PLAN FOR THE DESIGN, DEVELOPMENT, IMPLEMENTATION, AND OPERATION OF THE NATIONAL WATER INFORMATION SYSTEM

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By Melvin D. Edwards

ABSTRACT

The Water Resources Division of the U.S. Geological Survey is developing a National Water Information System (NWIS) that will integrate and replace its existing water-data and information systems of the National Water Data Storage and Retrieval System, National Water Data Exchange, National Water-Use Information, and Water Resources Scientific Information Center programs. It will be a distributed data system operated as part of the Division's Distributed Information System, which is a network of computers linked together through a national telecommunication network known as GEONET.

The NWIS is being developed as a series of prototypes that will be integrated as they are completed to allow the development and implementation of the system in a phased manner. It also is being developed in a distributed manner using personnel who work under the coordination of a central NWIS Project Office. Work on the development of the NWIS began in 1983 and it is scheduled for operation in 1990. This document presents an overall plan for the design, development, implementation, and operation of the system. Detailed discussions are presented on each of these phases of the NWIS life cycle. The planning, quality assurance, and configuration management phases of the life cycle also are discussed. The plan is intended to be a working document for use by NWIS management and participants in its design and development and to assist offices of the Division in planning and preparing for installation and operation of the system.

1. INTRODUCTION

The Water Resources Division (WRD) of the Geological Survey (USGS) began the design and development of a National Water Information System (NWIS) in April 1983. The NWIS is intended to integrate and replace the existing water-data and information systems of the following programs of the Division:

- o National Water Data Storage and Retrieval System (WATSTORE): The primary system used by the Division for the storage, retrieval, and dissemination of its water data.

- o National Water Data Exchange (NAWDEX): An interagency program managed by the Division which indexes water data available from both Federal and non-Federal agencies and coordinates a nationwide user-service program for the identification and acquisition of available water data.

- o National Water-Use Information Program (NWUIP): A national program for gathering site-specific water-use information through a network of State Water-Use Data Systems and the aggregation of water-use information in a National Water-Use Data System (NWUDS).

- o Water Resources Scientific Information Center (WRSIC): A program for abstracting water-resource publications worldwide and providing a bibliographic user-service program.

Initial plans and designs for the NWIS were developed by a special task force established by WRD for this purpose in April 1983. The task force presented a plan for the design, development, implementation, and operation of the NWIS in October 1983 (Edwards, M. D., and others, Geological Survey, written commun., 1983). This plan presented several alternative procedures and techniques to be considered for use in the NWIS, from conceptual design to implementation. Since that time, some of the procedures and techniques presented in the plan have been modified and others have been developed for use. This document updates the original plan to include the latest procedures and techniques adopted for use in the continuing design and development of the NWIS. It discusses organizational responsibilities associated with the design, development, implementation, and operation processes; the various tasks associated with these processes; and how the tasks will be managed and accomplished.

1.1 Purpose of the Plan

The NWIS represents the largest system redesign, conversion, and development effort ever undertaken by WRD. Its development strategies involve the use of personnel from all levels of the Divison. System development will also involve the use of many new software, hardware, and data-base technologies and concepts that are changing and advancing very rapidly. Because of the size and complexity of the effort, the Division needs an established framework for the consistent and effective planning, management, development, and operation of the NWIS. A mechanism also is needed for informing personnel of the tasks involved in the NWIS life cycle and how these tasks will be managed and accomplished. This plan serves both of these needs. It is intended to be a working document that will be periodically updated to include new strategies, procedures, and management practices as they are developed.

1.2 Scope of the Plan

This plan discusses the environment and the conditions under which the NWIS will be developed. Major development strategies for the system are presented. The management of the project is discussed in terms of organizational responsibilities, development costs, staffing, and scheduling. The plan also identifies and discusses the tasks necessary to design, develop, implement, and operate the system.

1.3 Acknowledgments

Acknowledgment is given to the following members of the National Water Data System Task Force who developed the original plan for the design, development, implementation, and operation of the National Water Information System upon which this document is based:

Isabelle Halley des Fontaines, U.S. Geological Survey, Water Resources Division
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2. OVERVIEW OF THE PLAN

The following subsections present a brief overview of the plan presented in detail in the remainder of this document.

2.1 Development Strategies

Three major strategies are being used in the development of the NWIS: (1) Interim systems are being developed for the conversion of existing software and data bases of WATSTORE. They will operate on the existing distibuted network of minicomputers while the NWIS is being designed and developed. (2) The system is being designed and developed in a distributed environment to make better use of the skills and expertise of personnel located in offices throughout the Division. (3) The system is being developed as a series of prototypes which will allow concepts and technologies to be tested and evaluated as independent models models, the partitioning and scaling of design and development projects to fit available resources, and users to test and evaluate individual components of the system as they are developed.

2.2 Management Responsibilites

The design, development, and implementation of the NWIS is being managed by the Division's Office of the Assistant Chief Hydrologist for Scientific Information Management (SIM). Several organizational groups support SIM in this activity. The Information Management and Computer Utilization Advisory Committee (IMACUAC) serves in an advisory capacity to SIM on matters related to policy, procedures, and user requirements. SIM is further supported by a Quality Assurance Board and a Configuration Management Board. These boards will monitor the design and development of the NWIS to assure adherance to standards and specifications, provide control over changes made to the design of the system, and certify and manage release of the system for implementation and operation.

The Branch of Computer Technology (BCT) within SIM has management and operational responsibility for the NWIS project. BCT is supported by various technical advisory committees and working groups which are appointed as needed and address specific technical issues and problems related to the NWIS and assist in the resolution of hydrologic and other discipline-related problems and issues pertinent to the design and development of the system.

The NWIS Project Office within BCT has responsibility for the design and development of the NWIS. The WATSTORE Program within BCT has responsibility for the design, development, implementation, maintenance, and operational support of interim systems for the NWIS on the minicomputer network. WATSTORE will also have future responsibility for the implementation, maintainance, and operational support of the NWIS. The Distributed Information System (DIS) Network Analysis and Operations Program within BCT maintains the telecommunication network for the Division and provides operational support to the national network of minicomputers. The DIS program will provide support to the NWIS in telecommunication matters, use of its distributed hardware systems, evaluation and selection of specialized hardware, and the testing, evaluation, and selection of proprietary software.

2.3 Funding and Development Costs

Funding requirements for the NWIS are estimated to be about $1 million per year for 5 to 7 years. Funding for the development of the system will be assessed as part of the technical support service charges assessed by the Division to all cost centers. The funds provided will be used to reimburse offices for personnel assigned to assist in developing the NWIS and the procurement of hardware and software needed to develop the system.

2.4 Planning

This document is an overall plan which defines the strategies and procedures to be used for developing the system. More detailed plans will be prepared to cover each phase of the system's design, development, implementation, and operation. These plans include the following: Annual work plans, detailed system design and development plans, plans for each individual task to be performed, plans for the testing and evaluation of software and data-base modules developed for use in the system, and plans for the implementation and operation of completed components of the system.

2.5 System Design

There are four major phases of the design process for the NWIS: (1) Requirements analysis, (2) Conceptual design, (3) Functional design, and (4) Detailed design. An analysis was made of the Division's existing data systems which defined the overall requirements of the NWIS. These overall requirements were used to develop a conceptual design which defines the objectives, scope, and structures of the overall system. The conceptual design will be updated periodically to include new concepts and technologies that have been introduced. As shown in figure 1, the NWIS system design has been subdivided into three

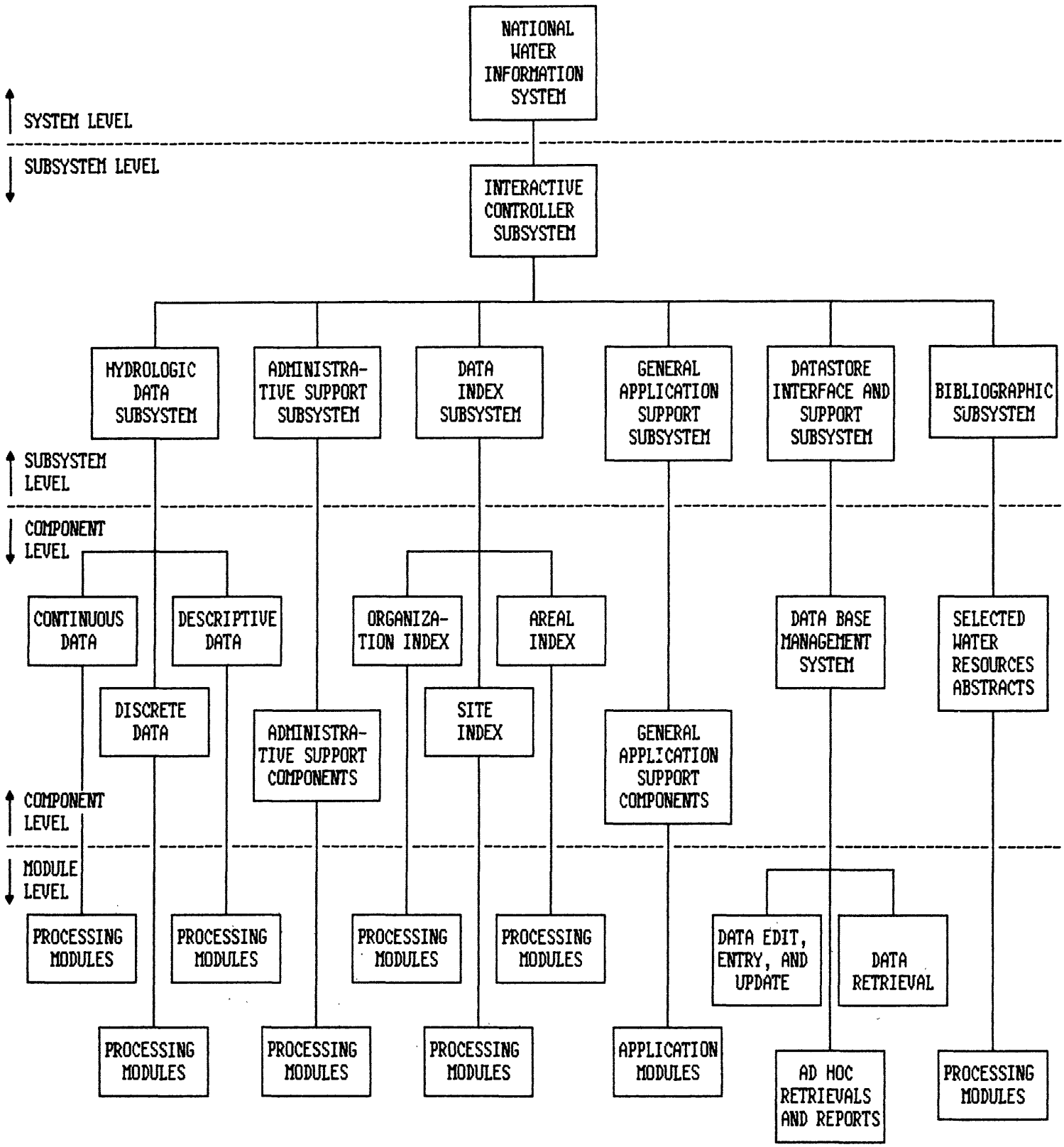


Figure 1.--Simplified structure of the National Water Information System.

subordinate levels: (1) Subsystems, (2) Components, and (3) Modules. Requirements analyses will be performed and functional design specifications will be developed for each subsystem and component in the system. Subsequently, detailed design specifications will be developed for each software and data-base module.

2.6 System Development

After detailed design specifications have been prepared, the NWIS will be developed in stages. The computer code will be designed, written in pseudocode, and documented. The documented code will be subjected to a detailed review to determine its adherance to the design specifications and to detect technical errors and logic faults in the code design. The computer source code will then be developed. The source code will undergo extensive testing to assure its completeness and accuracy. All software and data base systems will be approved by the Configuration Management Board before they are released for implementation and use.

2.7 Implementation and Operation

Implementation of the NWIS will involve the installation of approved software and data bases, conversion and validation of existing data to be stored in the released version of the system, and testing to verify complete and proper installation of the system. The system will be operated on individual computers located in regional, District, State, subdistrict, and other offices throughout the Division that will be linked together through the nationwide GEONET telecommunication network. Operation of the NWIS will require contingency planning for actions to be taken as the result of system failures, managing and controlling user access to the system, assistance to local users, monitoring the performance of the system, and capacity planning for future expansion of the system. Periodic internal control reviews will be conducted to assure that local nodes are operated in compliance with established operating policies and procedures.

2.8 Quality Assurance and Configuration Management

The design, development, implementation, and operation of the NWIS will be controlled through a program of quality assurance and configuration management. Quality assurance is a process that assures that the system is developed in compliance with design specifications and defined standards, meets the needs of the users, is properly documented, produces accurate results, and performs efficiently. Configuration management is a process of controlling changes to the system, approving systems for release, and managing the release of new versions of the system.

3. DEVELOPMENT STRATEGIES

The software and data base development required for the NWIS will be a complex and lengthy undertaking. Recognizing this, the Division has adopted new strategies which will include the development of the system in a distributed

manner and the use of application prototyping for phased development of the system.

3.1 Interim Systems Development

The design, development, and implementation of the NWIS is expected to take from 5 to 7 years with full operation of the system planned for 1990. Its implementation will, therefore, take place at the end of the life cycle of the minicomputer hardware in current use. In order to fully utilize the existing minicomputers, WRD decided in 1983 to proceed with the development of interim systems that would convert the existing systems used for the processing of hydrologic data from the Geological Survey's central mainframe computer for use on the distributed network of minicomputers. This was to be done with-out major redesign of the existing software and data base systems and would allow the Division to take advantage of the advanced computing capability of its Distributed Information System while the NWIS was being designed and developed.

Work is nearly complete on the interim systems. While no major design changes have been made to the existing applications, changes have been made to provide interactive processing capability and to modify the data base management systems for operation on the minicomputer hardware. Implementation of the interim systems, known as NWIS 85.1, began in fiscal year 1985. They are scheduled for full implementation in fiscal year 1987. They will remain in use until the NWIS system discussed in this plan is developed and implemented.

