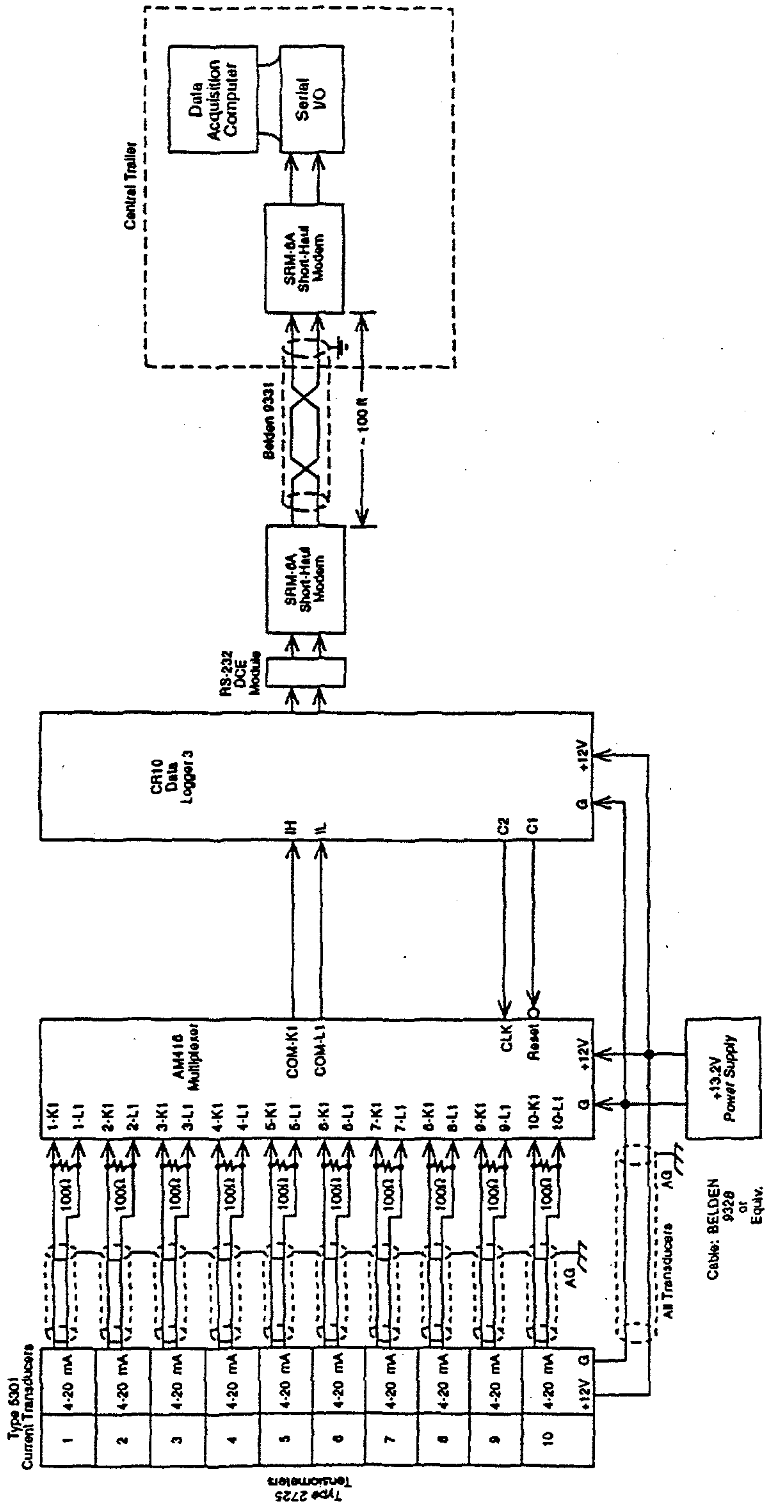

FIGURE 2.5 Conceptual Tensiometer Subunit

induction, neutron, and geologic logs to determine the location and thickness of the clay and sand layers. The EM probe will also be used to detect the arrival of tracer chemicals and nutrients at the monitoring locations by means of changes in EM conductivity.

The two logging tools will be accessed by using the Century Geophysical Ultra-Lite borehole logging system. The system consists of a computer, LCD screen, sealed keypad, and logging software. System software includes MS-DOS and the Personal Compu-Log (PCL) System software, which provides the logging and processing capabilities. Data sets will be output to floppy disk from this system. ACL for Windows, a separate analytical software program from Century Geophysical, will be used to analyze the geophysical data. This software will be loaded on individual personal computers (PCS) and not on the data acquisition PC. Multiple backups of the floppy disk from the Ultra-Lite logging system will be made after each logging event to minimize the possibility of data loss.

2.2 DATA ACQUISITION SUBSYSTEM

Data collected by the CR10 data loggers are transmitted to a MS-DOS-based data acquisition PC and then stored in appropriate files on a hard drive. This transmission takes place between RS-232 serial ports on the data loggers and the PC, which will be housed in a trailer located approximately 100 ft east of the FOS site. The PC will be equipped with a multichannel serial communications board providing eight serial ports. Three of these ports will be used to connect to the data loggers, and one port will be used to connect to a mouse. Standard serial cables, consisting of a DB9 connector at the data loggers and a DB25 connector at the PC, will be run from the data loggers (uphole equipment building) to the data acquisition PC (trailer).

The acquisition computer will be a ZEOS brand PC with an Intel 486 DX 50 CPU/microprocessor. It will be equipped with 128K of cache; standard 1.44-megabyte (MB) and 1.22-MB floppy disk drives, 32 MB of random access memory (RAM), two mirrored 500-MB hard drives, one parallel port, and a multichannel serial communications board. It will also include a high-speed VGA graphics card with 1 MB of RAM and Sierra DAC for 32,000+ colors and a 17-in. VGA multiscan, flat-screen, noninterlaced monitor. In addition, a 150/250-MB tape backup unit with an internal interface card will be included to facilitate system backups. Finally, an Ethernet card will provide a communications link to the data analysis subsystem.

