- PHASE I STUDY -
STATE GROUNDWATER DATA MANAGEMENT SYSTEM

FINAL
REPORT

Submitted
to
State of Maine
Land and Water Resources Council
Data Management Committee

Prepared
by
Mark A. Jadkowski

January 1987

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Current data management systems are used primarily for data storage and retrieval. Needs which are not being efficiently met include (1) comprehensive knowledge of what groundwater information is available in Maine, (2) access to the most up-to-date information available, (3) ability to answer inquiries and satisfy requests for data, (4) trend analysis of regional groundwater quality and quantity, (5) performance monitoring of pollution abatement systems and remedial containments, (6) rapid access to information for emergency response to hazardous materials spills, and (7) automated analysis and map-making from previously mapped information. In addition to these present needs, a number of additional data management requirements can be anticipated because of possible future groundwater programs.

Specific system functions and features required to fulfill Maine's groundwater data management needs are given in Section VI of this report. This list can be used to evaluate possible software/hardware configurations which may come under consideration in Phase II.

In general terms, two viable data management configurations should be considered by the State. These are (1) adopt one comprehensive data management system capable of handling most groundwater data, and phase out use of existing systems over time; or (2) continue use and development of separate data management systems, but tie them together using a geographic management information system (GIS) to index data.

These configurations are similar in that both will provide the State with geographic information management (GIS) capabilities and computerized storage and retrieval of groundwater data. However, a single system is better suited for complex queries and data analyses. It is also easier to operate. Several systems tied together by a GIS, on the other hand, would best utilize the effort that has already been made to computerize some data. This configuration would also allow agencies total control over data formats and portions of the system could be implemented quickly. In addition, we believe that a Phase II analysis will confirm that the former of these options is considerably more costly than the latter.

We recommend that the Phase II contractor continue to solicit involvement from the agencies and groundwater personnel involved in Phase I. Their participation was essential to the development of the ideas presented in this report. It is certain that as this project proceeds, they will wish to revise some of the requirements documented here. In addition, their involvement will be a necessary ingredient in gaining the cooperation of individual agencies, and commitments to a mutually accessible groundwater data management system at the user level.

As with most other computer programs, the usefulness of any system adopted by the State will depend primarily on the competency of those using and maintaining it. Based on our experience, the true costs of training or hiring competent personnel are frequently grossly underestimated. Phase II should provide an accurate cost analysis. In addition, a cost/benefit analysis of contracting an experienced outside party to provide information management services should also be developed.

We recommend that steps be initiated to insure the continued utility of a data management system once it has been implemented. These steps may include (1) designation of an individual to be charged with overall coordination of the system; (2) formation of a group responsible for ensuring that the system continues to meet the needs of users; (3) implementation of a Memorandum of Agreement among agencies involved with groundwater which recognizes the need for cooperation to insure the continued success of the system; and (4) funding at an adequate level to maintain the data base, coordinate groundwater data reporting, and train personnel.

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LIST OF ACRONYMS

CERCLA	-	Comprehensive Environmental Response, Compensation, and Liability Act
DAFRR	-	Department of Agriculture, Food, and Rural Resources
DEP	-	Department of Environmental Protection
DFA	-	Department of Finance and Administration
DHS	-	Department of Human Services
DOC	-	Department of Conservation
EPA	-	Environmental Protection Agency
GIS	-	Geographic Information System
MDOT	-	Maine Department of Transportation
MEGIS	-	Maine Geographic Information System
MGS	-	Maine Geological Survey
PCS	-	Permit Compliance System
PUC	-	Public Utilities Commission
RCRA	-	Resource Conservation and Recovery Act
SPO	-	State Planning Office
USGS	-	United States Geological Survey

I. Introduction

Eight state and federal agencies are major generators and/or users of groundwater information in Maine: Department of Environmental Protection (DEP), Department of Agriculture, Food and Rural Resources (DAFRR), Department of Human Services (DHS), Department of Conservation/ Maine Geological Survey (MGS), Maine Department of Transportation (MDOT), Public Utilities Commission (PUC), State Planning Office (SPO), and U.S. Geological Survey (USGS). A number of these agencies are proceeding with computerized data management. Most groundwater data management systems are designed to meet the specific needs of individual agencies.