Much of the software developed for NWIS 85.1, such as procedures for the processing of data received from automated instrumentation and specialized data-analysis packages, will be applicable for use in the NWIS. The NWIS 85.1 software will be analyzed and, where appropriate, will be integrated into the NWIS software system. Integration of NWIS 85.1 software into the NWIS will require some modules to be modified to add new functionality identified for the system, to fit the size and requirements of computer hardware selected for use by the system, and to interact with base management systems of the overall system.

3.2 Distributed Development

Distributed development has been used by the Division since 1983 in the design and development of the NWIS, including the interim systems. This method was chosen for the following reasons:

- Magnitude of the development task greatly exceeded the personnel resources traditionally available through the Headquarters staff of the Division for systems development activities.
- Development of the NWIS, to the greatest extent possible, using in-house personnel.
- Better use of skills, expertise, and experience of personnel throughout the Division.
- Direct involvement of users in the design and development of the system.

Design and development projects are accomplished through the recruitment and establishment of teams. Each team consists of a minimum of three people;

a designer/developer and two technical/peer reviewers. Members are assigned to each team as needed to accomplish the assigned task. Each team is assigned a team leader. For projects requiring multiple teams, a project leader is assigned for their coordination. All projects and teams are coordinated through the NWIS Project Office located in the Branch of Computer Technology of the Office of Scientific Information Management.

Teams will be staffed using Division personnel whenever possible. As each new design or development project is initiated, a description of the project and each task associated with the project will be distributed to all offices of the Division along with a request for assistance. The task descriptions will include a discussion of the work requirements, a description of the results or products to be produced, personnel requirements in terms of number of people necessary to complete the task, skills required, personnel time requirements, and scheduling for each task. Offices will, in turn, nominate personnel to be considered for the project, and team members will be selected from among those nominated.

Before work begins on a project, all team members including analysts and reviewers, will meet for orientation. At this meeting, any problems associated with the logistics of the project will be resolved and a work plan will be developed and agreed upon. The orientation will include the following:

- o Goals and objectives
- o Overview of work to be done and relationships to other projects and tasks
- o Overview of previous work that is relevant to the current project
- o Overview of tasks and subtasks associated with the project
- o Project management procedures:
  - -- Scheduling and milestones
  - -- Funding
  - -- Status reporting requirements and procedures
  - -- Telecommunication techniques and procedures
- o Design strategies and techniques
- o Quality assurance and configuration management procedures:
  - -- Walkthroughs
  - -- Reviews
  - -- Change requests for previous designs
- o Documentation requirements and procedures

Team members receive copies of the specifications for tasks to be performed during the orientation. Before actual work begins, the task specifications are reviewed for completeness and clarity. Any misunderstandings or problems are clarified with the NWIS project management staff at this point.

After orientation, team members will return to their home offices to begin work. Most work will be performed at their home office locations under the supervision of local managers who are given work plans and schedules to assure that the work is completed on time. Some tasks will, however, require team members to work together at a central location to use special equipment, perform tests, or other work that requires personal contact. Team members will be asked to meet periodically to perform reviews and conduct system tests. There will be frequent contact between the teams and the NWIS project management staff to

identify and correct operational problems and assure that work is being performed on schedule.

The full cost of team personnel, including salary, overhead, travel, and subsistence, will be assumed by the NWIS project.

3.3 Application Prototyping

Application prototyping has been adopted as the methodology to be used in the design and development of the NWIS. Application prototyping is an investigative, iterative approach to system design and development which involves the partitioning of the system into small functional components for development and testing. Each prototype will be a working model for the testing of designs, concepts, hardware, software, and data base technologies for use in the system. The application prototyping methodology offers the following advantages in the development process.

- o The method allows the NWIS to be partitioned into components that have the highest priority of need for design and development.
- o Design and development efforts can be scaled to fit available resources.
- o Users will be allowed to interact with the system and provide early feedback, thereby providing frequent input to its design and development.
- o New concepts, ideas, and technologies can be tested and accepted or rejected before large amounts of time and resources are committed.
- o Unacceptable designs, concepts, and procedures can be rejected or modified and retested without major impact on the overall design and development effort.
- o User feedback on prototypes will allow the the development of more comprehensive and accurate functional and technical specifications for the system.
- o User involvement in the design, development, and testing processes will provide better user acceptance of the system upon implementation.

The first step in the prototyping process is the partitioning of the NWIS into major prototypes. As given in table 1, the NWIS has been partitioned for prototyping by major subsystems and components of the system design. This is the initial partitioning of the system and the prototypes have been arranged in their general order of anticipated development. The order of development may, however, be rearranged as deemed necessary by the design and development priorities placed on the development of the system. Each prototype has been further partitioned into smaller prototypes. As the prototyping process progresses, concepts and techniques are accepted or rejected and new requirements are identified and documented for the system. As new requirements are identified, the number of prototypes within a subsystem or component will be expanded to include the additional functionality identified for the system.

Each prototype will test a different set of processing functions in relation to the system's data base, network, and software and hardware architectures. Prototypes will be developed as independent entities to test specific functions and concepts, or as enhancements to add additional functions and capabilities to previously implemented prototypes.

Table 1.--Major prototypes of the National Water Information System.

Prototype Number	Subsystem	Component	Functions
1.0	Data Index	Site Index	Process manual input transactions; Edit, enter, update, retrieve, and report data
1.1	Data Index	Site Index	Perform scheduled updates from NWIS 85.1
1.2	Data Index	Site Index	Perform network retrievals from NWIS 85.1 using output from the site index
1.3	Data Index	Site Index	Perform scheduled updates from STORET
2.0	Hydrologic Data	Discrete Data	Process water-quality data; edit, enter, update, report data
2.1	Hydrologic Data	Discrete Data	Receive and process data from the Central Laboratory
2.2	Hydrologic Data	Discrete Data	Process extreme events data
2.3	Hydrologic Data	Discrete Data	Process water-use data
3.0	Hydrologic Data	Descriptive Data	Process ground-water site inventory data
3.1	Hydrologic Data	Descriptive Data	Process basin characteristic data
4.0	Hydrologic Data	Continuous Data	Process manual input transactions for daily values; edit, enter, update, report data
4.1	Hydrologic Data	Continuous Data	Process Analog-to-Digital Recorder (ADR) data
4.2	Hydrologic Data	Continuous Data	Process Direct-Readout Ground Receive Station (DRGS) data
4.3	Hydrologic Data	Continuous Data	Process Adaptable Hydrologic Data Acquisiton System (AHDAS) data
5.0	Data Index	Organization Index	Process manual input transactions; edit, enter, update, retrieve, and report data
5.1	Data Index	Organization Index	Store summary counts from Site Index

Table 1.--Major prototypes of the National Water Information System.
-- Continued

Prototype Number	Subsystem	Component	Functions
6.0	Bibliographic	Selected Water Resources Abstracts	Process publication abstracts; edit, enter, update, retrieve, and report data
7.0	Data Index	Areal Index	Process manual input transaction; edit, enter, update, retrieve, and report data
7.1	Data Index	Areal Index	Index national water-use data
8.0	Administrative Support	User Accounting System	Process user-accounting data

The prototyping cycle for the NWIS is shown in figure 2. As shown, the development of each prototype is an iterative process of system design, development, and implementation. Rigid quality assurance and configuration management procedures will be applied throughout the prototyping process.

Successful prototypes will become an operational part of the NWIS. As each prototype is tested and accepted, it is combined with preceding prototypes to add additional functionality and capability to the operational system. Each successful prototype combined with the system remains as a part of the system to be used by succeeding prototypes. In this manner, the NWIS becomes increasingly larger with increasing levels of functionality as development progresses. At predetermined stages in the NWIS development, normally at the end of the development of a major subsystem, the operational and tested system will be approved for release and distributed for use. Using this process, the system can be placed into operation in stages, thereby minimizing the impact of its installation and implementation and the disruption of other systems in operation at each local computer node. Implemented releases will continue to be expanded and enhanced as additional applications are developed and approved for inclusion in the system.

4. PROJECT MANAGEMENT

The management of the NWIS is discussed in the subsections that follow. Discussions are presented on organizational responsibilities, development costs, staffing, and scheduling for the project.

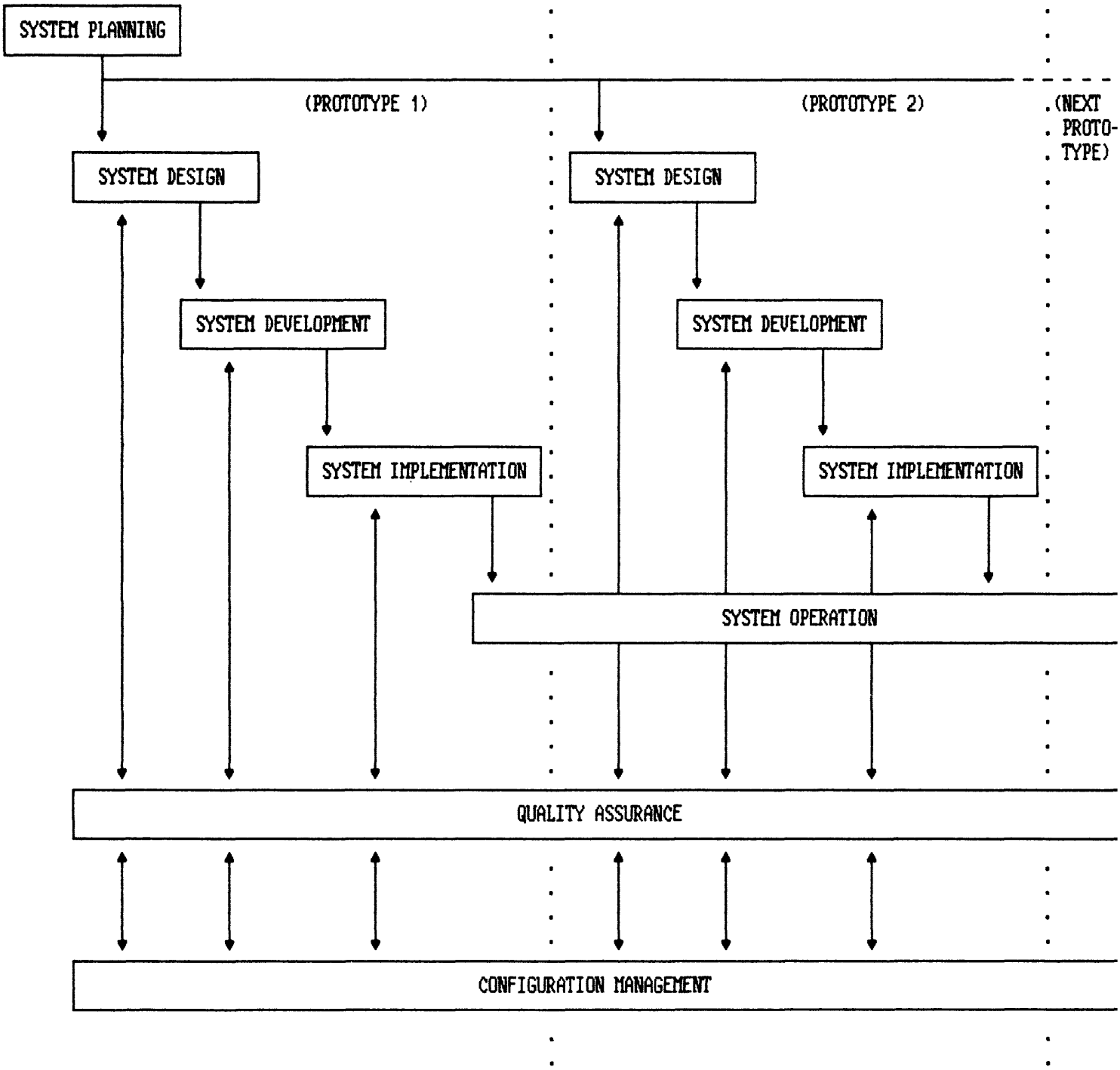


Figure 2.--Prototyping cycle of the National Water Information System.
(Modified from Buys, R. T., 1984, p. 1-4).

4.1 Organizational Responsibilities

Due to the distributed development strategies for the NWIS and its distributed mode of operation in the future, nearly all offices within the Division will ultimately become involved in its design, development, implementation, and operation. Responsibilities of the various offices and organizational groups are discussed in the subsections that follow.

4.1.1 Office of Scientific Information Management

Primary responsibilities for the design, development, and implementation of the NWIS and the coordination of its operation lie within the Office of the Assistant Chief Hydrologist for Scientific Information Management (SIM) located at the Geological Survey's National Center in Reston, Virginia. As shown in figure 3, SIM is supported by a number of offices, committees, and working groups that are active in NWIS activities.