As illustrated in Figure 2.6, a suite of software programs will be developed on the PC to provide a number of data access and management functions. The first set of programs will assist in managing the Campbell Scientific data loggers. Along with the PC208 commercial package provided by Campbell Scientific, several ANL-written programs will be available to facilitate data

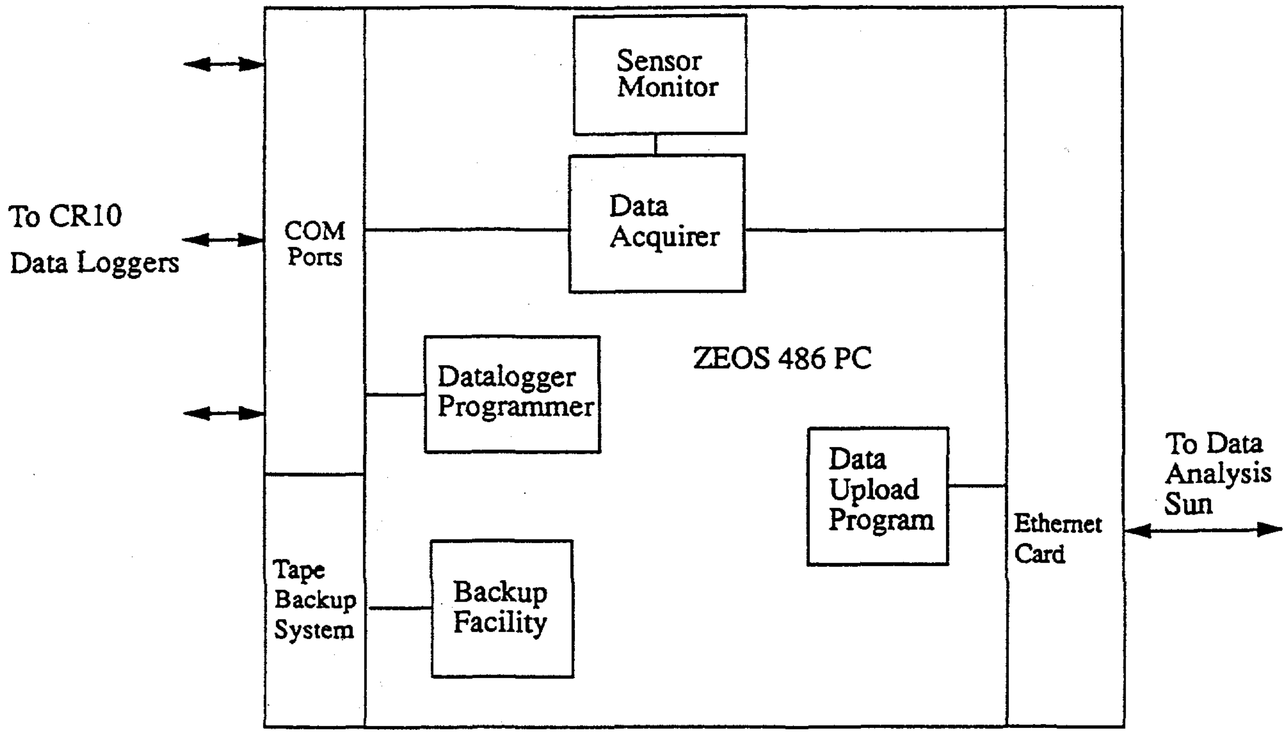

FIGURE 2.6 Overview of Data Acquisition Subsystem

collection from the CR10 data loggers. A commercial communication library (Greenleaf ProComm 4.0) will be used to access the serial ports of the PC and interface with the data loggers. ANL will provide the following three software programs to automate the data collection process:

- The Data Acquirer program will retrieve the sensor data from the CR10 data loggers at the appropriate time intervals. Data will be stored in files on the hard disk and automatically sent to the data analysis subsystem by using PC-NFS.

- The Datalogger Programmer software program will permit the user to reprogram the CR10 data loggers on the basis of desired measurement intervals and specified sensors. The utility will automatically rewrite the data logger programs and send (electronically) those programs to the data loggers.

- The Sensor Monitor program will allow the user to view the status of readings taken by the Data Acquirer. A daily log showing the times of recorded readings over the day will be automatically printed by the program.

Several safeguards will minimize the possibility of data loss. The data acquisition software will automatically perform daily backups of the sensor data. The tape backup system will be used so backups can be unattended. Data will be backed up to floppy disk and distributed each week. A copy of each weekly data backup will be available at the trailer. In addition, copies of each weekly data set will be distributed to ANL and SNL. User interaction will be required to change the media and transport the backups to the two sites for storage. Furthermore, the sensor data will be automatically transferred to the networked data analysis subsystem, which provides a secondary copy of all data. To supplement the regular backups, data will also be protected by using a mirrored-drive system on the PC. All sensor data will be written to both drives. If one of the two hard disks crashes, the system will be able to continue collecting and storing data. To safeguard against the possibility of losing geophysical logging data, backup copies of the floppy disk from the Ultra-Lite logging system will be made after each logging event. A copy will be available at the trailer, and copies will be distributed to ANL and SNL.

To further protect the system, an uninterruptable power supply will be used. If the machine reboots, the FOS site engineer/operator will be notified, and the PC will automatically restart the software, thereby allowing the data collection cycle to continue. If a program invokes an error condition, the operator will be notified, and the system will perform error recovery operations. The data acquisition system will be protected from unauthorized users, and it will be physically protected by restricting access to the trailer.

2.3 DATA ANALYSIS SUBSYSTEM

The purpose of the data analysis subsystem is to allow the user to analyze the sensor data acquired by the data acquisition subsystem. The data analysis subsystem consists of a Sun SPARCstation 2, analytical software, and data transfer utilities. As illustrated in Figure 2.7, the data analysis system will integrate the physical and chemical data in the system and format the data for the commercial analysis packages. The analytical software included on this machine will be the Statistical Analysis System (SAS), Xess spreadsheet package, SitePlanner, and FrameMaker. The data transfer utilities will include a program to query a subset of the available sensor data and a program to perform backups of the data analysis subsystem. Copyrighted software and hardware will adhere to all copyright laws.

The Sun SPARCstation 2 has 96-MB of RAM; an 8-mm, 2.3-gigabyte (GB) tape drive; a CD-ROM reader; 1.093 GB of storage capacity (424 MB on an internal drive and 669 MB on an external drive); a 1.44-MB floppy drive; a 19-in. color monitor; and a black and white Postscript printer. The Postscript printer will be shared with the data acquisition subsystem by using PC-NFS. Moreover, the Sun is configured to accommodate future expansion. The UNIX operating system and OpenWindows will be installed on the Sun. The Sun SPARCstation 2 will receive sensor data from the data acquisition subsystem via an Ethernet link by means of standard coaxial cable or twisted pair. PC-NFS will use the TCP/IP protocol to facilitate data transfer between the two subsystems.