Statewide, however, groundwater information can be most useful when it is mutually accessible by all of the generators and/or users of data. Current groundwater data management systems do not provide this accessibility.

The Maine Land and Water Resources Council is an interagency coordinating body of the State Planning Office composed of the Commissioners and Directors of State agencies that use, manage, and regulate the State's natural resources. Its Standing Committee on Data Management is committed to improving the effectiveness and overall coordination of the State's natural resources data management systems. Accordingly, the Groundwater Interagency Coordination Subcommittee of the Groundwater Standing Committee and the Data Management Committee of the Council initiated this study to analyze existing groundwater data management systems and data management needs within the agencies that are currently collecting and/or using groundwater information.

The objectives of this study are to (1) evaluate how existing data management systems are currently being used to support State efforts to manage Maine's groundwater, (2) identify what new arrangements will be needed to implement any further management programs now under consideration by the council, and

(3) serve as the foundation for a subsequent Phase II effort which will include the technical design of a mutually accessible State groundwater data management system.

In order to achieve the above objectives, accurate up-to-date information on agencies' needs was required. A questionnaire was designed to determine (1) what types of groundwater data are generated and how it is managed, (2) which agencies are outside users of this data, (3) which agencies are sources of groundwater data, (4) what opportunities exist for improving accessibility to groundwater data among agencies, (5) what resources are available for data management, (6) what needs are met by current groundwater data management systems, (7) what needs are not being met by current data management systems, (8) what data management functions and features would be most desirable, (9) what additional requirements might arise due to anticipated future programs, (10) if there are any contractual bounds in effect that might restrict data management options, and (11) what the costs are of maintaining current data management systems.

Most questionnaire respondents were contacted in person. The names, titles, addresses, and telephone numbers of key groundwater personnel are given in Appendix A. An agency-by-agency synopses of the responses to the questions posed are given in Appendix B.

The following sections provide a statewide analysis of questionnaire responses. They provide information on (1) the types of groundwater data in Maine, (2) current forms of groundwater data management, (3) accessibility to groundwater data, (4) State groundwater data management needs, (5) desirable functions and features of a mutually accessible groundwater data management system, and (6) conclusions and recommendations on how to proceed with Phase II.

II. Groundwater Data in Maine

Six state and federal agencies are involved in programs which generate groundwater data. These are (1) Department of Environmental Protection, (2) Department of Conservation/ Maine Geological Survey, (3) Department of Human Services, (4) Maine Department of Transportation, (5) Public Utilities Commission, and (6) U.S. Geological Survey. The groundwater programs administered by each are listed in Table 1 together with categories of data collected.

All groundwater information collected in Maine consists of a location (geographic index) and data related to that location (relational data). For example, well locations are related to ownership data, and sand and gravel aquifer areas are related to predicted well yields and other other types of information. These types of data are sometimes referred to as "geo-referenced" or "geo-coded".

The techniques necessary to manage geo-referenced information depend on the type of geographic index required to represent the location, the category of relational data at that location, and record and file expandability requirements. The implications of each of these factors are explained below.

Type of geographic map index

- Sites at which groundwater data is available can be represented on a map by either a point, line, or an area. For example, well locations are represented by a point, but bed-rock fractures are delineated by lines. Each of these distinct map indexes and the relational data corresponding to them require special management techniques.