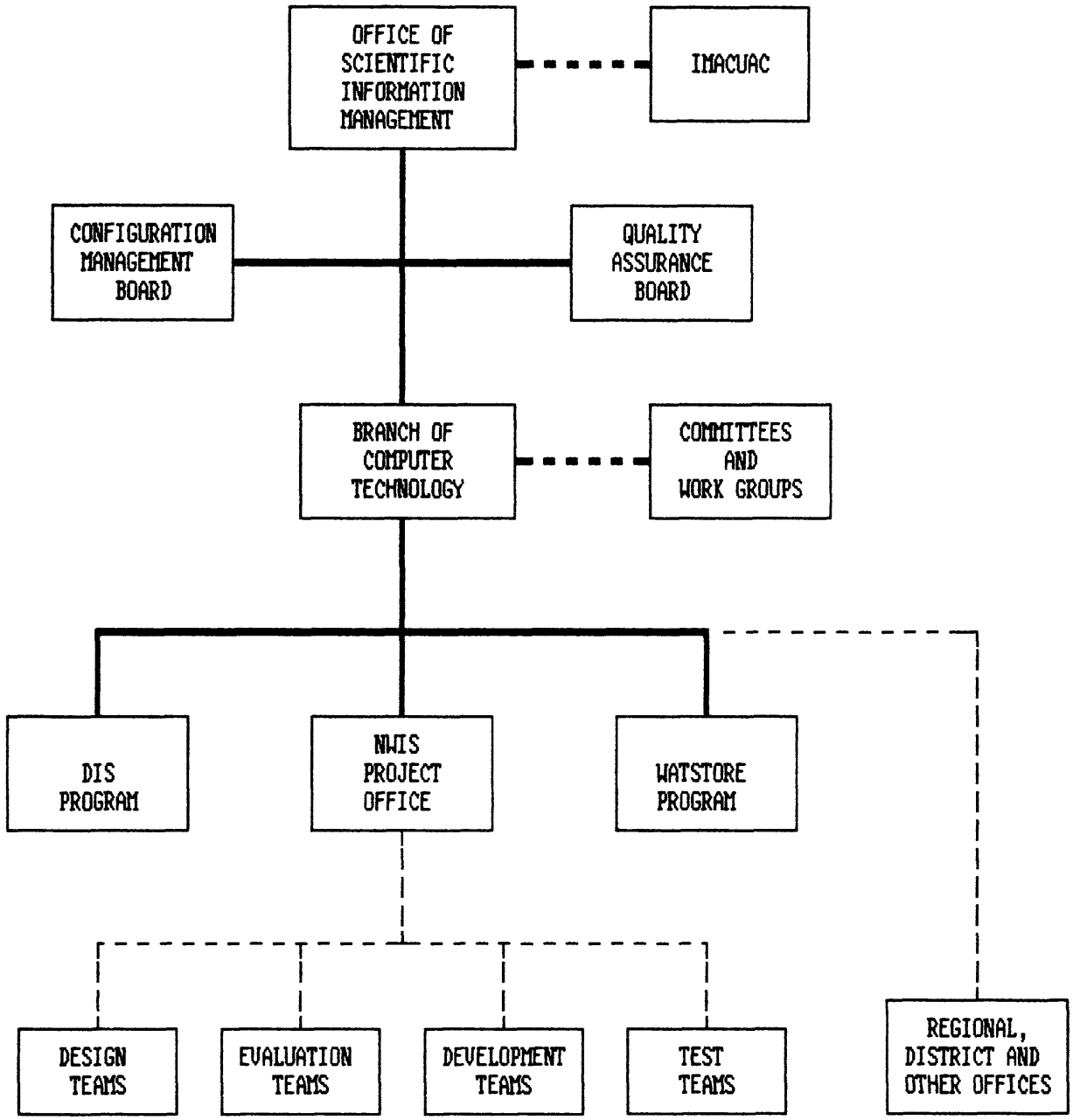
4.1.1.1 Information Management and Computer Utilization Advisory Committee

Since the implementation of the distributed network of minicomputers in 1982, the Information Management and Computer Utilization Advisory Committee (IMACUAC) has monitored and provided advice on the development and operation of the network. The IMACUAC is chaired by the Assistant Chief Hydrologist, SIM, and is comprised of representatives of SIM, the Assistant Chief Hydrologist for Operations, the Assistant Chief Hydrologist for Program Coordination and Technical Support, WRD District Chiefs from each region, regional computer specialists, and regional research hydrologists. The IMACUAC has also monitored and provided advice to the NWIS project since its inception in 1983. The committee will continue to provide advice to the NWIS in matters relating to project policy and procedures, funding, development scheduling and priorities, and user relationships.

4.1.1.2 Configuration Management Board

The configuration management program for the NWIS will be conducted under the direction of a Configuration Management Board. This board will work under the auspices of the Assistant Chief Hydrologist, SIM, who will appoint its members. The board will consist of members selected from headquarters, regional, and District offices of the Division. The board will work closely with the NWIS Project Office in the management and operation of the configuration management program. It will have the following general responsibilities.

- Approval of changes and enhancements to the NWIS
- Verification and validation of changes and enhancement
- Certification of software and data base systems
- Approval and scheduling of system releases



EXPLANATION:

DIS - Distributed Information System
IMACUAC - Information Management and Computer Utilization Advisory Committee
NWIS - National Water Information System
WATSTORE - National Water Data Storage and Retrieval System

Figure 3.--Organizational structure for the design, development, implementation, and operation of the National Water Information System.

4.1.1.3 Quality Assurance Board

The quality assurance program for the NWIS will be conducted under the direction of a Quality Assurance Board. This board will work under the auspices of the Assistant Chief Hydrologist, SIM, who will appoint its members. The board will consist of members selected from headquarters, regional, and District offices of the Division. The board will work in close concert with the NWIS Project Office in the management and operation of the quality assurance program. It will have the following general responsibilities:

- Approval of system design, development, and documentation standards
- Audit and monitoring of systems design and development activities
- Oversight of system and documentation reviews, walkthroughs, and quality-assurance team activities
- Approval of system test plans and procedures
- Monitoring and approval of system tests and evaluations
- Verification and acceptance of systems
- Problem and change request analysis

4.1.1.4 Branch of Computer Technology

The Branch of Computer Technology (BCT), SIM, has direct management responsibility for the design, development, and implementation of the NWIS and the coordination of its operation. As shown in figure 3, a variety of technical advisory committees, special interest groups, and working groups may also be established and coordinated by the BCT as needed. These groups will provide advice and counsel on special user requirements for the NWIS, address specific technical issues related to the design, development, implementation, and operation of the system, and provide special forums for the discussion and resolution of hydrologic and other discipline-related problems and issues pertinent to the design and development of the system.

4.1.1.5 National Water Information System Project Office

The National Water Information System (NWIS) Project Office was established in the Branch of Computer Technology, SIM, in April 1986. It has been assigned responsibility for the design and development of the NWIS. It has the following general responsibilities:

- Planning and management of system design and development
- Recruitment, orientation, and coordination of design and development teams
- Administering the quality assurance and configuration management programs
- Testing and accepting software and data base systems
- Coordinating the testing and evaluation of new software, hardware, and data base technologies
- Coordinating the development and publication of NWIS documentation

The NWIS Project Office is intended to be a temporary organizational structure within SIM to direct and manage the design and development of the NWIS

during the period that interim systems are being developed and implemented for the operation of existing hydrologic data systems on the distributed network of minicomputers. After the minicomputer-based interim systems (see subsection 3.1) have been completed and implemented, the functions and responsibilities of the Project Office will be merged with those of the existing WATSTORE Program.

4.1.1.6 National Water Data Storage and Retrieval System Program

The National Water Data Storage and Retrieval System (WATSTORE) Program within the Branch of Computer Technology, SIM, has responsibility for the operation and maintenance of the existing National Water Data Storage and Retrieval System and the design, development, conversion, and implementation of interim systems for the operation of the WATSTORE systems on the Division's distributed network of minicomputers. It will have the following NWIS responsibilities in the future:

- Continued design, development, enhancement, and maintenance of software and data base systems
- Release and distribution of systems
- Coordination of the installation and operation of systems in the distributed environment
- User training and assistance
- Data base administration
- Administration of the quality assurance and configuration management programs

4.1.1.7 Distributed Information System Network Analysis and Operations Program

The Distributed Information System Network Analysis and Operations Program within the Branch of Computer Technology, SIM, will provide the following support to the NWIS:

- Telecommunication Support
  - -- GEONET national network planning, interfacing, and enhancement
  - -- Local Area Network (LAN) planning and interfacing
  - -- User training and assistance for telecommunication systems
- Hardware Support
  - -- Installation, maintenance, and operation of National Node computer systems and peripheral hardware
  - -- Assistance in evaluation, selection, and procurement of microcomputers and peripheral hardware
  - -- Coordination of distributed minicomputer and microcomputer network operations
  - -- User training and assistance for hardware systems
- Software Support
  - -- Assistance in testing, evaluation, selection, and procurement of proprietary software
  - -- Assistance in distribution and installation of software and data base systems

4.1.2 Regional, District, and Other Offices

The NWIS will be a distributed data system coordinated by SIM. The system will be maintained and operated on local computer nodes in regional, District, State, subdistrict, project, and other offices throughout the Division. Each office operating a configuration of the NWIS will be responsible for its management and operation; local user assistance and services; new-release updating; maintenance, management, and administration of the local data bases associated with the system; and coordination with other nodes in the network. These offices will also provide personnel support in the design and development of the system.

4.2 Development Costs

Funding for the NWIS development costs will be provided from the technical support service charges assessed by the Division to all cost centers. Projected development costs for the system are presented in table 2.

Table 2.--Projected life cycle costs of the National Water Information System.

	Funding (In Thousands of Dollars)							
Fiscal Year	1983	1984	1985	1986	1987	1988	1989	1990
Staffing and Administration			50	100	150	175	200	225
Design and Development Team Support	150	150	395	450	600	500	300	200
Hardware (*)			50	350	150	150	150	0
Software (*)			25	50	50	50	50	0
Contractual Support	420	570	650	300	100	100	100	100
Total	570	720	1,170	1,250	1,050	975	800	525
Total Projected Development Costs	$7,060,000							

* - Used for prototyping purposes only.

Total cost of implementing and operating the NWIS will depend upon the data base management system selected, size and type of hardware selected for development purposes, and selection and procurement scheduling of hardware to replace the existing network of minicomputers. Personnel requirements and costs for implementing the NWIS will be approximately equal to existing costs for implementing and operating the NWIS 85.1 interim systems.

4.3 Staffing

Full-time staffing for the NWIS will consist of personnel of the NWIS Project Office and the WATSTORE Program. Staffing for design and development teams will be recruited, to the largest extent possible, from personnel of Division offices. These personnel will be recruited for short time periods to work on specific tasks and projects. Project personnel will be funded by the NWIS project. Funding will include salary, benefits, travel, and subsistence for the periods worked. For special skills not available from within the Division, assistance will be sought through the competitive procurement process.

4.4 Schedule of Development

Work began on the design of the NWIS in April 1983. It is scheduled for implementation and operation by the end of fiscal year 1990. Major milestones and tentative time schedules for the development and implementation of the system are shown in figure 4.

5. THE NATIONAL WATER INFORMATION SYSTEM LIFE CYCLE

Adequate management of any segment of the NWIS requires an overall understanding of its entire life cycle. The life cycle can be defined as all tasks and activities associated with the system from the time work began on planning for its development until it is no longer used. The life cycle consists of seven phases:

- o System Planning
- o System Design
- o System Development
- o System Implementation
- o System Operation
- o Configuration Management
- o Quality Assurance

Figure 5 shows the interrelationships of these phases. It is important to understand that each software and data-base module of the NWIS must progress through all phases of the life cycle. The first five phases of the cycle have a discrete beginning and ending. That is, one phase must be completed before a module advances to the next phase. Effective management of the cycle at each phase, however, requires a careful assessment of the results of the previous phase, planning for entry to the next phase, an assessment of impacts on future phases, and the ability to define the accuracy and completeness of the results of the current phase. These requirements are achievable through two phases of the life cycle which apply to all other phases of the cycle. The first life cycle phase, the quality assurance phase, assures the accuracy and completeness of the system through controlled reviews and audits of each phase of development and through the enforcement of standards, tests, assessments, and evaluations to be applied throughout the life cycle. The configuration management phase serves as the vehicle for controlling and managing hardware, software, resource, and procedural changes within the system. These two phases will be discussed first because of their applicability throughout the life cycle.