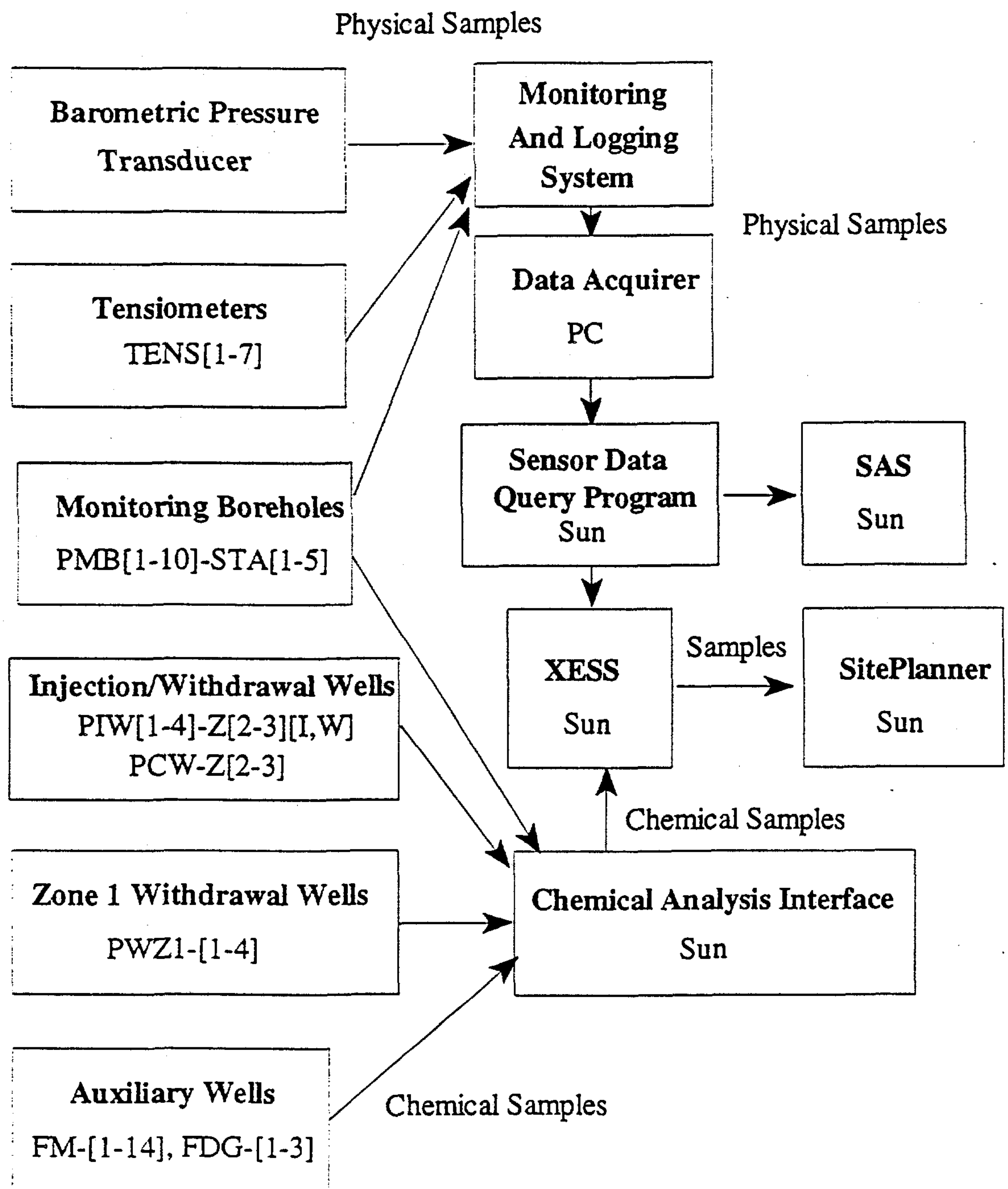

FIGURE 2.7 Data Flow through Data Analysis Subsystem

In addition, the Sun will transfer specific sensor information to a floppy disk for off-site storage and/or analysis. The local Postscript printer will be used to produce hard copies and print daily logs.

SitePlanner is an environmental data management and analysis tool developed by ConSolve. It uses an object-oriented database that stores data on each well in an object. Objects may be derived from more than 30 classes, ranging from a boring to a water interval sample. On the basis of these classes, the analyst may define new classes that contain additional information (e.g., add the ability to associate a time with each sample). Chemicals that are not recorded by SitePlanner can also be defined. The amount of information that SitePlanner can analyze depends only on the amount of memory on the Sun. The user will be able to query the system for specific information and visualize the site data by creating plan and profile surfaces on the basis of subsurface data and boring information. The user will load the results into Xess and transfer the data to SitePlanner for analysis.

SAS is a statistical package developed by the SAS Institute, Inc. This package, which will reside on the Sun SPARCstation, includes various statistical functions (linear regression, analysis of variance, etc.) and graphing capabilities (scatter plots with prediction confidence ellipses, residual versus predicted plots, etc.). Hard-copy output will be generated through the SAS package by using the local Postscript printer.

An interface will integrate chemical analysis data with the physical sensor data. The Chemical Analysis Interface program will allow the user to manually enter chemical analysis data. Before they are entered, however, they will be reviewed as described in the chemical sampling and QA document. This program will also allow independent verification of the data entered by another user. It will allow files to be examined, reports to be generated, and data to be exported to spreadsheets for later analysis and integration.

Once the analysis is completed, the user may use FrameMaker to develop the required reports containing the results of the analysis. FrameMaker, a word processing program developed by Frame Technology Corporation, allows the user to develop quality reports that can include text and graphics.

Finally, a backup utility will allow the user to specify which directories will be backed up. Backups will be performed daily and weekly. Weekly backups will be distributed to SNL and ANL and stored in the trailer. User interaction will be required to change the media. The utility will back up the specified data to the limits of the media that are used (i.e., 2.3 GB for tape backups and 1.44 MB for floppy backups).

Because the data analysis subsystem will use the UNIX operating system, it will generally be able to recover from power fluctuations by automatically rebooting. However, some situations can cause the system to fail and thus require a manual reboot. Because the data analysis subsystem will usually be used in an attended mode (i.e., used by an analyst/operator), these situations should not cause a serious problem. The data acquisition subsystem will not be affected by an error state in the data analysis subsystem.

The only program on the data analysis subsystem that must execute continuously is the backup utility, because system backups will be done automatically. UNIX can start specified processes when it is recovering from a system crash. Therefore, the backup utility will be able to be executed by the system. If a hard drive crashes, backup data will be used to restore the lost information. If sensor information is lost during the crash, it will be retrieved from either the last backup or the data acquisition subsystem. If the Sun crashes, the data acquisition subsystem will be unaffected.