Groundwater data category

- Distinct categories of relational data require a range of special storage formats. For example, water quality reports can involve many parameters, sample collection notes and chain of command, and other information. On the other hand, well yields consist of simple numerical figures. Each of these requires a particular storage and reporting format, and also

Agency	Data Collection Program	Data Categories							Data Management System
DEP	[1] Sand and Salt Storage Pile Monitoring (W)*	O	ML	WQ					Manual, FRAMEWORK (IBM PC)
	[2] Sand and Gravel Aquifer Mapping (W)*	O	ML	WQ					Manual, WATSTORE, STORET
	[3] Waste Discharge Lic. (W)	O		WQ	CI	WY			Manual, PCS
	[4] Complaint Response (W)	O		WQ					Manual
	[5] Licensing & Enforc. (L)	O	ML	WQ	CI			HG	Manual,HONEYWELL DPS/6
	[6] RCRA Facilities (O&H)	O		WQ					Manual,HONEYWELL DPS/6
	[7] Superfund Sites (O&H)	O		WQ					Manual
	[8] Oil Storage Sites (O&H)	O							HONEYWELL DM-IV
	[9] Oil Spill Sites (O&H)	O		WQ					Manual, IBM PC
MGS	[10] Sand and Gravel Aquifer Mapping *		ML	WQ		WY		HG AA	Manual
	[11] Bedrock Aquif. Mapp.		ML			WY	WL	BF	Manual, BURROUGHS
	[12] High Groundwater Transmissivity Mapping		ML			WY		BF AA	Manual
	[13] Regional Lineament Maps		ML			WY		BF AA	Manual
	[14] Well Information	O	ML		CI	WY	WL	HG	BURROUGHS DataManager
DHS	[15] Public Water Dev.	O	ML	WQ	CI	WY	WL		Manual
	[16] Public Water Monitoring	O	ML	WQ					Manual, IBM PC
	[17] Private Well Analyses	O		WQ					Manual, IBM PC
MDOT	[18] Sand and Salt Storage *	O		WQ	CI				LOTUS (IBM PC)
	[19] Preconstruction Info	O		WQ	CI				Manual
	[20] Pollution Claims	O		WQ					Manual
	[21] Exploratory Borings						WL	HG	Manual
PUC	[22] Water Utilities	O				WY			D-BASE III (IBM PC)
USGS	[23] Basic Data Collection		ML	WQ			WL	HG	WATSTORE(PRIME)
	[24] Well Information	O	ML		CI	WY	WL		WATSTORE(PRIME)
	[25] Hydrology Studies Prog.*	O	ML	WQ	CI	WY	WL		WATSTORE(PRIME)

(O&H) - DEP Oil & Haz. Mat. Bureau
(L) - DEP Land Bureau
(W) - DEP Water Bureau
AA - Aquifer Areas
BF - Bedrock Fracture
CI - Well Construction/Installation
HG - Hydrogeologic Description
ML - Map Location
O - Ownership WL - Water Levels
WQ- Water Quality
WY - Well Yield
* - Multi-Agency Programs

Table 1. Index to programs which generate groundwater information, data categories, and current data management systems in Maine. Index numbers (1-25) are used for reference throughout this report. Data categories are explained in Table 2.

special computer coding to facilitate data sorts and other queries.

Record and file size.

- Data volume and record expandability requirements, must also be considered in a data base architecture. For example, some groundwater monitoring wells have water quality data generated on an on-going basis (growing record size), but well ownership is recorded once only (fixed record size). The former case requires a system configuration that permits data file expandability, while the latter does not.

Geographic indexes, data categories, and record and file sizes pertaining to data generated in Maine are listed in Table 2. More detailed information can be found in Appendix B.

III. Current Forms of Groundwater Data Management

Descriptions of the data management systems currently being used by state and federal agencies in Maine can be found in Appendix B. A comprehensive summary list was given in Table 1. The following sections discuss (1) manual filing of groundwater data, (2) computerized systems currently used, and (3) compatibility of existing data management systems.

Manual Filing

Most of the State's groundwater data is managed manually. Bedrock fractures and aquifer boundaries are drawn on maps. Locations of some wells are also drawn on maps. Written forms with relational data are filed. When data is needed, a manual search must be made to locate it and retrieve it.

For large manual data bases, such as DHS well analyses records, searches are very cumbersome. Requests for information are difficult and expensive to fulfill. Complicated sorts of the type needed to analyze trends in the quality and quantity of the State's groundwater resources are practically impossible.