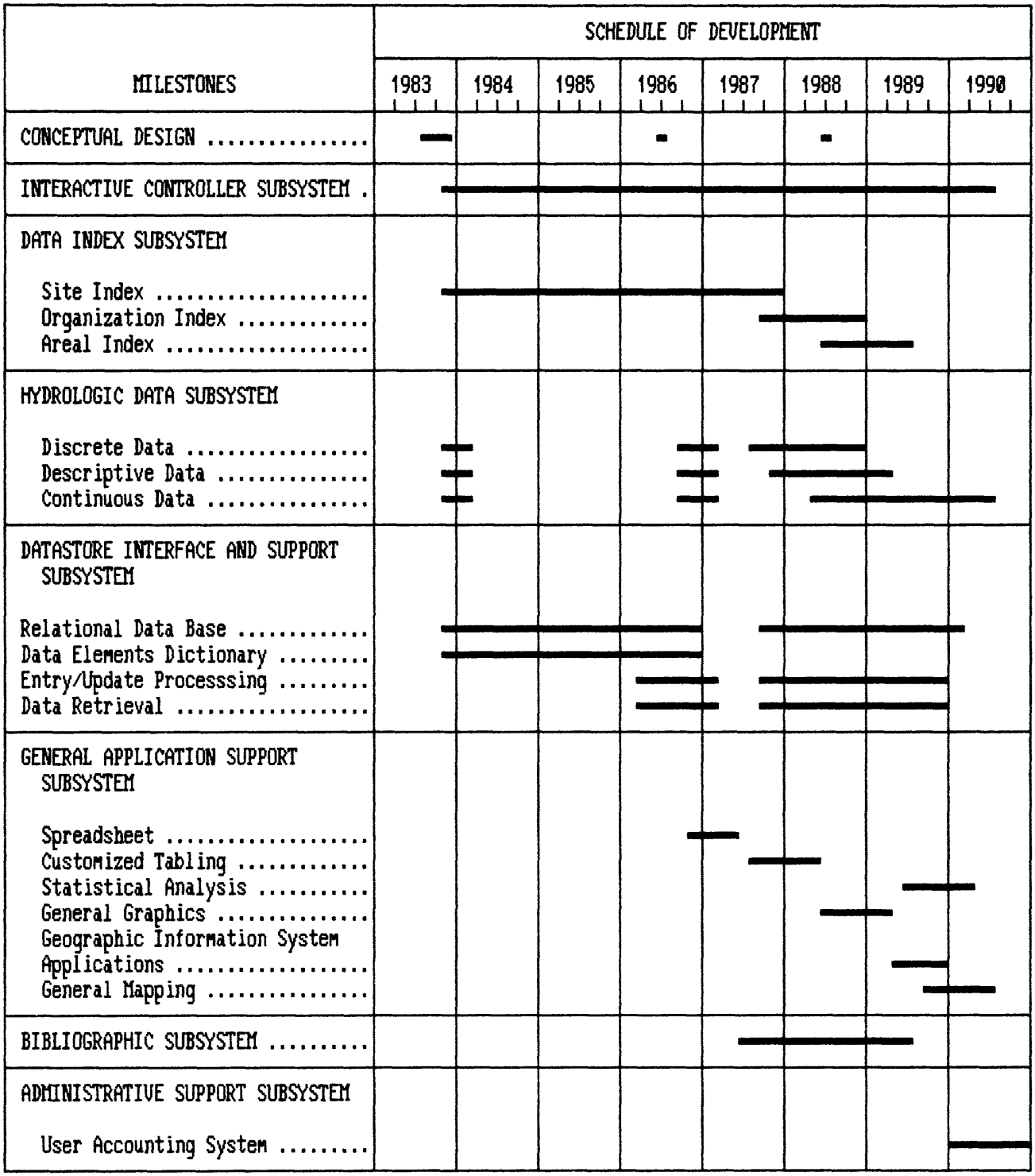
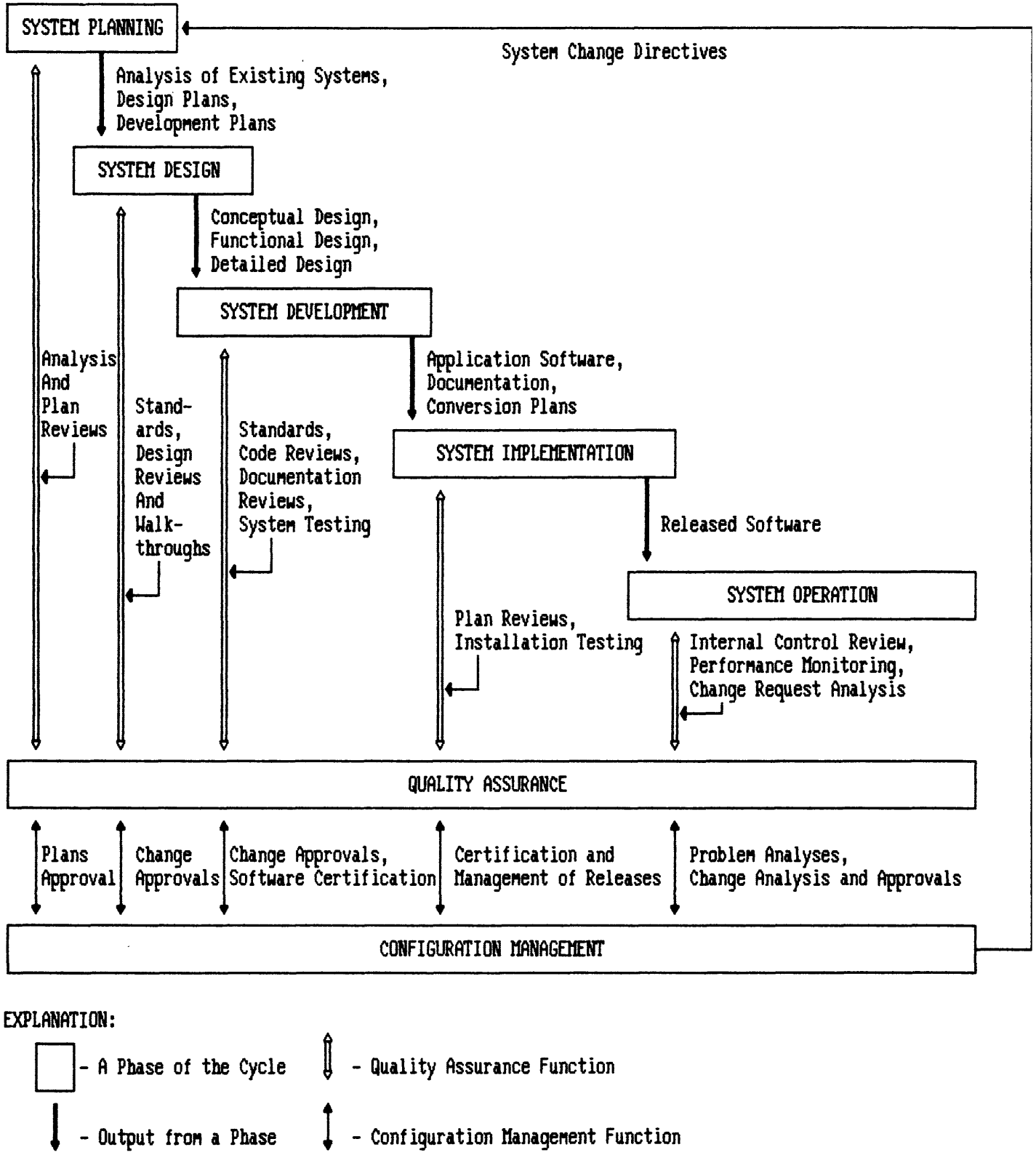


Figure 4.--Milestones and development schedule of the National Water Information System.



EXPLANATION:

- A Phase of the Cycle
- Quality Assurance Function
- Output from a Phase
- Configuration Management Function

Figure 5.--Phases of the National Water Information System life cycle. (Modified from Buys, R. T., 1984, p. 1-4).

5.1 Quality Assurance

The wide scope and distribution of the NWIS requires that an effective program of quality assurance be conducted to assure that the system is developed in a complete and consistent manner, in compliance with system design specifications. Quality assurance is a process that is designed to ensure that the system fulfills user needs, is well defined throughout its life cycle, produces accurate results, and performs efficiently (Buys, R. T., 1984, 233 p.). It is applied in each and every phase of the NWIS life cycle. The major functions of quality assurance consist of the following:

- Standardization: Federal Information Processing Standards (FIPS) will be used wherever applicable within the system. All Geological Survey review and publication policies and procedures will be followed in the preparation of documentation. Additional standards and guidelines will be developed and implemented by SIM in areas such as computer programming, system design, system testing, and other areas where standards do not exist.

- Walkthroughs: A walkthrough is a process in which a developer or designer explains concepts, designs, strategies, and development techniques to an assigned review team. This process allows immediate feedback to the developer/designer on the acceptability, completeness, and accuracy of the design or procedure as well as advice and suggestions on different concepts and techniques that may be used in the design or or development process. In this manner, poor design, faulty logic, and misinterpretations of specifications can be easily and quickly corrected before design documentation or system development begins. A walkthrough also helps the reviewers to better understand the design or development processes and strategies and will assist them in future reviews.

- Reviews: Peer and technical reviews will be conducted frequently throughout the system design and development phases of the life cycle. Each design or development team will be assigned a minimum of two reviewers. Reviewers will be assigned as needed to each team to assure complete technical competency in each specific area of design or development. Hydrologists and other discipline specialists, systems analysts, computer specialists, programmers, computer technicians and aids, and other personnel will be reviewers. Reviews will be conducted on initial and detailed designs, computer code, plans and procedures and all levels of the system's documentation.

- Documentation: All plans, designs, and software and data-base systems will be documented by the respective teams. Federal Information Processing Processing Standards (FIPS) Publication 38, "Guidelines and Documentation of Computer Programs and Automated Data Systems" (U.S. National Bureau of Standards, 1976, 55 p.) will be used as the standard for the content and format of documentation. Required amendments to FIPS Publication 38 and guidelines not covered by FIPS will be developed by the NWIS Project Office and submitted to the Quality Assurance Board (QAB) for approval. Analysis and design documents will be published in the Geological Survey Bulletin publication series. All other documents

will be published as Geological Survey Open-File reports. All documents will receive a minimun of two colleague reviews. Reviewed documents will be submitted to the NWIS Project Office for review and subsequent approval by the QAB. After approval by the QAB, documents will be returned to authors to be processed through the required channels for Division and Director's approval prior to publication.

- o Tests: Tests are conducted at all levels of the system development process by assigned review teams using approved test plans and validated test data sets. Unit, modular, integration, system, acceptance, and regression tests are conducted on all modules of the system. Each of these tests is discussed in subsection 5.5.4 of this plan. Testing is done at the times of system development and system implementation, and each time a change is subsequently made in the system.

- o Audits: Periodic managerial and technical audits will be made of NWIS projects to assure that work is done on schedule and within allocated funding, task and design specifications are followed, operational procedures are followed, and developed systems are functioning properly. Audits will be made by NWIS project management personnel or assigned audit teams.

5.2 Configuration Management

Configuration management is a structured methodology designed to maintain control of changes that may be made to the system during each phase of the life cycle. Because of the large scope of the NWIS and its distributed structure, a rigorously enforced program of configuration management will be required to assure that changes are made to the system in a controlled and systematic manner, and that changes are validated, tested, and accurately distributed to all operational nodes. The major functions of configuration management are the following:

- o Problem Reporting: Problems encountered during the development, testing, and operation of the NWIS will be documented by review and test teams and the users and will be reported to the Configuration Management Board (CMB). The CMB will assess proposed solutions to the problems and recommend corrective actions. Solutions will be documented by the Branch of Computer Technology and forwarded to the CMB which will validate that problems have been satisfactorily resolved.

- o Baselining Systems and Documents: A version of a system or document is baselined when it has been officially approved by the CMB. All designs must be baselined before development begins and all systems must be baselined before they are implemented. No document or system is baselined until it has successfully completed required technical reviews and acceptance tests. Once baselined, all future changes to the document or system must be documented and approved by the configuration management process before they are made.

- o Controlling Changes: After a system or document is baselined, all changes recommended by users or test teams will be documented and accom-

panied by an analysis of the impact of the change on the system or document. The CMB will evaluate the request and either approve or reject the change. If the change is approved, the CMB will determine the priority of need of the change and forward it to the Branch of Computer Technology for development and implementation. The CMB will subsequently monitor the development and testing of the change. After validation that the change has been made and successfully tested, the CMB will certify it for release and schedule its distribution with the Branch of Computer Technology.

- o Maintaining Libraries: Central libraries of all software and documentation developed for the NWIS will be maintained by the Branch of Computer Technology as a part of the configuration management process. Libraries will be maintained at varying levels ranging from initial drafts of documents and untested code to approved documents and code that have passed acceptance testing and are certified for release. This process will allow each step of the system design and development phases to be documented until the system has been completed.

- o Managing System Releases: No system or documentation will be released until the CMB has validated that all review, approval, and testing has been successfully completed. Once satisfied that the system and its documentation are complete, fully functional, error free, and accepted by the users, the CMB will certify the system and its documentation for release. After certification, the CMB will schedule the release of the system with the Branch of Computer Technology, announce its availability, and monitor its implementation.

5.3 System Planning

The complexity of the management structure of the NWIS and the large number of people involved in its development places emphasis on the need for frequent, well documented plans. A variety of different types of written plans will be required in order to keep managerial and technical staffs informed of tasks, personnel requirements, methodology, and scheduling associated with each NWIS project. The following subsections describe the contents of the various plans to be prepared.

5.3.1 Life Cycle Management Plan

The life cycle management plan is a requirement of the U.S. Department of the Interior's Office of Information Resources Management. Its structure and content are defined in the manual entitled "A Project Manager's Guide to Application Systems Life Cycle Management" (U.S. Department of the Interior, 1985, 180 p.). The plan will be prepared and updated by the Branch of Computer Technology.

5.3.2 Annual Work Plans

A work plan will be developed by the NWIS Project Office each year to define tasks to be performed for the NWIS during the current fiscal year and tasks that will be implemented during the current year that will be carried forward to the next year. The work plan is the primary mechanism for keeping WRD management informed of the NWIS development plans and needs. The plan will consist of the following:

- o Definitions of tasks to be performed
- o Priorities of tasks to be performed
- o Milestones and schedules for each task
- o Estimated costs and personnel requirements for each task
- o Procurement needs for each task

5.3.3 Design and Development Plans

A plan must be prepared by the NWIS Project Office for the design and development of each subsystem and component within the NWIS. The plan will be used by the NWIS Project Office to assure that individual project managers understand the design or development tasks to be performed, to define the scope of the work to be accomplished, to define the resource requirements for the project, and to coordinate individual projects with the overall design and development effort. Each plan will consist of the following:

- o A description of all components and modules within the subsystem or component to be designed or developed
- o A discussion of the interrelationships of the subsystem or component with other subsystems and components of the NWIS and its dependencies or impacts on other subsystems and components
- o A discussion of the interrelationships of the components within the subsystem and the modules with the component and their dependencies or impacts on each other
- o A prototyping strategy for the subsystem or component
- o Requirements for the conversion of existing software modules or data bases for use in the subsystem or component
- o Outline of tasks to be performed in designing or developing the subsystem or component
- o Milestones and scheduling for the design or development actities
- o Estimated costs and personnel requirements for the design or development of the subsystem or component

5.3.4 Task Plans

Individual plans must be prepared by individual project managers for each design and development task to be performed. These plans are necessary in order for all design and development team members to understand how a task is to be accomplished, what is to be achieved, and what the deadlines for the task are. The plans will be distributed to District and field offices of the Division as in-house requests for proposals to allow managers to determine the feasibity of nominating members of their staff for work on the task. They will also be used

by the NWIS project management staff for the briefing and orientation of each design or development team as it is initiated.