3 MANAGEMENT

The overall management structure for the FOS subsurface biorestoration project is depicted in Figure 3.1. Three basic divisions of project personnel report to the program manager. Their responsibilities correspond to technical design and development, on-site operation and maintenance, and QA activities. The technical design and development area is further divided into monitoring and instrumentation and computer hardware/software. Although these are considered separate functions, project staff may have responsibilities in more than one of these areas.

As specified in the ANL QA Program Plan (ANL 1993a), management at all levels will regularly evaluate achievement relative to performance requirements. They will then validate or update, as appropriate, performance requirements, performance indicators and measures, and actions to ensure that quality is achieved. The management assessment process will periodically include an evaluation of the effectiveness of the QA plan and other management systems in fulfilling the objectives of the project. The results of management assessments, which focus on means of improving the quality of work performed, will be reported to the appropriate level of responsible line management.

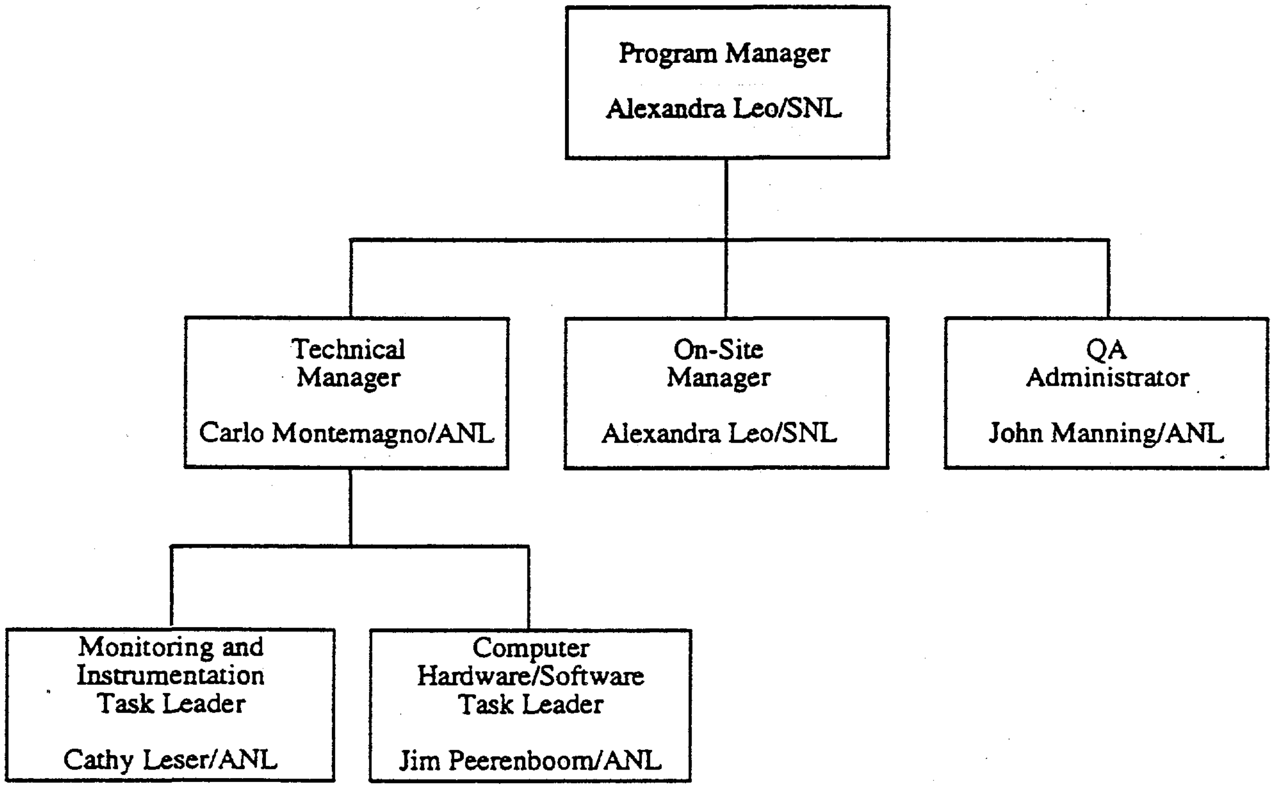

FIGURE 3.1 Management Structure for FOS Subsurface Bioremediation Project

When performance does not meet established standards, management will, with the assistance of others having appropriate expertise as required, determine the causes, identify corrective actions to improve performance, and follow up to evaluate the effectiveness of the actions.

Topics of management assessments may cover facility conditions at the FOS site; achievement relative to environment, safety, and health (ES&H) and programmatic goals; the effectiveness and adequacy of human and material resources; the effectiveness of personnel knowledge with respect to their tasks; and the degree to which the work environment and personnel interactions and participation promote the achievement and improvement of quality. Some assessments will be objective and performed according to established performance indicators. Other assessments may be a subjective component of the management system and will include the review and evaluation of research results by managers and/or committees formed by managers.

3.1 PROGRAM MANAGER

The program manager, who will provide overall programmatic guidance to all project, staff and oversee all project work. The program manager will also be responsible for coordination with SNL and ANL technical managers, DOE, and other relevant organizations and agencies. The technical manager, on-site manager, and QA administrator will report directly to the program manager. The program manager will approve overall project requirements and system design, implementation, testing, and fielding schedules and budget estimates.

3.2 TECHNICAL MANAGER

The technical manager, who will supervise all technical work on the project, will have the authority to make implementation, design, and testing decisions. Such decisions will cover monitoring instrumentation, computer hardware and software, and interfaces among these components. Task leaders responsible for monitoring instrumentation and computer hardware and software will report directly to the technical manager. Although these task leaders can recommend approaches and solutions, the technical manager, in consultation with the program manager and, as necessary, DOE, will make the final determination on technical issues.

3.3 ON-SITE MANAGER

The on-site manager will be responsible for all activities at the FOS site, including the installation and checkout, operation, and maintenance of all monitoring instrumentation and computer hardware. The on-site manager will ensure that all field operation procedures for the injection, withdrawal, and monitoring systems are followed and that the three-phase general operating strategy is properly executed. The on-site manager, or personnel designated by the on-site manager, will also ensure compliance with applicable on-site ES&H practices and QA procedures, monitor equipment operation, perform required recordkeeping, and execute necessary software backup procedures.

3.4 QA ADMINISTRATOR

Under the overall authority of the program manager, the QA administrator will develop, implement, and enforce QA practices and procedures for the project. Laboratory ES&H and QA personnel will provide QA support and assistance, as required. Although the program manager and QA administrator will be ultimately responsible for ensuring that QA practices and procedures are followed, QA is the responsibility of each individual staff member who supports the program. In other words, each staff member is responsible for following applicable QA practices and procedures and ensuring the quality of products.