Geographic Index	Groundwater Data Category	Record/ File Size	Comments
POINT	• Construction and Installation (CI)	Fixed	Includes monitoring and water wells. Construction, installation notes, materials, depth, diameter, etc.
	• Hydrogeologic Descriptions (HG)	Fixed	Generally from test pits, test borings, and well drillers logs.
	• Map Location (ML)	Fixed	Locations are marked on 71/2' USGS maps or Delorme Maine Atlas.
	• Ownership (O)	Fixed	Includes well owner or facility owner, address, job numbers, and other administrative information. Generally includes town name where the well or facility is located.
	• Water Levels (WL)	Growing	Well water levels, depth to water in test pits or test borings, well drawdown. Should be referenced to a common datum.
	• Water Quality (WQ)	Growing	Variable numbers of parameters. Can include sampling information, chain of custody, lab methods, and other quality control information.
	• Well Yield (WY)	Growing	Individual wells or well clusters.
LINE	• Bedrock Fractures (BF)	Growing	Continually updated and refined.
AREA	• Aquifer	Growing	Sand and gravel aquifer boundaries, recharge zones, and zones of high transmissivity. Drawn on maps. Partially derived from well information and test pits and borings. Continually updated and refined.
	• Non-point Pollution	Growing	Agricultural fertilizer and pesticide usage, land application of sludges and waste waters. Considered to be land

Table 2. List of groundwater data categories. Distinctions are made within geographic indexing requirements, data categories which will require special formats, and file or record size requirements.

Computerized Systems

The degree to which computers are used for groundwater data management varies from agency to agency. System capabilities also vary. The following sections summarize the systems currently in use.

Department of Environmental Protection

- The Bureau of Oil and Hazardous Materials Control utilizes a Honeywell mainframe data base (DM-IV) for oil storage tank registration. The system, which is also used by MDOT, may ultimately list 20,000-30,000 tank owners and locations.

- EPA's Permit Compliance System (PCS) is used for storage and retrieval of permit compliance information generated by the Bureau of Water Quality Control. The system resides on EPA's IBM national computer in North Carolina. Data is entered through "batching" of information. That is, data is entered on the DEP's Honeywell mini-computer, then electronically transferred to PCS. This system can also be used interactively.

- DEP's sand and salt pile inventory program resides on the FRAMEWORK data base and is used to store map location and ownership information for wells near storage facilities. The program, which resides on an IBM PC-XT, is used by the Bureau of Water Quality Control.

Maine Geological Survey

- Maine Geological Survey's greatest data management asset is the Maine Geographic Information System (MEGIS). Currently, the system is being utilized in a limited manner for bedrock aquifer mapping, and in a groundwater protection planning demonstration project.

  MEGIS is comprised of several software modules which support digitizing, editing, and map making. Polygon, line and point information can be digitized from existing maps or aerial photographs. The digital files can be edited to correct mistakes, and updated to include new or additional information. Later, when a "hardcopy" is desired, the system can be used to produce high quality maps of resources or areas of interest.

MEGIS also allows assignment of identifiers, or attributes, to mapped information. Often, just a number is used. Attributes allow system users to distinguish between features, such as lines that are roads and lines that are streams, or polygons that are aquifers and polygons that are not. Attributes can also be used to cross-index mapped features to relational information stored in an outside data base. For instance, a map polygon delineating geographic extent of a sand and gravel deposit can be indexed to aquifer characteristics such as transmissivity, expected well yield, and water quality parameters stored in another data management system.

Since MEGIS is not directly linked to a relational data base and lacks many analytical functions, it is not a GIS in a true sense of the term. Rather, it is a digital mapping system. Complex analysis of data is not possible with MEGIS except at high cost in time and money.

All digitizing, editing and mapping functions are performed at DOC in Augusta, but MEGIS software resides on an IBM 3033 at the University of Maine. The system utilizes Tektronix graphics terminals, a Talos digitizer, and a Houston DP8 drum plotter.

- MGS utilizes five Burroughs B-26 Mini-Workstations. Each workstation supports Burroughs DataManager and RBASE 4000 relational information management systems. Currently, MGS is using these workstations to store relational data corresponding to geographic information stored on MEGIS. Burroughs systems are also used to manage well information.