Each plan will consist of the following:

- o A description of the task to be performed
- o Goals and objectives of the task
- o Defined interrelationships, dependencies, and impacts of the task with other tasks within the system or subsystem
- o Milestones and schedules for the task
- o Personnel skills and resources required for the task
- o Estimated costs of the task
- o Quality assurance and configuration management procedures to be followed for the task
- o Descriptions of products to be produced by the task
- o Team composition and leadership
- o Project management procedures and requirements for the task

5.3.5 Test and Evaluation Plans

A plan must be developed by the system designers for the testing and evaluation of each software or data base module developed within the NWIS for accuracy, completeness, and adherance to its design specifications. Likewise, a plan must be developed by each evaluation team for each hardware system, data base management system, and proprietary software package to be tested and evaluated for use with the NWIS. Each plan will consist of the following:

- o A discussion of the goals, objectives, scope of the testing and evaluation
- o Methodologies and procedures to be used in the testing and evaluation
- o Definition of the levels of testing to be performed
- o Scheduling for the testing and evaluation
- o Expected results of the testing and evaluation
- o Validated data sets and/or software to be used for testing and evaluation
- o Personnel skills and resource requirements for the test or evaluation
- o Estimated costs of the test or evaluation

5.3.6 Implementation Plans

As each prototype or new release of the NWIS is certified for implementation, a plan must be developed by the Branch of Computer Technology that defines how the software systems and related data bases will be implemented for operational use. It will be distributed to all local system managers in advance of implementation to allow them to prepare for the implementation of the new system components. The plan will include discussions of each of the following:

- o Site preparation requirements
- o Conversion of existing data and information resources for inclusion in the new release of the system
- o Distribution strategy for data and software to operational nodes of the NWIS

- o Installation strategy for software and data bases at each node
- o Hardware, telecommunication, and data storage requirements at each node
- o Installation testing and problem reporting strategies
- o Organizational and staffing requirements
- o Training requirements
- o Documentation requirements
- o User assistance strategies
- o Schedule of installation
- o Estimated implementation costs

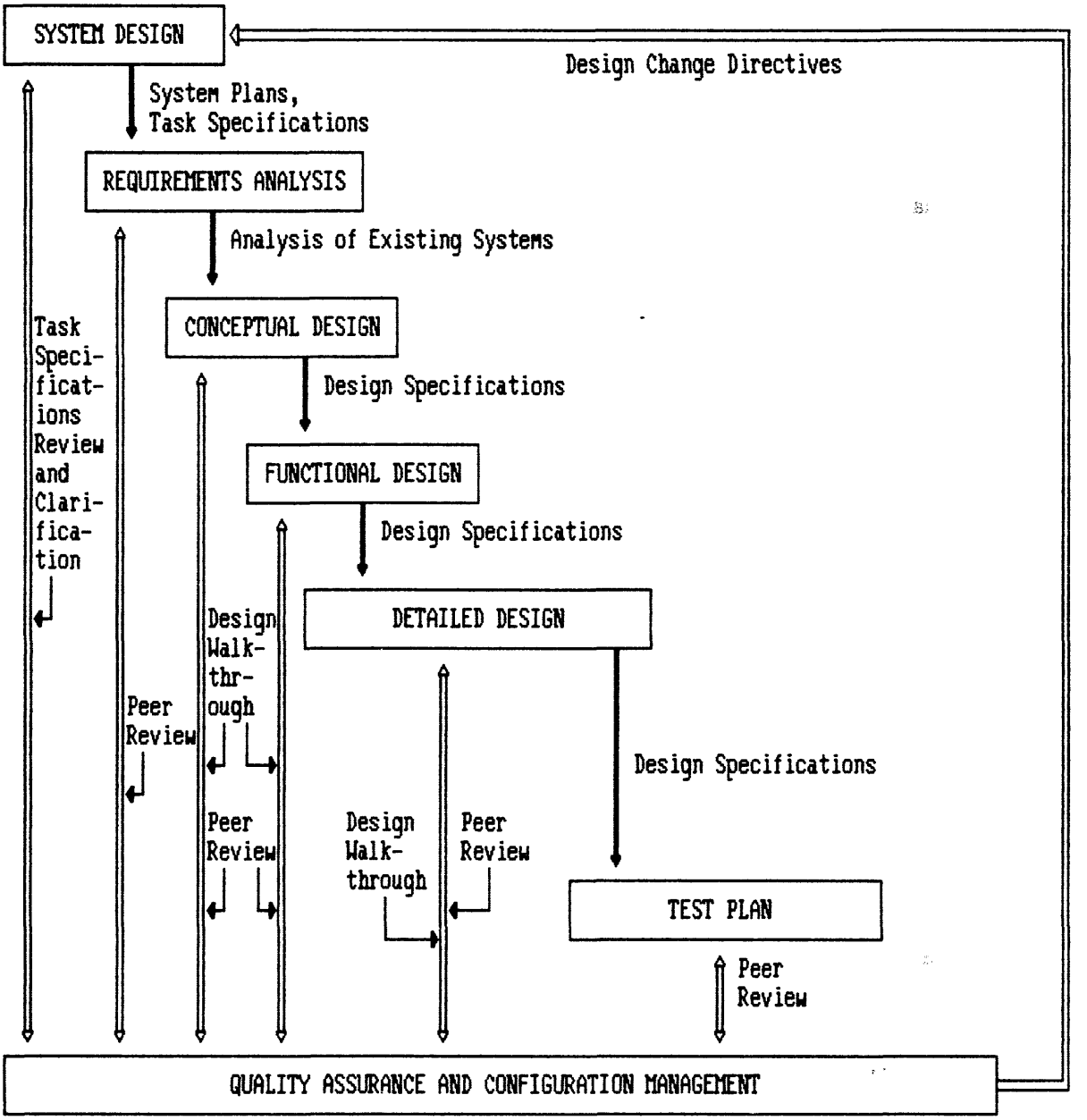
5.3.7 Operation Plans

Prior to implementation of the NWIS for general use, plans must be developed by the Branch of Computer Technology for daily operation of the system. These plans will be distributed to all nodes of the NWIS. They will include the following strategies and procedures:

- o System and network management
- o Ongoing user-assistance and training
- o User access and charging
- o System security
- o Performance evaluation
- o System audit, review, and evaluation
- o Problem reporting, change control, and configuration management
- o Software maintenance
- o Distributed data base management
- o Capacity planning
- o Contingency planning for system down times and catastrophic failures

5.4 System Design

Figure 6 shows the steps of the design phase of the NWIS. There are four major steps in the design process: (1) requirements analysis, (2) conceptual design, (3) functional design, and (4) detailed design. Requirements analyses will be performed at all levels of the system: (1) System, (2) Subsystem, (3) Component, and (4) Module. Conceptual designing will be done at the system level. Functional designing will be done at the subsystem and component levels. Detail designing will be done at the module level. Design of the NWIS is an iterative process at all levels of the design. After each design step is completed, the individual design is technically reviewed. These reviews most often identify flaws and deficiencies that require the design to be modified. Also, new requirements and enhancements for the system are continually being identified that frequently require design modifications. Appropriate changes will continue to be made to the NWIS throughout its life cycle as modifications and enhancements are accepted for inclusion in the system. This means that the system's design is in varying stages of completeness at any given time with some portions undesigned, some undergoing modification, and others being developed and implemented. This iterative process is important since it allows many modifications and user-suggested enhancements to be analyzed and integrated into the system throughout the life cycle.



EXPLANATION:

- A Step of the Phase

- Output from a Step

- Quality Assurance and Configuration Management Function

Figure 6.--Design phase of the National Water Information System.

The various steps of the NWIS design phase are discussed in the subsections that follow.

5.4.1 Requirements Analysis

The first major phase of the NWIS design is a requirements analysis. The purpose of this analysis is to identify and understand the functional and data requirements of the system being designed. At the same time, recommendations and suggestions from the user community are sought to further define new and additional functional and data requirements for the system.

The initial reqirements analysis for the NWIS was performed by the special task force established by the Division in April 1983. This analysis consisted of a complete analysis of the existing water-data and information systems of the Division (Edwards, M. D., and others, Geological Survey, written commun., 1983). The analysis consisted of the following:

- Inventories of functions, processes, data flows, data stores, software, and computer operating environments of each system
- Analysis of structure, content, processes, procedures, and operating environment of each system
- Analysis of functional, data, operating, and management relationships among the existing systems
- Analysis of flow of data within each system and, where applicable, between systems
- Identification of known and determined deficiencies in each system
- Identification of redundancies or commonalities of data, functions, and processes among the existing systems
- Analysis of types of data being processed, volumes of data stored, and the structures of the data-storage systems
- Analysis of support data and functions required for each system
- Ientification of sources and users of data in each system
- Analysis of software required to operate each system
- Analysis of work loads associated with each system

From this analysis, the minimum functional, data storage, software, operating environment, and work load requirements were determined for the NWIS. Subsequent reviews of the NWIS design resulted in suggested changes and additions to the system. Each of these changes or additions were analyzed for their impacts on each of the above set of requirements and added to the requirements or rejected, as appropriate.

A requirements analysis must be performed by assigned design teams for each additional preexisting system that is considered for integration into the NWIS. Similarily, a requirements analysis must be performed for each subsystem, component, and module that is subsequently added to, or redesigned, within the NWIS. These analyses will be performed for the determination of functional and data requirements and will consist of the following:

- Description of the existing systems, if applicable
- Description of the proposed software, hardware, and data structure
- Analysis of existing and proposed systems for the following:
  -- Organizational and personnel responsibilities, if applicable

  - -- Operating environment (computers, peripheral hardware, communications)
  - -- Interrelationships with other subsystems, components, or modules
  - -- Functions and processes
  - -- Data flows (input, output, internal transfers, volumes)
  - -- Structure, content, and volume of data storage
  - -- Support data and functions
  - -- Software structure and functions
  - -- Work loads
- o Summary and descriptions of improvements:
  - -- New capabilities
  - -- Upgraded existing capabilities
  - -- Elimination of existing deficiencies
  - -- Improved performance
  - -- Elimination of redundancies or existing capabilities that are no longer needed
- o Impacts on the existing system, subsystems, components, and modules:
  - -- Equipment
  - -- Telecommunication
  - -- Software
  - -- Organization
  - -- Operation
  - -- Development
- o Cost considerations that may influence design, development, implementtation, and operation
- o Alternatives considered for the design

5.4.2 Conceptual Design

The conceptual design of the NWIS is intended to: (1) Provide the system's designers, developers, and users with an overview of the system's objectives and scope; (2) Present the network architecture, data base content and structure, software architecture, and hardware configurations for the system; and (3) Allow the staff of WRD and other members of the user community to review and evaluate the system for relevance, completeness, deficiencies, and needed enhancements prior to developing functional and detailed designs for the system. It serves as the "blueprint" for the continued design and development of the system.

The conceptual design for the NWIS was developed by the WRD's special task force in October 1983 (Edwards, M. D., and others, Geological Survey, written commun., 1983). It was updated in June 1986 (Edwards, M. D., Putnam, A. L., and Hutchison, N. E., 1986, 38 p.) to include new concepts, design changes, and new technologies recommended and adopted for the system since 1983. It will continue to be periodically updated throughout the NWIS life cycle to reflect major design changes and new technologies and concepts introduced for use in the system.

5.4.3 Functional Design

The purpose of the functional design is to describe how the system will function and what its processing requirements are. During the functional design, the system architecture described in the conceptual design is partitioned

into major subsystems and components. The major subsystems and components established for the NWIS are:

- o Interactive Controller Subsystem
- o Hydrologic Data Subsystem
  - -- Continuous Data Component
  - -- Discrete Data Component
  - -- Descriptive Data Component
- o Data Index Subsystem
  - -- Organization Index Component
  - -- Site Index Component
  - -- Areal Index Component
- o Datastore Interface and Support Subsystem
  - -- Data Base Management System Component
- o Administrative Support Subsystem
- o General Application Support Subsystem
- o Bibliographic Subsystem
  - -- Selected Water Resources Abstracts Component

Additional subsystems and components may be added to the system, or components may be added to existing subsystems, as additional requirements are identified for the system.

After the system is partitioned, a functional design is developed by an assigned team for each subsystem and its associated components. The design will describe the purpose, structure, contents, and functions of each module within a subsystem. It will consist of the following:

- o A description of the subsystem and each of its components
- o A description of the operating environment
  - -- Hardware
  - -- Support software
  - -- Interfaces with other systems, subsystems, and components
- o Logical structure and contents of related data base components
  - -- Data element definitions
    - Name
    - Definition
    - Type (character, integer, binary, floating point)
    - Format
    - Mandatory requirements
    - Occurrences (single, multiple)
    - Addressing requirements (key, non-key)
    - Editing criteria
    - Computational or derivation criteria
- o Logical structure of the subsystem/component
- o Processing requirements and strategies
  - -- Functions and processes
  - -- Data flows
- o General input requirements
  - -- Interactive screens (content, format, and sequencing)
  - -- Transaction definitions
- o General data editing requirements
- o Data computation and derivation procedures

- o Data storage
  - -- Temporary storage (content, format, media, volume)
  - -- Transaction files (content, format, media, volume)
  - -- Audit trails (content, format, media, volume)
- o Data updating requirements and strategies
  - -- Input sources
    - - Manual
    - - Machine-readable
  - -- Transaction descriptions
- o General output requirements
  - -- Retrieval criteria
  - -- Output product criteria
  - -- Transaction descriptions
- o User assistance facilities
  - -- Online documentation
  - -- User prompts and tutorials
- o Additional design considerations
  - -- Descriptions of known requirements not included in the design

5.4.4 Detailed Design

The detailed design of the NWIS translates the functional design into technical specifications from which software and data-base modules are developed. The specifications must be written at a level of detail complete enough for development to take place without additional design work by the analysts or programmers.

Detailed specifications will be prepared by an assigned design team for each individual software or data-base module to be developed. For software, this may include a main procedure consisting of multiple subroutines to perform a general set of functions or a single subroutine to perform a specific set of functions that may be used by multiple software modules. The detailed specifications will consist of the following:

- o A description of the module
- o Descriptions of each major function of the module
- o Performance requirements
  - -- Data accuracy
  - -- Validation procedures and requirements
- o Timing requirements
  - -- Response times
  - -- Processing times
  - -- Data transfer and transmission times
- o Operating environment
  - -- Hardware
    - - Computer hardware
    - - Peripheral devices
    - - Data storage devices
    - - Input/output devices
    - - Data transmission devices
  - -- Support software
  - -- Interfaces with other subsystems, components, or modules

-- Data Storage
  - Internal storage requirements
  - Online device storage requirements
  - Offline device storage requirements
-- Security and privacy requirements
-- Controls and monitoring requirements

o Design characteristics
-- Operating procedures and implementation requirements
  -- Error handling
  -- Load, start, stop, recovery, and restart procedures
-- Module inputs
  - Menus
  - Interactive screens (content, format, sequencing)
  - Machine-readable input (content, format, sequencing, media)
  - Online documentation requirements
-- Module logic
  - Structure
  - Data flows
  - Narrative description of each major function and process
-- Module outputs
  - Data structures (content, format, sequencing, media)
  - Table and reporting formats
  - Error messages and responses
  - Prompts and tutorials (content, format, sequencing, media)
  - Graphics (charts, diagrams, maps)
  - Statistics
-- Logical and physical characteristics of data bases and files used by the module

5.4.5 Test Plan

After completion of the detailed design, the design team will develop a plan for testing the software or data-base component to be developed from the design specifications. Contents of the plan were previously discussed in subsection 5.3.6. Data sets must be generated as part of the test plan that will effectively test all functions of the software and its data outputs as defined in the specifications. Matrices of the test data will be developed and documented that define the known values of all input data elements and the expected output values for each data element. The matrices will also contain cross references to the design specifications for each function to be tested. If new or unique data files and data structures are required for the testing, two test data sets must be developed; one for use by the software developers for testing of their software and one for the formal testing of the software under controlled conditions. The plan must cover all phases of the test to be performed including modular, integration, system, acceptance, and regression testing. The test plan will also be developed to assure the following types of testing:

- o Functional Testing: Testing to assure that the functional requirements of the design are met.