The QA administrator will also be responsible for establishing and maintaining QA files and controlling releases of computer software. Software trouble reports and change requests will be controlled by the QA administrator, who is the chair of the configuration control board (see Section 5.1). The QA administrator will also control passwords and commercial, off-the-shelf software products.

4 QUALITY ASSURANCE CRITERIA

Consistent with DOE Order 5700.6C and the ANL QA Program Plan (ANL 1993a), this section addresses 10 quality assurance criteria organized into three categories: management, performance, and assessment. These criteria are the foundation of the QA program for the FOS subsurface biorestoration project. Where appropriate, references are made to other sections of this QA plan that address the criteria in greater detail.

4.1 MANAGEMENT CRITERIA

4.1.1 Criterion 1: Program

A description of how to implement the QA practices and procedures for the data acquisition and management system developed to monitor the FOS subsurface biorestoration project is provided in this QA plan. Section 3 describes the organizational structure, functional responsibilities, levels of authority, and interfaces for those managing, performing, and assessing the adequacy of work. Specific project requirements, goals, and objectives are discussed in the ANL FOS reports referenced in Section 1.3.

4.1.2 Criterion 2: Personnel Qualifications and Training

The program manager and QA administrator will ensure that all employees are cognizant of their responsibilities under this QA plan. They will also assure that the proficiency of personnel in assigned tasks is suitable and educate all personnel in the execution of standard operating procedures for processes and activities that affect the validity of analytical, statistical, and modeling results. Sections 3 and 6.2 cover these issues in greater detail.

4.1.3 Criterion 3: Quality Improvement

To improve performance and quality, the program manager, technical manager, on-site manager, and QA administrator will specify goals and objectives for quality improvement and identify, analyze, resolve, and follow up on quality issues and problems. Items and processes that do not meet established performance requirements will be identified and controlled to reduce the risks associated with their use. Significant and recurring deficiencies will be analyzed to identify root causes, determine corrective actions to minimize or eliminate recurrences, and apply "lessons learned" to identify opportunities for improvement.

A primary purpose for analyzing quality problems will be to identify potential improvements in planning and working practices that would help prevent problems and use resources more effectively. The type of analysis conducted will be appropriate to the nature of the deficiency, and the formality and rigor of the analysis will be commensurate with the importance or significance of the deficiency. QA practices will be periodically examined to determine whether different or modified practices would more effectively address management goals.

Management at all levels will empower personnel to excel in performing their work and will provide and implement a process for resolving problems, including professional differences of views. Personnel at all levels will be involved in setting goals and developing methods for quality improvement.

Correction of quality problems will involve personnel at the lowest decision-making level possible. Management at all levels will foster a "no-fault" environment in which all personnel will be encouraged to identify and report unsafe working conditions.

4.1.4 Criterion 4: Documents and Records

Project records (documents) such as logbooks and laboratory notebooks, QA plans, calibration data, analysis results, training records, and computer program documentation will be controlled for traceability and retrievability. The details of records collection, maintenance, and retention are covered in Section 7.

4.2 PERFORMANCE CRITERIA

4.2.1 Criterion 5: Work Processes

The program manager and other line managers will inform personnel about the acceptable bounds of work performance, including the performance objectives for which personnel are held accountable. Work process reviews will be held as needed to help workers meet performance requirements and help reduce risks. Criteria for acceptable work performance and achievement of performance objectives will be defined for personnel; the goal is to give employees regular feedback on the acceptability of their work and opportunities for improvement.

Personnel at all levels will be familiar with the relevant instructions and limitations for the work they perform. Before undertaking a task, the performer will ensure that preconditions have been met, there are no interferences that would prevent the effective pursuit of the work, and the performance requirements and QA actions are understood.

Work will be performed under conditions that encourage meeting performance requirements; appropriate technical standards and administrative controls will be identified. Advisory or mandatory written guidance, instructions, or procedures will be used for qualification, validation, and verification to the extent that they contribute to meeting performance requirements. Written procedures, which range from guidance on acceptable work practices to task-specific instructions, will be controlled in a manner commensurate with risk (see Section 7).

Items that significantly affect quality will be identified and controlled to ensure their proper use; maintained to prevent their damage, loss, or deterioration; and properly handled, shipped, and received. Equipment used for data collection or for in-process monitoring of work will be calibrated and maintained as required to achieve the performance requirements.

4.2.2 Criterion 6: Design

Items and processes will be designed on the basis of sound engineering and scientific principles and appropriate technical standards to ensure that they perform as intended. The design bases and standards being used and the basis for their selection (e.g., DOE specification, calculations, analyses) will be clearly specified at an early stage of design. Design changes will be controlled. Technical and administrative design interfaces will be identified and controlled.

In all cases, design specifications and bases will address minimum requirements for controlling effects on health, safety, and the environment. The technical manager and task leaders performing design work will specify applicable design codes and standards to be used as minimum requirements for all work.

The scope of activities for which these requirements are applicable includes the design and modification of facilities, physical devices, software, and systems that provide services and functions such as training, data processing, financial and human resource management, information management, and ES&H protection.

4.2.3 Criterion 7: Procurement

Standard processes used by ANL's Environmental Research Division (ER) will be employed to ensure that items and services procured from both internal and external suppliers meet established requirements and perform as specified and that procurement procedures conform with DOE and federal requirements. Commensurate with the complexity, cost, risk, and programmatic significance of items and services, and with the quantity and frequency of their procurement, standard ANL and ER processes will be used to (1) identify their applicable technical and administrative requirements,

(2) prepare acceptance criteria, (3) accept purchased items and services, and (4) respond when nonconforming items are received.

Prospective external suppliers will be evaluated and selected on the basis of specific ANL procurement criteria. The program manager and other line management will routinely verify that approved suppliers can continue to provide acceptable items and services and will ensure that specifications and expectations are properly communicated to prospective suppliers.

4.2.4 Criterion 8: Inspection and Testing

On the basis of quality requirements, items that do not provide accurate results will be replaced by items that satisfy all requirements. Verification will be based on calculations and visual inspections of equipment and data, as appropriate. Equipment that has failed a performance test will be clearly marked as inoperable and removed from inadvertent use until it has been repaired, replaced, and/or recalibrated. The QA administrator will ensure that all logbooks and laboratory notebooks are complete and legible. Purchased software will be considered acceptable if it performs in accordance with its accompanying documentation. Software written in-house will be tested extensively before being put into use, as described in Section 5.