Department of Human Services

- IBM PC-XT micro-computers are used to manage public and private water supply administrative information used for billing and mailing and, in the case of public supplies, for reporting water quality violations.

- DHS has been conceptualizing possible comprehensive groundwater data management arrangements for some time and is anxious to implement one. Overall, a desirable system would consist of two components: one for managing data collected six

months prior and another for long term archiving and retrieval. The first component would involve at least one mini-computer at the Public Health Laboratory. The computer would be used to track test kits, track laboratory samples, and manage laboratory results. Information not more than six months old would be kept on-line and thus immediately accessible from remote terminals or through a micro-computer.

The second component would involve microfiching, and long term storage on computer media which could be accessed by different agencies through the State's IBM mainframe. Data need not be immediately accessible, but the system should have the capability of satisfying inquiries within a reasonable period of time.

Maine Department of Transportation

- LOTUS is used on an IBM PC-XT for storage and spreadsheet analysis of DOT sand and salt storage facility information.

Public Utilities Commission

- Annual reports submitted by water utilities contain information on total groundwater usage and individual well production. These figures are computerized on an IBM PC-XT using Water Utility Data Base, a customized version of D-BASE III.

U.S. Geological Survey

- USGS utilizes its Water Data Storage and Retrieval System for management of most groundwater data. The system resides on the Agency's Boston Prime Computer. It consists of several files which are grouped and stored by common characteristics and data collection frequencies. Additional data files can be added as needed. Currently, files are maintained for the storage of (1) surface-water, quality-of-water, and groundwater data measured on a daily or a continuous basis, (2) annual peak values for streamflow stations, (3) chemical analyses for surface or groundwater sites, (4) water data parameters measured more frequently than daily, (5) geologic and inventory data for groundwater sites, and (6) summary data on water use. In addition, an index file of sites for which data are stored in the system is also maintained.

WATSTORE allows extensive statistical analyses of data to be performed with the Statistical Analysis System (SAS). Queries are also possible. Data can be displayed in computer printed tables and graphs, and also in the form of two-dimensional contour plots and three-dimensional plots.

- WATSTORE is based on INFO, a proprietary relational data base management program. USGS also utilizes ARC/INFO, an integrated geographic information management system. ARC/INFO is also based on INFO, but the program includes many mapping functions not found in WATSTORE. Since both ARC/INFO and WATSTORE utilize INFO formats, relational data files can be shared by the two systems.

The Water Resources Division Augusta office has one direct line to the USGS Prime computer in Boston. This line provides sixteen multiplexed ports which give the agency personnel remote access to both WATSTORE and ARC/INFO. However, most GIS functions must be performed in Boston because of mapping hardware requirements.

Recently, the Augusta office has made a request for an IBM PC-AT based version of ARC/INFO. If purchased, the PC version would act as a satellite workstation to the Boston ARC/INFO system. This arrangement would provide the office with in-house analytical and mapping capabilities.

Compatibility of Existing Data Management Systems

The term "compatibility" is difficult to define. In computer jargon, two or more systems are generally compatible if data can be transferred between them in a usable format. In an operational sense, groundwater data management systems would, at minimum, have to share some common scheme in which information was organized and cross-indexed to other data. Given this commonality and a sufficient effort, data could then be transferred from one system to another. This being possible, the systems could then be integrated.

Much of the groundwater data in Maine is organized first by the name of the town where the site is located, then by owner, facility name, or project number. Most other forms of data share no organizational features at all. Given this situation, we conclude that little compatibility exists between systems.

The lack of a common data organization scheme is a major obstacle to the development of an integrated and mutually accessible groundwater data management system. Possible solutions to this problem are presented in the following sections.

IV. Accessibility to Groundwater Data

The development of sound recommendations for a truly accessible management system requires knowledge of what personnel are involved with groundwater data, and an understanding of the interactions between agencies that use data and those that generate data. It also requires that all possible ways of improving accessibility to groundwater information be considered. The following sections deal with these prerequisites.

Interactions Between Data Sources and Users

Names and affiliation of key groundwater personnel are given in Appendix A. The flow of information between agencies that generate groundwater data and those that use it are shown in Table 3. Additional information can be found in Appendix B.