- o Performance Testing: Testing to assure that response times, run times,

and other phases of execution are within acceptable limits and time frames.

- o Load/Stress Testing: Testing performance under heavy loading and stress conditions, such as many concurrent users, in a short time span.

- o Volume Testing: Testing performance and accuracy using large amounts of data over longer time spans.

- o Reliability Testing: Testing against reliability objectives such as mean time between failures.

- o Recovery Testing: Testing software and data base recovery procedures.

- o Servicibility Testing: Testing and evaluating for the servicibility and maintenance features such as dump programs, audit trails, trace programs, and diagnostic messages.

- o Storage Testing: Testing storage capabilities and capacities such as main memory requirements and capabilities under varying user and loading conditions and disk work area capacities under large input/output conditions.

- o Data Base Integrity Testing: Testing to assure that data are being processed and stored within acceptable levels of accuracy and completeness without loss of data or loss of precision of stored values.

- o Linkage/Flow Testing: Testing to assure that data flows between procedures and other modules is as defined.

- o Security Testing: Testing to assure that system security procedures work and that violations can be detected during system operation.

5.4.6 Design Quality Assurance and Configuration Management

The following quality assurance and configuration management processes will be applied during the design phase:

- o Quality Assurance:
  - -- Design walkthroughs
  - -- Design reviews
  - -- Documentation reviews
  - -- Design and documentation standards

- o Configuration Management:
  - -- Design change analysis and approval
  - -- Verification and validation of changes

More detailed discussions of quality assurance and configuration management procedures were previously presented in sections 5.1 and 5.2.

5.4.7 Design Data Dictionary

As previously discussed in section 3.2, the NWIS is being designed and developed in a distributed manner using personnel located throughout the WRD. Because of the large number of people involved in the design and development processes and their wide geographic distribution, a mechanism is needed for sharing information about current and previous design and development work and to assure consistency in the use of system nomenclature, naming conventions, data and data-element definitions, and a wide array of other items used in the design and development processes. A design data dictionary will be developed for this purpose. It will be maintained on the national node of the DIS network and will be accessible by all designers and developers over the GEONET telecommunication network. It will be an interactive system and its use will be required in all design and development activities. The dictionary will contain the following information:

- Data element definitions (type, name, format)
- File and data base structures and formats
- Record formats
- Screen formats
- Naming conventions and assigned names (software, file, table)
- Data, design, development, and documentation standards
- Identification and descriptions of previously developed software modules and subroutines available for use
- Identification of design and development team personnel

5.5 System Development

During the development phase of the NWIS, software and data bases are developed using the detailed design produced in the design phase of the life cycle. Figure 7 shows the steps of the development phase. The various steps and tasks associated with the system development phase are discussed in the subsections that follow.

5.5.1 Code Design

After design specifications have been completed, the developers will begin the design of the computer code necessary for the task. This will be accomplished through the use of structure charts, data flow diagrams, and flow charts. After the code design is completed, the design will be reviewed by an assigned team of technical reviewers. The developers present the design to the reviewers and explain its structure and concepts. The design is then reviewed in detail by the review team to assure that it complies with, and meets the full functional requirements of, the detailed design specifications. After review, the design is modified by the developers, as needed, to correct deficiencies identified by the reviewers.

5.5.2 Pseudocode

All software will be initially written in pseudocode using standards

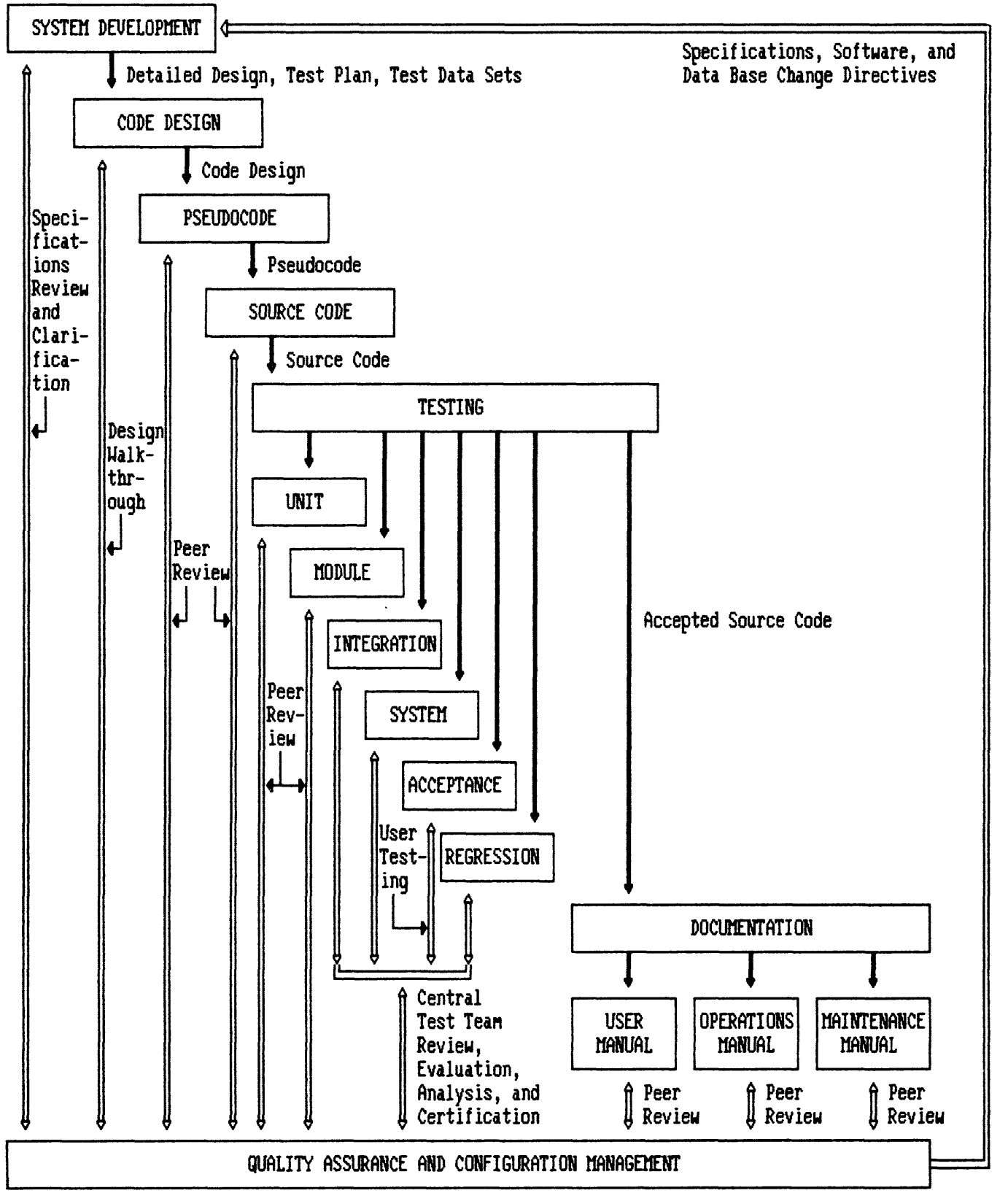


Figure 7.--Development phase of the National Water Information System.

established for the NWIS. Pseudocode is syntactically similar to high-level programming languages. It is written, however, in English-like statements that are more easily understood and interpreted by reviewer personnel that are not fully trained in computer programming. This phase of the development is important because it allows hydrologists and other discipline specialists to inspect and review the code for scientific correctness.

While pseudocode is not expected to be written on a one-to-one level with program-language statements, it must be developed at a level of detail sufficient for a reviewer to fully understand the structure, logic, and functionality of the software. The pseudocode must define and explain:

- All input and output transactions
- Internal data storage and handling transactions
- Data editing procedures
- Data computation and derivation procedures
- Logic and order of execution of major functions and processes defined by the design specifications
- Placement, content, and points of call of all subroutines
- Linkages with external procedures and subroutines

The pseudocode will be supported by a cross-reference table that will allow reviewers to relate the code to the structure charts of the code design and applicable sections in the text of the detailed design specifications.

After development, the pseudocode will be forwarded to the reviewers of the development team for review and analysis. The reviewers will assure that the code meets the full functional requirements of the design specifications. The code will subsequently be modified by the developers to correct any logic errors, omissions, or other deficiencies identified by the reviewers. This process will be repeated until the pseudocode is considered by the reviewers to be accurate and complete.

5.5.3 Source Code

After the pseudocode has been accepted and approved by the reviewers, development will begin on the source code to be executed on the computer. This code will be a detailed translation of the pseudocode. It will be written in a programming language specified by the NWIS project management staff. Currently (1986), FORTRAN 77 is being used as the primary programming language of the NWIS. Other languages may be used as dictated by interface and efficiency requirements of the software being developed. The design data dictionary will be used during the development process to assure that all formats, naming conventions, file structures, and other standards are adhered to. During the source code development, any changes or major deviations from the structure and content of the code design and pseudocode must be evaluated by and reconciled with the development team reviewers. Any changes or deviations from the design specifications must be evaluated by and reconciled with the designer and the NWIS project management staff. Any changes made at this point in the development process must also be integrated into the previously developed design specifications, code design, and pseudocode.

After the source code has been written and successfully compiled, it will be forwarded to the team reviewers. The reviewers will assure that the code adheres to the code design and meets the full functional requirements of the design specifications. The code will subsequently be modified by the developers to correct any logic errors, omissions, or other deficiencies identified by the reviewers. The review process will be repeated until the code is considered by both the developers and reviewers to be accurate, complete, and ready for testing.

5.5.4 Testing

Software and data bases developed for use in the NWIS will undergo a rigorous program of testing to assure their accuracy, completeness, adherance to design specifications, and adequate and acceptable performance. Testing will be performed under test plans previously developed by the designers. The following subsections describe the types of testing to be performed.

5.5.4.1 Unit Testing

Unit testing is the process of testing the individual subroutines or procedures in a larger software module. It is focused on the smallest components of the module and allows testing to be conducted in a stepwise manner as the code development progresses. Unit testing is conducted by the developers using self-generated test data or data sets provided by the design team. The results of the tests are analyzed and evaluated by the development team reviewers.

5.5.4.2 Modular Testing

Modular testing is the process of testing all subroutines and procedures in a module as a complete entity. Modular testing is conducted at two levels: (1) The module is tested by the developers using self-generated test data or data sets provided by the design team. The results of the tests are analyzed and evaluated by the development team reviewers. (2) The module is tested by a central test team. The central test team conducts the testing under an approved test plan using validated test data sets. The results of the testing are analyzed and evaluated by the central test team.

5.5.4.3 Integration Testing

Integration testing is the process of testing all units and modules within a software subsystem to assure that they work together in accordance with the design specifications. Testing in this area focuses on data compatibility, the absence of module interface problems, and completeness of functional requirements. Integration testing is conducted by a central test team under an approved test plan using validated test data sets.

5.5.4.4 System Testing

System testing is the process of testing the overall NWIS software and data base systems each time a new software or data base subsystem or module is integrated into the system. Testing in this area focuses on data compatibility, the absence of module interface problems, completeness of functional requirements, data base accuracy, and performance improvement or degradation. System testing is conducted by a central test team under an approved test plan using validated test data sets.

5.5.4.5 Acceptance Testing

Acceptance testing is the process of testing the NWIS, or a portion of the NWIS software and data base systems, by the users. This form of testing is often referred to as "Beta" testing. Dependent upon the degree of testing, the tests may be performed in either a simulated or an actual working environment. Users test the system for ease of use, reliability, and adherance to user documentation. Acceptance testing is conducted under the supervision of a central test team using an accepted test plan and validated data sets created from existing data resources. Results of the tests are analyzed and evaluated by the central test team which recommends subsequent changes or enhancements to be made to the system, subsystem, or module based upon suggestions, comments, and recommendations made by the users during testing. This is the final phase of testing before a system, subsystem, or module is released for implementation.

5.5.4.6 Regression Testing

Regression testing is the process of testing an entire system or subsystem each time changes are made to a module within the system or subsystem to assure that unchanged parts of the system or subsystem are not adversely affected. Regression testing will be conducted by a central test team that will use an approved test plan and validated test data sets.

5.5.4.7 Test Analysis Report

After the successful completion of each modular, integration, system, acceptance, or regression test, a test analysis report will be prepared by the central test team. This report will document the results and findings of the test and an analysis of the results. It will serve as a basis for defining changes or corrections that must be made to the system, subsystem, or module tested. If a test is completely successful, it will serve as a basis for a statement of software or data base readiness for implementation or testing at the next higher level, as appropriate.

5.5.5 System Documentation

The following documents will be prepared by each system development team:

- Users Manual - This document will contain a description of the

module and its applications along with complete instructions for use. Instructions will include necessary access procedures, input preparation, use of the software or data base, and responses to be made to error messages generated during execution.

- o Operations Manual - This document will be used by site managers and others to install the module for operational use. It will contain descriptions of the module, its operating environment, required data base support, and linkages to other support software or data bases. It will contain complete instructions for compiling and installing the software for execution, creation of necessary data bases and files, required computer resources, and other information necessary to implement the module for operational use.

- o Maintenance Manual - This document will be used by programmer and data base administrator personnel for future maintenance of the module. It will include a complete description of the module including the structure and content of all software, data bases and support files, and its operating environment. It will also include listings of the pseudocode and source code for the software, data flow diagrams, and data base and support-file formats, structures, and data elements. Concurrent with this documentation, programmers will make liberal use of comments for the imbedding of explanations and instructions within the source code of the associated software. This documentation must contain all the information necessary for future personnel to understand and interpret the software and data stores sufficient to make necessary changes and enhancements to the module.

In addition to the above documents, descriptions of each module will be abstracted from the documentation and stored as part of the system's online documentation.