4.3 ASSESSMENT CRITERIA

4.3.1 Criterion 9: Management Assessment

Each year, the QA administrator will evaluate the QA plan. Management problems perceived by project staff will be brought to the attention of the program manager for review and correction.

4.3.2 Criterion 10: Independent Assessment

As deemed necessary by the program manager, independent assessments will be conducted to assist line management in identifying opportunities for quality improvement. If the results of an assessment identify deficiencies, line management will be responsible for either (1) identifying and implementing corrective actions or (2) reconciling the results of the assessment through interaction with the program manager and the QA administrator.

5 CONFIGURATION MANAGEMENT

Configuration management involves the formal control of all computer software and supporting documentation throughout the system life cycle. For purposes of this QA plan, it also involves all equipment inspection and hardware/software testing. As shown in Figure 5.1, the life cycle extends from concept development and requirements definition through operation and maintenance. It entails configuration identification, control, status accounting, release management, and audit and assessment activities.

5.1 RELEASE MANAGEMENT

Configuration management is a functional responsibility of the QA administrator. The software development functions, which are controlled by the technical manager, are separate from the software review and release functions. The QA administrator elicits assistance from the technical

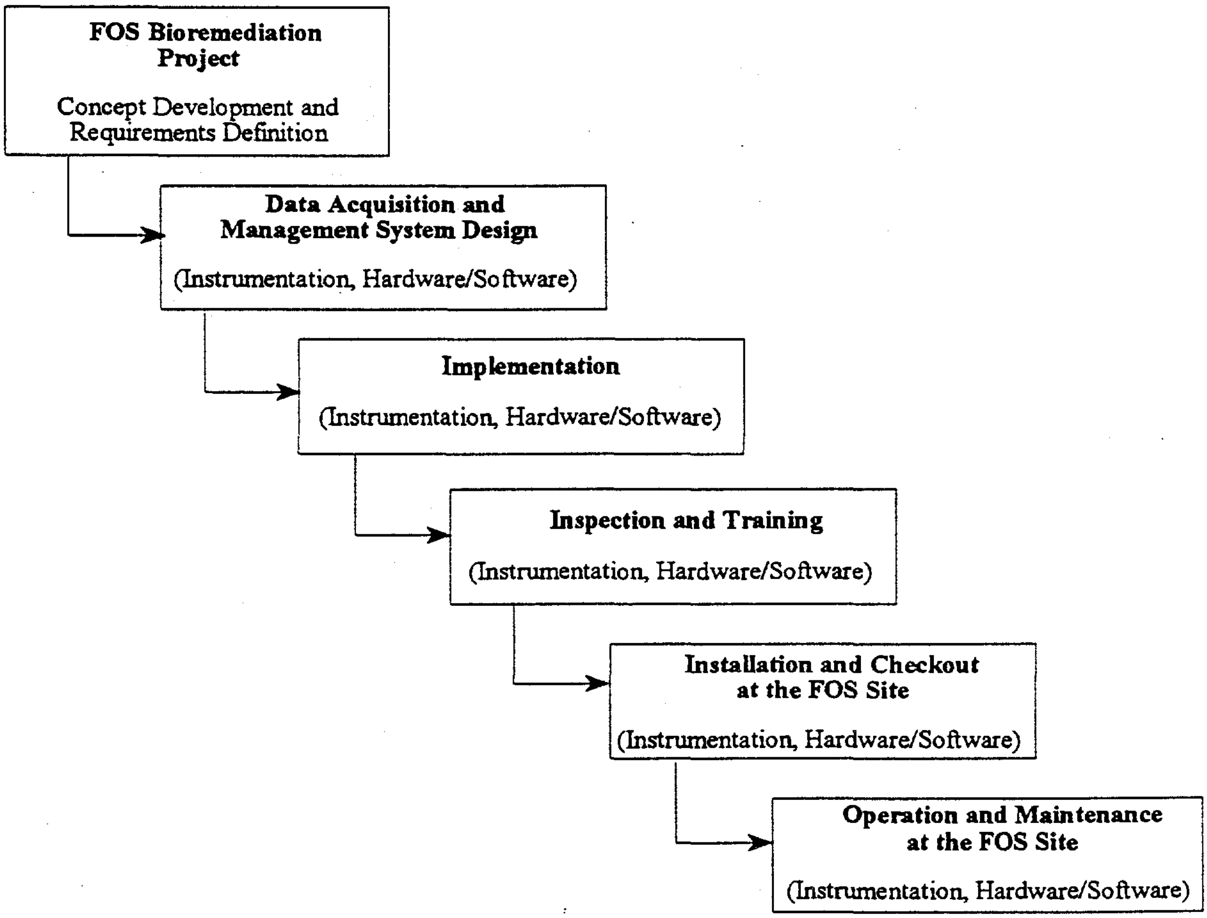

FIGURE 5.1 FOS Subsurface Bioremediation Project Life Cycle

manager and computer hardware/software task leader, as needed, to evaluate, implement, and test software changes.

A configuration control board (CCB) will be established to review, approve, and document all major software changes and releases. The CCB will be chaired by the QA administrator and include the technical manager, monitoring and instrumentation task leader, and computer hardware/software task leader. The QA administrator or an individual designated by the QA administrator will perform virus checks on all PC and Sun software prior to release, as described in Sections 2 and 6. The program manager has final budgeting, scheduling, and release authority.

5.2 RELEASE IDENTIFICATION

A system release scheme (i.e., version identification scheme) will track all software releases. This scheme will assign a unique identifier to each version of the software. The initial software release package, which will contain software for the PC and Sun SPARCstation 2, will be designated as version 1.0. Each individual software application package after version 1.0 will be tracked separately. Each new version will be documented so that all changes incorporated since the previous release and other details appropriate for identifying the release can be easily identified. In addition, all standards, practices, and conventions used to develop a release will be documented.

5.3 CHANGE AND DISTRIBUTION REQUESTS

Control procedures for changes in software configuration will be implemented to ensure the traceability of the software configuration through its development and evolution. Change control will be applied in a cost-effective manner, on the basis of the knowledge that although controls add to the up-front cost of developing and maintaining software, a lack of controls increases the vulnerability of the software and the potential for software failure, with its associated costs. The specific controls to be implemented will vary, depending on the function of the software, recognized risks of the application, and the system's software environment (Sun SPARCstation or PC).

Approval procedures will be applied to all custom software to authorize and document any changes made after initial installation at the FOS site. An audit trail will enable the QA administrator to document all software modifications and provide a record of what changes were made, who made the changes, why the changes were made, and the dates of the changes. The developer will document all change requests in a log book so that a record of change requests can be reviewed with the QA administrator.