Opportunities for Improving Data Accessibility

Ten opportunities for improving accessibility to groundwater data were identified during interviews with agency personnel. These are summarized in Table 4 together with a list of agencies which might benefit from each. The recommendations range in complexity from a simple newsletter to a geographic information system. The costs of implementation also vary a great deal. However, each contributes greatly to overall groundwater data accessibility. In this case, cost is not proportional to potential benefit. A discussion of the recommendations follows.

Users of Groundwater Data	Sources of Groundwater Data: DEP	MGS	DHS	MDOT	PUC	USGS
DEP	1,2,3, 4,5,6, 7,8,9	10,11 12,13, 14	16,17	18		23,24, 25
MGS	2,6,7	10,11, 12,13, 14	SEE NOTE 2			23,24, 25
DHS	1,6,7, 8,9	10	15,16, 17			
MDOT	1,2,6, 7,8	10,11, 14	SEE NOTE 2	18,19, 20,21		
PUC	1,2	10			22	23,24, 25
USGS	2	10,11, 12,13, 14	SEE NOTE 2		22	23,24, 25
DAFRR	5					
SPO	SEE NOTE 1	SEE NOTE 1	SEE NOTE 1	SEE NOTE 1	22	23,25
EPA	2,3, 6,7		15			
OTHER	1,2,3, 4,5,6, 7,8,9	10,11, 12,13 14	15,16, 17	18,19, 20,21	22	23,24, 25

NOTE 1 - Site specific figures on yield or water quality are rarely used. Rather, SPO is interested in statewide or regional summaries.
NOTE 2 - This data is useful, but seldom used because DHS files are difficult to sort.

Table 3. Sources and users of groundwater data in Maine. Index numbers refer to data from specific groundwater programs. An explanation can be found in Table 1. The user category "OTHER" includes consulting engineers and hydrogeologists, attorneys, regional planning and conservation commissions, private citizens, etc.

Action	Beneficiary Agencies
• Publish a State groundwater newsletter to enhance communication and cooperation between groundwater personnel.	DEP,MGS,DHS, MDOT PUC,SPO,USGS, Others
• Index all past and present groundwater programs. Include data categories, dates, personnel, location of data files, etc. A Key person should be charged with keeping this index up-to-date.	DEP,MGS,DHS,MDOT, PUC,SPO,USGS, Others
• Include a geographic information system component in future programs. The exact role of the GIS might differ from project to project, but it should, at a minimum, serve as a tool for determining availability of groundwater data near a map location. Tabular attributes assigned tolocations with available data should include dates, program name, data categories, data format, location of data file, and cross-references.	DEP,MGS,DHS,MDOT, PUC,SPO,USGS, Others
• Develop and standardize a system for determining map locations of wells and test pits and borings. It should be easy to use and include some measure of confidence.	DEP, DHS, DOT, PUC
• Computerize DHS water quality analyses of private and public wells. All records should be indexed by map location.	DEP, MGS, DHS,MDOT, SPO, USGS, Others
• DEP, DHS, and MDOT should standardize water analysis report forms. Reports should include map location, ownership, and basic water quality parameters. Quality assurance information such as sampling method, chain of custody, laboratory name and analytical technique should also be recorded.	DEP, DHS, DOT
• Develop capabilities for laboratories to deliver results in the above format and also transfer data in STORET, PCS, and WATSTORE formats.	DEP,DHS,USGS,EPA
• Improve accessibility to STORET, PCS and WATSTORE by establishing interactive links to EPA 's national computer, and USGS's regional computer and; providing training for designated personnel.	DEP, DHS, EPA
• Develop data file translators for transfer of information between MEGIS and ARC/INFO, and between BURROUGHS system and WATSTORE and ARC/INFO.	MGS, PUC, USGS
• Results of groundwater investigations which are conducted by DEP as follow-up to violation reports should be circulated to DHS.	DHS

Table 4. Suggested actions for improving accessibility to groundwater data among agencies. Potential beneficiaries of each action are also listed.