5.5.6 Development Quality Assurance and Configuration Management

The following quality assurance and configuration management processes will be applied during the development phase:

- o Quality Assurance:
  - -- Code design walkthroughs and reviews
  - -- Code reviews
  - -- Documentation reviews
  - -- Development and documentation standards
  - -- Problem analysis
  - -- System testing, verification, and acceptance

- o Configuration Management:
  - -- Change analysis and approval
  - -- Verification and validation of changes
  - -- Certification and release of software systems and data bases
  - -- Tracking of design changes and software distribution

More detailed discussions of quality assurance and configuration management

procedures were previously presented in section 5.1 and 5.2.

5.5.7 System Certification

No software or data bases will be implemented within the NWIS until they have been certified for release. This certification will be made by the Configuration Management Board (CMB). Before certification, the Board will review the system documentation and test analysis reports. It will verify that all standards were followed during development; all tests were conducted with approved plans using proper procedures; test results show the module or component to be complete, accurate, and within acceptable performance levels; all required changes have been made, tested, and validated; the implementation will have no adverse effects on existing components of the system; and the supporting documentation is complete and approved for publication. After certification, the module or subsystem will be released for implementation.

5.5.8 Proprietary Software

A variety of commercially available proprietary software packages, including data base management systems, are expected to be used to satisfy the functional and computing requirements of the NWIS. Their selection and use must be given careful consideration during the development cycle since their implementation may affect data bases and other software modules that already exist in the system, are under development, or are being designed for development.

Before a proprietary package is procured, the functional requirements to be satisfied by the package will be documented. An industry-wide survey will be made to determine the availability of existing packages that may meet the defined functional requirements. Packages meeting the requirements will then be tested, analyzed, and evaluated by a central test team using an approved test plan and validated test data sets. After completion of the testing and evaluation, a test analysis report will be produced by the test team. This report will document the results and findings of the test and an analysis of the results. The analysis will include a comparison of the functionality and performance of the packages tested and the expected impact of each package on the existing components of the system. It will also define deficiencies identified in each package, present functions and capabilities that may exceed the functional requirements and design specifications, and a recommendation for a selection. The results of the testing and evaluation and the recommendation for selection will be reviewed by the Configuration Management Board. If a package is found acceptable for use, it will be certified for procurement and installation.

Functions within the NWIS that are expected to utilize proprietary software include the following:

- Data base management and maintenance
- Interactive screen generation and management
- Statistical analyses
- Numerical summaries
- Tabling and reporting
- General graphics

- o Thematic and geographic mapping

5.5.9 Hardware

The NWIS Project is evaluating 32-bit microcomputer technology for use in the system. In addition, it will be using many configurations of peripheral hardware to support its operation. The peripheral hardware will include 16-bit microcomputers and other intelligent workstations, data base servers, file servers, telecommunication servers, plotters, and specialized printers. Because of the diversity of hardware to be used and the rapid changes being made in microcomputer technology, hardware must also be given careful consideration in the NWIS development phase. Many proprietary software packages may be hardware dependent. Existing hardware may not have the functional capabilities or computing capacities needed for the NWIS. New, emerging hardware may have useful capabilities that have not yet been considered for the NWIS. For all of the above reasons, several configurations of computers and peripheral hardware are expected to be used in the first few years of the NWIS life cycle. There will, therefore, be a nearly constant evaluation of hardware being made for potential use in the NWIS. Each time a new hardware configuration is selected for use in the NWIS, existing software and data base systems must be transported to the new hardware. The selection and installation of new hardware must then be made in a manner that will cause a minimum of disruption to the NWIS development processes.

During the development of the NWIS, hardware will be tested, analyzed, and evaluated in much the same manner as proprietary software packages. As each piece of new hardware is considered for use in developing the NWIS, its capabilities will be analyzed for compliance with the functional requirements and detailed designs of the system. If the hardware is shown to have a high potential for use in the NWIS, it will be tested and evaluated by a central test team using an approved test plan and validated software packages and data sets. After completion of the testing, a test analysis report will be produced by the test team. The report will document the results and findings of the test. If hardware is tested from multiple vendors, the analysis will include a comparison of the functionality and performance of the hardware available from each vendor. Each piece of hardware will also be analyzed and evaluated for computing capacity, ability to meet the functional requirements of the NWIS, transportability of existing software for operation on the hardware, compatibility with other hardware in use by the NWIS, online data storage capacity, comparative cost with other similar hardware, and ability to meet the software requirements of the NWIS. The team will also make a recommendation for hardware selection. The results of the testing and the recommendation for selection will be reviewed by the Configuration Management Board (CMB). If the hardware is found to be acceptable for use in the NWIS, it will be certified by the CMB for procurement and installation. Hardware evaluations made for the NWIS and experience gained from its use during the development of the NWIS, will be used as input in defining requirements for replacement of the existing hardware of the DIS at the end of its life cycle. In this manner, the hardware requirements of the NWIS will be fully integrated in the replacement requirements for the DIS.

5.6 System Implementation

The NWIS is being designed and developed in a phased manner. Likewise, it will be implemented in phases. As each subsystem or major component is developed and certified for release, it will be distributed to all nodes of the NWIS network for implementation. After the initial installation of the first operational components of the system, subsequent installations will involve the implementation of new software and data base components that must be integrated into the existing system or new releases of existing software and data base components that must be replaced in the existing system. Development of the NWIS is expected to take from 3 to 5 years. Varying configurations of the system will, therefore, be in operation throughout the development life cycle. For this reason, well organized and definitive implementation plans (see subsection 5.3.6) are critical to the orderly and effective implementation of the system over an extended time period. These plans are also necessary to allow local nodes of the network to make advance preparations and plans for implementation of each new release of the system. Figure 8 shows the steps of the NWIS implementation phase. Each step of this phase will be involved in the implementation of each new release of the NWIS system. The various steps are discussed in the subsections that follow.

5.6.1 Release Announcement

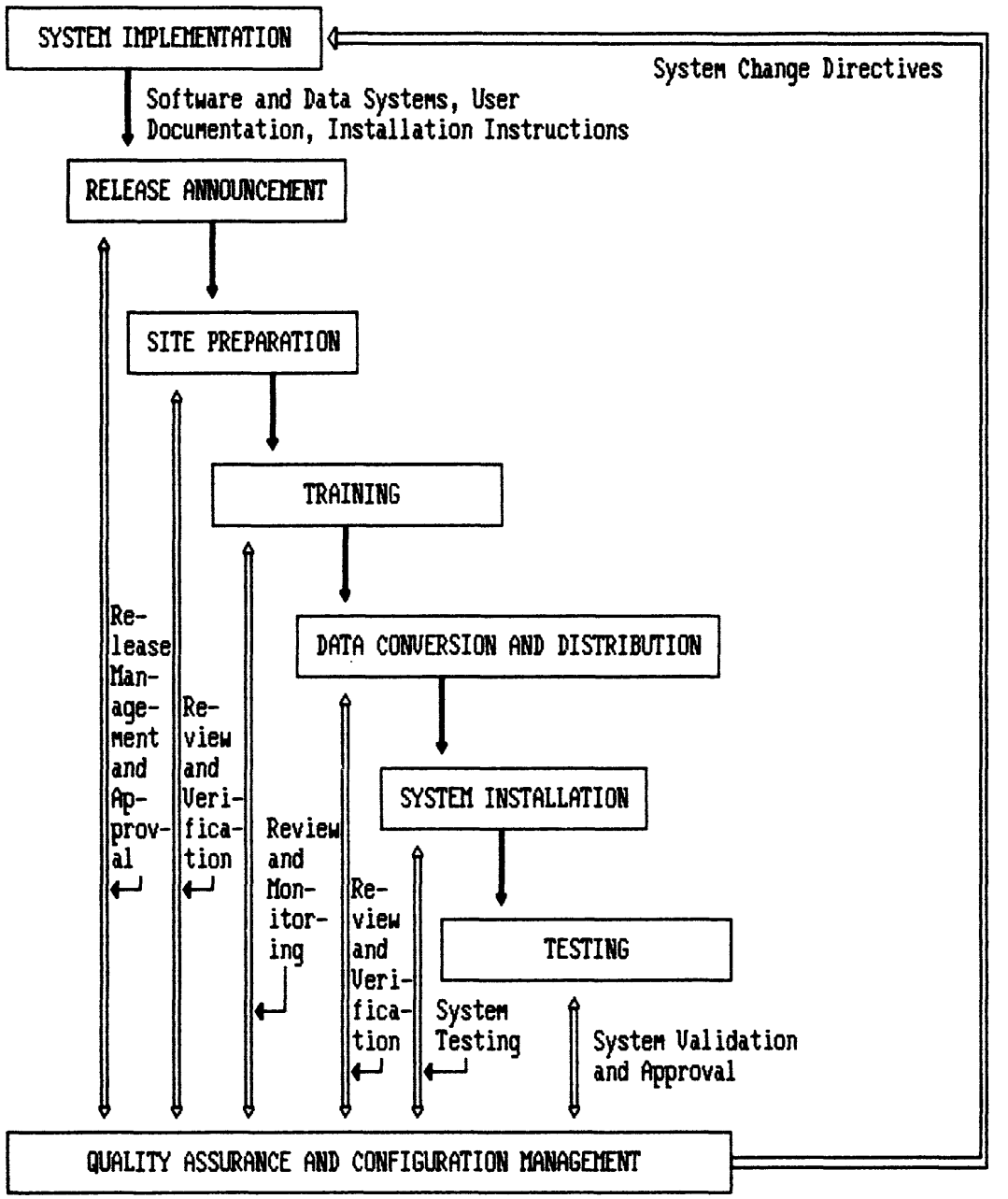
Each new release of the NWIS will be announced to all of the NWIS network nodes several weeks in advance of the scheduled implementation date. The release will be accompanied with an implementation plan and documentation that will inform the nodes of the implementation schedule; hardware, data storage, and software requirements of the installation; training requirements and schedules; and any special conditions associated with the implementation. Sufficient time will be provided between the announcement and the implementation date to allow nodes to make complete preparations for the installation and implementation of the system release.

5.6.2 Site Preparation

Wiring, air conditioning, construction, renovations, and other physical preparations for the NWIS are expected to be minimal. An exception to this may be the installation of local area networks which are are likely to be recommended for the operation of the NWIS. In all cases, however, each node will be given sufficient advance notice of hardware, software, and data-storage requirements of implementation to allow for procurements and other preparations necessary for the receipt and installation of each system release.

5.6.3 Training

Every effort is being made to design and develop the NWIS in a manner that will require a minimum of classroom training. Some training will, however, be required. For the system to be used effectively, training must be acquired in advance of the implementation of a new release of the system. Training will be required for users of the system, for site managers that will be installing and



EXPLANATION:

- A Step of the Phase
- Output from a Step
- Quality Assurance and Configuration Management Function

Figure 8.--Implementation phase of the National Water Information System.

operating the system, and for data base administrators that will have data management responsibilities for the system. Immediately prior to implementation of a new release, training aids will be prepared, training courses developed, and training agendas and schedules will be made available. Courses will be conducted as frequently as necessary to assure that all user, operator, and maintenance personnel receive adequate training prior to working with the system.

5.6.4 Data Conversion and Distribution

All data previously processed and archived by the existing data systems that are being replaced by the NWIS must be converted, validated, and distributed to the appropriate nodes of the NWIS network for storage and use. In most cases, this will be a one-time process that will occur as each applicable software subsystem is implemented.

Data conversion and validation will be accomplished using software that is designed, developed, and tested as previously discussed in sections 5.4 and 5.5. The software will be used to:

- Correct any known deficiencies or errors in the data
- Derive or compute, where possible, new data-element values required by the NWIS data base design
- Validate existing data-element values using known support data sets or other defined criteria
- Reformat the data into forms compatible for entry into the NWIS data base
- Partition the data into geographic subsets for distribution and entry into the NWIS data base

Most of the hydrologic data to be stored in the NWIS will already be distributed and stored at the individual computer nodes of the DIS in the early phases of implementation of the NWIS. In these cases, the distributed data sets will be converted on-site for entry into the NWIS. Other data, such as support data and indexing information, that are maintained in central files or data bases will be converted and distributed at the time of implementation of the various releases of the NWIS.

5.6.5 System Installation

After each site has been properly prepared, training accomplished, and data converted, the NWIS will be installed at each of the local nodes of its network. The installation process will include the following:

- Establishment of defined directories on the computer system
- Partitioning of online disk storage for NWIS data storage
- Establishment of software and data base access privileges and other security measures
- Loading of all sotware modules and packages
- Loading of all data subsets into the NWIS data base
- Testing and validation of the installation

Each site will be provided with operations manuals and instructions that will define the installation process and testing and verification procedures to be followed.

5.6.6 Installation Testing

After implementation of each release of the NWIS, its installation will be tested and verified to assure that all software systems are completely and properly installed, all required data are stored and available, all security procedures are active and functional, and that the entire system functions as required. The installation and verification testing will be conducted at each site after each installation of a new release of the NWIS. The testing will be conducted by local personnel in coordination with an appointed test team using an approved test plan and validated test data sets. The test plan, validated test data sets, and testing instructions will be distributed to each site manager along with the NWIS release to be installed. The results of the testing at each site will be reviewed by the Configuration Management Board to validate that all sites have a complete and properly installed system.

5.6.7 Implementation Quality Assurance and Configuration Management

The following quality assurance and configuration management processes will be applied during the implementation phase:

- Quality Assurance:
  - -- Training review and monitoring
  - -- Test plan review
  - -- Installation plan review
  - -- Installation and verification testing

- Configuration Management:
  - -- Certification and management of NWIS releases
  - -- Problem reporting and analysis
  - -- Change analysis and approval
  - -- Verification and validation of changes
  - -- Approval of test plans and procedures
  - -- Installation verification and approval

More detailed discussions of quality assurance and configuration management procedures were previously presented in sections 5.1 and 5.2.

5.7 System Operation

The NWIS will be operated in a distributed environment using the DIS computer nodes in at least 45 States and Puerto Rico. Each node within the network will be individually managed and operated by the local computer staff. Since each node in the network will be accessible from any other node in the network as well as from a large number of external gateways to the network, it is imperative that the NWIS be managed and operated in a consistent manner at all

nodes. For these reasons, well organized and definitive operation plans, as previously discussed in subsection 5.3.7, are critical to the orderly and effective operation of the NWIS.