5.4 INSPECTION AND TESTING

Testing of components and integrated system testing will be conducted in the laboratory prior to installation at the FOS site to ensure quality and performance. Electronic components of the downhole equipment array (thermistors, pressure transducers, tensiometers, data loggers, etc.), computer hardware, and application software will be tested.

5.4.1 Incoming Inspection

5.4.1.1 Temperature Probes

The thermistors and attached cables will be inspected physically and electrically to ensure that they meet manufacturer specifications. Physically, the probes will be examined for correct housing material and measured for correct housing outer diameters and length. Also, the neoprene seal and external splice protector will be examined for integrity. The attached cable will be examined for manufacturer's type and length.

Electrically, the resistance of the thermistors will be measured at ambient temperature to ensure that they meet specifications, which will also ensure cable lead continuity. Thermistor electrical isolation from the probe housing will be tested for high resistance.

5.4.1.2 Pressure Transducers

The pressure transducers and attached cables will be inspected physically and electrically to ensure that they meet manufacturer specifications. Physically, the probes will be examined for correct housing material and identification markings and measured for correct housing outer diameter and length. Also, the cable seal will be examined for integrity, and the placement of the filter stone will be verified. The attached cable will be examined for manufacturer's type and length.

Electrically, each pressure transducer will be tested for response by using the Geokon readout box.

5.4.1.3 Data Loggers

The data loggers will be tested by downloading temperature and pressure measuring programs into them; internal and external thermistors will be checked for correct temperature indications, and pressure transducers will be checked for correct pressure indications. These tests will ensure that the CR10's excitation outputs, analog/digital conversion input circuits, and data storage circuits are operating correctly.

The Ultra-Lite borehole data logger will be tested for sensor recognition and proper operation of any MS-DOS and PCL System software.

5.4.1.4 Multiplexers

The multiplexers will be tested by applying clock and reset pulses while measuring the multiplexed input-to-output connections for electrical continuity.

5.4.1.5 Logging Devices

The following logging devices will be visually inspected for correct type, completeness, and serial numbers: tensiometers, lysimeters, logging tools, and air-lift samplers.

5.4.1.6 Uninterruptible Power Supplies

The uninterruptible power supplies will charged for the recommended time and then tested to determine how long they will supply operating power to the computers and instrumentation subsystems with no external alternating current (AC) power input.

5.4.2 Assembly of Instrumentation Electronics

5.4.2.1 Temperature Data Logger and Multiplexers

The temperature data logger, range resistor box, and short-haul modem will be securely mounted within the dusttight and watertight data logger enclosure. The multiplexers will be securely mounted within their similar enclosures. The data logger enclosure, multiplexer enclosures, and temperature calibration test set will be securely mounted on a water-sealed, shock-mounted, rectangular, 3/4-in.-thick plywood backboard.

The interconnecting wiring — including direct current (DC) power wiring, multiplexer to data logger wiring multiplexer clock and reset wiring, data logger to short modem wiring, and calibration test set wiring — will be installed, cabled, and attached by tie-wrap to the backboard.

The temperature probe cables will be inserted through the enclosure cable fittings, connected, and attached by tie-wrap during final assembly.

5.4.2.2 Pressure Data Logger and Multiplexers

The pressure data logger, multiplexers, interface unit, and short-haul modem will be securely mounted within their dusttight and watertight enclosures on a separate shock-mounted backboard. The interconnecting wiring will be installed, cabled, and attached by tie-wrap to the backboard. The pressure sensor cables will be inserted through the enclosure cable fittings, connected, and attached by tie-wrap during final assembly.

5.4.2.3 Tensiometer Data Logger and Multiplexer

The tensiometer data logger, multiplexer, voltage-to-current converter box, short-haul modem, and calibration test set will be securely mounted within their enclosures on a separate shock-mounted backboard. The interconnecting wiring will be installed, cabled, and attached by tie-wrap to the backboard. The cables from the tensiometer current converters will be inserted through the enclosure cable fittings, connected, and attached by tie-wrap during final assembly.

5.4.3 Testing and Calibration of Electronic Sensors

5.4.3.1 Temperature Probes

The temperature data logger will be calibrated to an accuracy of 0.1°F by means of the temperature calibration test set, which incorporates a set of resistance values for thermistors T1 and T2 provided by YSI. Then, all 50 YSI 071 probes and 44018 thermilinear thermistors will be calibrated individually by being electrically connected to a multiplexer attached to a data logger with one set of range resistors. Each probe will be calibrated in a constant-temperature water bath. Calibration temperatures will be approximately 5°C and 30°C to represent the range of temperatures expected at the FOS site. The temperature settings and voltage readings will be recorded and used as the basis for calculating multiplier and offset values to give the linear relationship between temperatures (°C) and voltage (mV). The accuracy will be checked by using a constant-temperature water bath set at approximately 20°C. Each thermistor will be calibrated to a thermometer traceable to the National Institute of Standards and Technology. The signal from the thermistor will be processed through a data logger. The temperature settings and the readings for each thermistor will be recorded.

5.4.3.2 Pressure Transducers

The pressure data logger will be calibrated to an accuracy of 0.1 pound per square inch (psi) by using a calibration oscillator to simulate a set of transducer frequency data and by using a resistor to simulate the transducer thermistor. The transducer's pressure indication will be tested in a column of water at depths of 1, 3, and 5 ft. Readings will be taken with a portable readout box that is compatible with the pressure transducers. These readings will then be converted to pressure readings by using calibration data supplied with the pressure transducer. The signal from the pressure transducer will be processed through a data logger. The frequency and the corresponding pressure reading for each depth measurement will be recorded.

5.4.3.3 Tensiometers

The tensiometer data logger will be calibrated to an accuracy of 0.1 centibar vacuum by using a digital current source to simulate the 4- to 20-mA current convertor output of the tensiometer. Then all 10 tensiometers will be tested individually by being connected, one at a time, through a multiplexer to the data logger input. Because the tensiometer will also be outfitted with a current transducer, the signal from the current transducer will be processed by a data logger.

5.4.4 Testing of Data Acquisition and Data Analysis Subsystems

To test the data acquisition and data analysis subsystems, both unit-level and integrated system testing will be performed. Each software program will be analyzed by using simulated data sets. Extreme values will be tested to reveal any limitations in the software. For example, data collection software will be tested to determine whether it can adequately handle the minimum expected measurement interval. Sample data sets will be developed to test whether data analysis packages are correctly manipulating sensor data. All software components will be tested to ensure that they fulfill their intended functions.