- All groundwater professionals in Maine would benefit from better flow of information pertaining to groundwater programs in the State. An informal newsletter can be used to enhance communication, and increase cooperation between groundwater personnel.

- A central groundwater program index and a "key contact" position can be used to provide access to information on data availability. The index should include data types, dates, names, location of data files, etc. An index would also provide an element of continuity to knowledge about the States groundwater data. In many instances, when a key groundwater professional leaves State employment, knowledge about availability of data and its location is lost.

- As mentioned earlier, current data management systems lack the commonalities in organization required for compatibility. A geographic information system component should be included in all future programs to tie data to a common map base. The exact role of the GIS might differ from project to project, but it should, at a minimum, serve as a tool for establishing the availability of data at a map location. Map location, then, can be used as a basic organizational unit that will permit integration of relational data bases containing well yield, water quality, hydrogeology, and other types of information. Tabular attributes assigned to locations should include dates, program names, data categories, data formats, location of data files, other management systems, and cross-references.

- In order to implement the previous suggestion, and also the next one, a standardized system has to be developed for determining map locations of wells and test pits and borings. This system must be designed such that homeowners, with no map-reading experience, are able to indicate the locations of wells when submitting water quality samples. Some measure of confidence should be recorded with each location. In addition, this system must be such that map coordinates (UTM or lat/long) can be easily determined and the locations digitized.

- Currently, DHS is computerizing administrative information pertaining to private and public well water analyses. In addition, the corresponding test results should also be computerized. All records should be indexed by map location. Both measures increase the ability of other agencies to obtain frequently needed groundwater quality information.

- A standardized water quality analysis reporting format should be utilized by DEP, DHS, and MDOT laboratories. It should include map location, ownership, and basic water quality parameters such as temperature, pH, conductivity, BOD, etc. Quality assurance information such as sampling method, laboratory name and analytical technique should also be recorded. A reporting format that incorporates these elements would add reliability to the data and make it more useful to others.

- State laboratories should have the capability to directly transfer data from the above format to either STORET, PCS, or WATSTORE. This will eliminate duplicate data entry and the corresponding potential for error.

- A great deal of the State's groundwater information has already been entered on EPA's PCS and STORET, and USGS's WATSTORE data management systems. These are open to use by State agencies. However, State groundwater personnel lack the training necessary to take full advantage of these systems. In addition, the computers which support the software are difficult to access because of poor communication links. These systems, therefore, go largely unused. The usefulness of PCS, STORET, and WATSTORE can be improved by establishing interactive links to EPA's national, and USGS's regional computers, and by training designated personnel in the use of these systems.

- A data file translator is currently being developed to allow transfer of map features (points, lines, areas, and ID) between MEGIS and ARC/INFO. A similiar translation should be developed to allow transfer of relational data between BURROUGHS system programs and WATSTORE and ARC/INFO.

- Results of groundwater investigations which are conducted by DEP as follow-up to violation reports should be circulated back to DHS. This will insure that DHS files are complete.

V. State Groundwater Data Management Needs

An assessment of data management needs must include (1) needs met by current data management systems, (2) current data management and analysis needs not being met, and (3) anticipated additional data management requirements. These are discussed in the following sections.

Needs Met by Current Data Management Systems

Currently, the uses of both manual and computerized data management systems are limited primarily to storage and retrieval of information. In most cases, particularly manual files, rapid retrieval of information is not possible. This is largely because these systems do not easily lend themselves to sorts and other, more sophisticated, queries and data management and analysis functions. These must, for the most part, be done manually. This is not to say that basic information needs cannot be met using current systems. They are met somehow, just not in the most effective and efficient manner.

Current Data Management and Analysis Needs Not Being Met

During interviews with users of groundwater information, a number of data management and analysis needs which are not currently being met were identified. These needs are listed in Table 5 together with reasons why they are not being met and the

agencies which are affected. These are discussed below in more detail. Possible management options which address data accessibility needs were discussed in Section IV. Options which address data management and analysis problems are presented in Section VI.