The steps of the NWIS operation phase are shown in figure 9. The various steps are discussed in the subsections that follow.

5.7.1 Contingency Plan

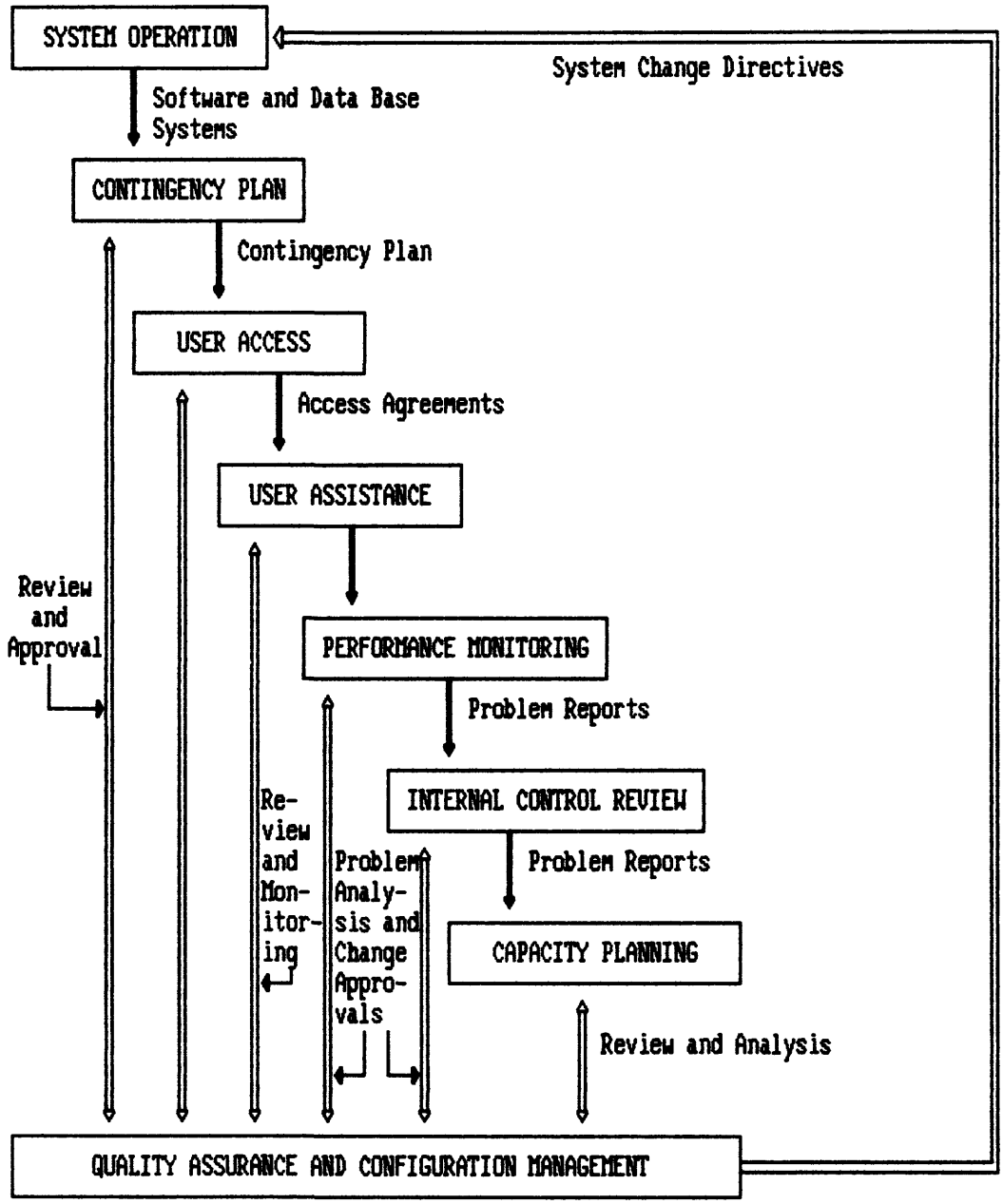
Each individual node of the NWIS will be responsible for day-to-day operation of the system. Therefore, each node will develop a contingency plan to fit its specific and localized needs. The contingency plan will be reviewed and approved by the Configuration Management Board and the Branch of Computer Technology (BCT) prior to the NWIS being placed into operation. It will outline the major areas of risk associated with the operation of the system and the backup and recovery procedures to be followed in the event of system failures that will require the system to be out of operation for an extended period of time. A copy of each plan will be filed with the BCT. The contingency plan will consist of the following:

- Identification of risks associated with natural and malicious disasters to the various system resources
- Strategies to be used to combat the identified risks
- Identification of all hardware, software, data, communication, documentation, and operational resources requiring backup
- Identification of one or more alternative processing sites
- Backup and recovery procedures for potential failures and disasters

5.7.2 User Access

Access to the existing data systems to be replaced by the NWIS is currently (1986) provided to nearly 300 users outside the Geological Survey. These users have direct dial-up access to the systems. An even greater number of users are expected to desire access to the NWIS because of expanded software and data capabilities and localized accessibility. This direct-access service will be continued as a part of the operation of the NWIS. Policy and guidelines for the use of the Division's computer systems have already been developed and distributed (Cohen, P., Geological Survey, written commun., 1986).

While many users will consistently access only one node within the NWIS network, many others will require global access to data stored on multiple nodes. In all cases, each user will be required to sign an access agreement with a host node within the network. The host node will assign access privileges to the user. Access to multiple nodes within the network by a user will be accomplished either through negotiated access with the manager of each node for which access is desired or through global, network query software that will be available for accessing and retrieving data stored on any node within the network. Each individual site manager will be responsible for the maintenance of security precautions established to prevent unauthorized access or systems abuse by outside users.



EXPLANATION:

- A Step in the Phase
- Output from a Step
- Quality Assurance and Configuration Management Function

Figure 9.--Operation phase of the National Water Information System.

Users will be expected to reimburse the Division for use of the computer systems and the NWIS. A user accounting system will be developed and implemented for documenting each indiviual's use of the system and the computation of charges associated with the use. Specific guidelines and procedures for the billing and collection of user charges will be issued prior to allowing access by outside users.

5.7.3 User Assistance

An adequate program of user assistance is a key factor in the success of any automated system with many users. User assistance will be provided in the NWIS at both the local and national levels. Local site managers and data base administrators will be responsible for providing assistance to users of their system. Global user assistance will be provided by the national node of the NWIS. User assistance will consist of the following:

- Assistance in working with individual computer systems including resolving access problems and difficulties and use of the operating system including its syntax, commands, and utilities
- Interpretation and clarification of user manuals and instructions
- Interpretation and clarification of user prompts, tutorials, and error messages
- Telecommunication problems and resolutions
- Software and data base failures and problems

5.7.4 Performance Monitoring

After the NWIS is operational, it will be important to monitor operations to determine levels of performance, user reactions and levels of satisfaction with the system, and overall response to the needs of the users. Such monitoring will assist in identifying existing or potential problem areas and areas of operation that need improvement. Performance monitoring will generally be done by site managers in cooperation with a central monitoring team using an approved monitoring plan. Monitoring will be performed under the direction of SIM and the Configuration Management Board.

In order to evaluate system performance, performance data must be collected over a period of time. These data may be collected by observation, user interviews, or the use of monitoring tools. Monitoring tools will consist of the following:

- Job accounting packages: These packages record data associated with user logons, connect times, run times, and other operating functions of the computer's operating system.

- Software monitors: These packages provide information on utilization of individual software modules within the system.

- Application monitors: These monitors enable individual computer programs to be measured and monitored at the source statement level.

- o Hardware monitors: These are software or recording devices used in evaluating system overhead.

System performance will be assessed against a variety of specified criteria. The monitoring criteria will consist of the following:

- o Volume: The amounts of different types of information that are processed over measured time periods.
- o Throughput: The number of transactions processed during a specified time interval.
- o Turnaround Time: The elapsed time between initiating and completing a job or application process.
- o Data Entry Response Time: Elapsed time required to process a data entry transaction.
- o Inquiry Response Time: Elapsed time required to respond to a system inquiry request.
- o Terminal Response Time: Interval between the time a user enters the last character of input and the time the first character of output appears on the screen.
- o Availability: The percentage and amount of time the system is avail- to the users.
- o Transmission Rate: Maximum and average times elapsed to transmit particular information or transactions between two locations.

Several system components may affect overall performance of the NWIS. These components include computer memory, secondary storage configurations, telecommunication network configurations, system software, application software, batch and online application processing, data storage volumes, and data base management facilities. Performance monitoring will consist of measuring the following parameters:

- o Central Processing Unit (CPU) Utilization: Scheduling, downtime, time used, paging, and other uses.
- o Input/Output (I/O) Channel Utilization: Amount and percentage of use.
- o I/O Device Utilization: Numbers of accesses, frequency of access.
- o Job/Project Utilization: CPU time, elapsed time, I/O times, lines of print.
- o Data Base Management System (DBMS) Utilization: Number of accesses, frequency of access, time per transaction, and other uses.
- o Terminal Response Time: Response times measured during average and peak workload conditions.

- o Application Workload: Number of transactions, number of jobs, volumes of data, throughput rate, and other factors.

If performance evaluations indicate performance deficiencies, specific system improvements must be recommended to correct the deficiencies. This requires isolating the exact cause of the deficiencies. The following will be evaluated to isolate the causes:

- o Computer configuration
- o Resource management policies of the operating system
- o Efficiency of system software
- o Efficiency of application software
- o Effectiveness and efficiency of the data base management system
- o Speed of hardware components
- o Application processing workload

The results of the performance monitoring will be used by SIM and the Configuration Management Board to identify problem areas and to improve the performance of the system. Improvements may involve any of the following corrective actions:

- o Replacement or modification of hardware components (computers, terminals and workstations, controllers, memory modules, and other components)
- o Change or modification of operating system resource management policies
- o Balancing the workload by reconfiguring the hardware peripherals (disks, tape drives, printers, and other devices)
- o Restructuring the data base
- o Reprogramming inefficient application software
- o Redistributing the application workload

5.7.5 Internal Control Review

After the NWIS has been operational for a period of time, it will be necessary to review and evaluate the system to assure that it is operating in compliance with established operating policies and procedures and that it is effectively meeting the needs of the users. This process is called an internal control review. A series of these reviews will be held periodically throughout the system's life cycle.

The reviews will be conducted at each operational node of the NWIS on a schedule that will allow each node to be reviewed at least once every three years. They will be conducted by a central test team working with an approved review plan. In general, the reviews will be used to ascertain that nodes are operating under current operating policies and procedures with the current release of the NWIS. The following will be reviewed:

- o System, software, and data base security procedures
- o User access control and management
- o User-assistance procedures and effectiveness, including user training
- o Software maintenance and testing procedures
- o Release validation of NWIS software being used

- o NWIS documentation library and its completeness and availability to users
- o Data computation and derivation procedures (using validated test data sets)
- o Data base administration and management procedures
- o Systems maintenance practices and procedures including system backup procedures and schedules and system recovery procedures and facilities
- o Operating contingency plan and its completeness and applicability to current conditions

The results of the reviews will be documented, analyzed, and used by the Configuration Management Board and the Branch of Computer Technology to identify problems in NWIS operations that need correction as well as deficiencies and errors in the system that may require software and data base corrections, redesign, or enhancement.

5.7.6 Capacity Planning

Capacity planning for the NWIS operation phase addresses the problems of forecasting NWIS workloads, determining the computer capacity needed at each node of the network, and effectively managing the system's resources to meet the NWIS performance and service requirements. Capacity planning provides answers to the following questions:

- o How long can the current system configuration be retained before an upgrade or replacement is required?
- o What additional resources will be needed to satisfy the future workload requirements of the NWIS?

Once the NWIS becomes operational, it is expected to grow rapidly for a period of 3 to 5 years as new subsystems and components are developed and implemented as part of the system. Capacity planning will be critical in assuring that the NWIS does not grow at a rate that will exceed the operating capacities of each of its nodes.

Since workloads and processing requirements may vary significantly between nodes of the NWIS network, each node will be responsible for capacity planning at its respective operating level. The capacity planning process will consist of four major activities:

- o Defining the capacity of existing resources and the characteristics of system applications
- o Measuring the utilization of resources
- o Forecasting future workloads
- o Determining future resource needs

Many factors will affect the NWIS capacity planning process. Some of the major factors include the following:

- o Size, speed, and computing capacity of existing computers
- o Volumes of data to be processed and stored
  - -- Number of data collection sites being serviced by each node

- -- Characteristics of the data being collected or measured
  - -- Frequency of data collection or measurement
  - -- Extent and volume of real-time data handling
- o Characteristics of applications at each node
  - -- Tabling/reporting (high input/output requirements)
  - -- Statistical analyses (high input/output requirements and high CPU utilization)
  - -- Hydrologic modeling (high CPU utilization)
  - -- Geographic Information System (high peripheral data storage requirements)
  - -- Volumes of interactive processing (dedicated CPU utilization) versus batch processing (scheduled CPU utilization)
- o Number of users and their frequency and duration of access
- o Peripheral applications required in addition to NWIS requirements
  - -- Software development
  - -- Financial accounting
  - -- Operating system requirements and overhead

Effective methods must be developed and implemented for the measurement of existing resources and their rate of use and the projection of future growth in applications and resource requirements. A prototype capacity planning system has been designed for use with the NWIS (Stratman, R. H., 1985, 89 p.). This system will be tested for future use in the NWIS and redesigned, where needed, to better fit the revised operating environment of the system.

5.7.7 Operation Quality Assurance and Configuration Management

The following quality assurance and configuration management processes will be applied during the operation phase:

- o Quality Assurance
  - -- Contingency plan review
  - -- Performance monitoring plan review
  - -- Internal control review
  - -- Performance monitoring
  - -- Internal control review and operations monitoring
  - -- Change request reviews

- o Configuration Management
  - -- Problem reporting and analysis
  - -- Change analysis and approval
  - -- Verification and validation of operational changes
  - -- Approval of plans and procedures
  - -- Computer resource capacity changes

More detailed discussion of the quality assurance and configuration management procedures were previously presented in sections 5.1 and 5.2.

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