In addition to being tested individually, software components will be tested when integrated. Such testing will reveal any incompatibilities among the programs. Stress testing will determine how the system behaves under error conditions. For example, the data collection procedure will be tested to ensure it will continue even if another program causes an exception error, and the two subsystems will be tested to ensure that even if a problem occurs on one subsystem, the other one will continue to function. (For example, if the data analysis subsystem is off-line, the data collection process must still be able to continue to retrieve data.) Any limitations or restrictions on interoperability will be documented, and corrective actions will be taken.

5.4.5 Testing of Electronic Sensors at SNL before Their Installation

5.4.5.1 Temperature Probes

After they are shipped from ANL, the thermistors and attached cables will be reinspected physically and electronically at SNL. Physically, the neoprene seal and external splice protector on each probe and the attached cable will be examined for integrity. Electronically, each thermistor will be tested for response by using a temperature readout set consisting of an excitation source, range resistors, unit conversion circuit, and digital voltmeter. Each thermistor will be submerged in a 55-gal drum filled with water, and the temperature reading will be recorded.

5.4.5.2 Pressure Transducers

After they are shipped from ANL, the pressure transducers and attached cables will be reinspected physically and electronically at SNL. Physically, the cable seal and the attached cable will be examined for integrity, and the placement of the filter stone will be verified. Electronically, each pressure transducer will be tested for response by using the Geokon readout box. Each pressure transducer will be submerged to a depth of 1 ft in a 55-gal drum filled with water. The frequency readings will be converted to pressure readings by using calibration data supplied with the pressure transducers. The frequency and corresponding pressure reading for each depth measurement will be recorded.

6 SECURITY MANAGEMENT

Security management involves the protection of the hardware and computer software components associated with the three data acquisition and management subsystems. It involves physical security, personnel security, information security, disaster recovery and contingency planning, and virus prevention and detection.

6.1 PHYSICAL SECURITY

The field instrumentation, computer hardware, and ancillary equipment used in the FOS subsurface biorestoration project will be subject to physical safeguards to prevent the loss of equipment, software, or information from natural hazards, theft, and malicious acts. During system implementation and testing, all equipment will be housed in a locked room on the ANL site in Illinois. This site is fenced, patrolled, and has controlled access. Similarly, the equipment will be housed in physically controlled facilities (uphole equipment building and trailer) it is at the FOS site in Livermore, California. The uphole equipment building and trailer will be locked when not in use. The SNL Livermore site is fenced, patrolled, and has controlled access.

6.2 PERSONNEL SECURITY

Personnel granted access to the work areas at ANL and the FOS site will have varying levels of authorization to directly handle equipment. Program line managers will take measures to ensure that sensitive materials and software requiring protection are not accessed by unauthorized individuals.

Personnel at all levels will be appropriately qualified and trained to perform their assigned work with a proficiency that meets the project's mission, goals, objectives, and performance requirements. Personnel will be educated and/or trained as appropriate to maintain suitable job proficiency. Qualification and training criteria will be subject to ongoing review for adequacy and effectiveness.

The type of education and training will reflect the nature of the work. Appropriate indicators of qualifications and training include university/college degrees or other professional certification and postdegree experience. For cases in which degrees, certificates, licenses, and the like are not sufficient to assure quality, training commensurate with the complexity and risks of the tasks to be performed will be provided.

Personnel with line management responsibilities will be qualified by education, training, and/or experience in managerial, communication, and interpersonal skills suitable for the FOS project.

Argonne personnel and non-ANL persons working at ANL facilities and at the FOS site will be trained in ways to recognize and eliminate, minimize, or control, as appropriate, the environmental, safety, and health hazards associated with their tasks and workplace.

6.3 INFORMATION SECURITY

Information collected from the monitoring equipment and stored in the data acquisition and data analysis computers will be protected from unauthorized access, disclosure, modification, and destruction. A password protection system will limit access to data files. All copyright laws applying to commercially purchased software will be followed.

6.4 DISASTER RECOVERY AND CONTINGENCY PLANNING

Procedures will be established to protect hardware, software, and data in the event of an emergency. Three backup copies of monitoring data will be created and stored to guard against loss in the event of a facility disaster, such as a fire or earthquake at the FOS site. One backup copy will be stored in the trailer, one in another building on the SNL site, and one at ANL in Illinois. Section 2.2 provides more discussion of backup procedures for the data acquisition and management system.

6.5 VIRUS PREVENTION AND DETECTION

A virus prevention and detection check will be established for both the PC and the Sun. A periodic virus scan of the systems will be done, and all incoming and outgoing PC media will be checked by using the Virhunt Anti-Virus Protection Program, which is approved by DOE. The integrity of the Sun operating system will be protected by a UNIX security checking tool known as Computer Oracle Password and Security System (COPS). COPS provides the following:

- System security profiling (file, directory, and device permissions/modes; path checks; unrestricted NFS mounts, etc.);
- Password inspection;
- File integrity (CRC of important files);

- Kuang expert system (security access/dependency chain analysis); and

- Identification of vulnerable versions of system utilities.

In addition to the above software controls, there will also be physical access controls. To provide security, the only network link will be between the PC and the Sun, which are located in the trailer. A modem link to the Sun will be used only for off-site inspection and maintenance. Only authorized users will have access to the computers.

7 RECORDS COLLECTION, MAINTENANCE, AND RETENTION

This section identifies the QA documentation to be retained; states the methods and facilities to be used to assemble, safeguard, and maintain this documentation; and designates the retention period. These records will be protected against damage, loss, and deterioration.

A complete QA record is a document that is protected from additional entries and whose revision would be subject to a change control process. All changes must be reviewed for adequacy and approval by the appropriate personnel.

All documents generated for the FOS project will be assembled, filed, indexed, and stored on a continuing basis. As each document becomes a QA record, it will be entered into the project administrative file. This file will contain all original materials and be maintained by the QA administrator at the ANL site in Illinois. This file will also include:

- Master copies of the software,
- Copies of drawings and specifications,
- Results of experimental and analytical measurements,
- Logbooks and notebooks (original of downhole installation notebook will be at SNL),
- Training records,
- User documentation,
- Program documentation,
- Procedure documentation,
- Status reports, and
- Quality Assurance Plan.

A control logbook will be established at both the uphole equipment building and the trailer to inventory all records and maintain the updated status of each record. While in use, the control logbooks will be maintained by the on-site manager and archived by the QA administrator. These QA files will be retained for a minimum of 5 years. After 5 years, the files may be moved to archival storage in accordance with DOE Order 1324.2A, *Records Disposition*, unless other requirements take precedence.