- There is a need for comprehensive knowledge of what groundwater information is available in Maine. Poor communication between groundwater professionals and the lack of a central data availability reference are prime reasons why this need is not presently being met. A state groundwater newsletter, central groundwater information index, and geo-referencing availability of data are a few options for dealing with this problem.

- A number of agencies require access to the most up-to-date groundwater information available. This need is not being met largely for two reasons. First, there is a lack of commitment to groundwater data management from some agency administrators. Secondly, current data management systems do not allow quick data entry; easy updates, or timely transmittal of information. A number of the specific data management functions and features and recommendations discussed in sections VI and VII address these problems.

- Many agencies are unable to answer departmental, interagency, and outside inquiries about availability of data in a timely manner. This is primarily because current data management systems, particularly manual systems, do not allow easy sorting of relevant information. This problem is most acute at DHS. When data is available, often it is difficult to retrieve, and agencies lack the personnel resources to satisfy requests. In order to remedy this problem, data must be computerized and organized based on map location. A commitment must also be made to properly train personnel.

- The State's need to monitor spatial and temporal trends in groundwater quality and quantity is not being met. This is largely because the State's groundwater data is managed in a manner that does not allow easy sorting and reporting of the

Data Management/Analysis Needs Not Currently Met	Cause	Agencies Affected
• Comprehensive knowledge of what groundwater information is available in Maine.	Poor communication and lack of a central data index.	DEP,MDOT, SPO,USGS
• Access to the most up-to-date groundwater information available.	Current data management do not allow quick data entry, easy updates, or timely transmittal of information.	MGS,DEP, MDOT
• Answer departmental, interagency, and outside inquiries, and satisfy requests for groundwater data.	Difficulty of locating and sorting manual files.	DEP,DHS, MGS,MDOT
• Analyses and reporting of regional groundwater quality and quantity trends.	Current data management systems do not allow easy sorting and reporting of relevant	DEP,DHS, SPO,MDOT, PUC,USGS
• Performance monitoring of NPDES pollution abatement systems and remedial containments for oil and hazardous materials.	Current data management systems don't allow easy trend analysis of water quality in nearby wells.	DEP,EPA
• Rapid access to accurate information on hydrogeology, land use, well locations, etc. for emergency response to hazardous materials spills.	Lack of a comprehensive geo-referenced data management system.	DEP
• Mutual access for MGS and USGS to each other's groundwater information.	Incompatibility of data management systems.	MGS,USGS
• Automated analysis and map-making from previously mapped information (analytical GIS functions).	MEGIS lacks classification schemes and other analytical tools needed to manipulate relational information.Current software is not adequate for analysis of complex data sets.	MGS

Table 5. List of current groundwater data management and analysis needs not being met at the present time. Major reasons why these needs aren't being fulfilled and agencies which are affected are also given.

needed information. An integrated data management system capable of performing complicated queries, analyses, and reporting would be an extremely valuable tool for this purpose.

- Groundwater monitoring is conducted for detection of failed National Pollution Discharge Elimination Systems (NPDES) and remedial containments for oil and hazardous materials regulated by DEP. Trend analysis of water quality in monitoring wells may in some instances reveal problems prior to large scale release of pollutants into the environment. However, ongoing trend analysis is time consuming and expensive if done using current data management systems (particularly manual files).

- Rapid access to accurate information on hydrogeology, land use, well locations and other parameters is a prerequisite to timely and effective emergency response to spills of hazardous materials. Currently, DEP is unable to manage relevant data effectively due to lack of a geographic information system.

- MGS and USGS require mutual accessibility to each others' computerized groundwater data. This is not possible at present due to the lack of data file translators which permit the transfer of information between MEGIS and ARC/INFO, and BURROUGHS software and WATSTORE and ARC/INFO.

- MGS requires a geographic information system capable of automated analysis and map-making from previously mapped information. Full GIS capabilities would streamline the Agency's day-to-day activity of preparing groundwater resources maps. Although MEGIS allows many mapping functions, the system lacks the classification schemes and other analytical tools needed to manipulate relational data in an efficient manner and then map the results. Complex analysis of data is not possible except at high cost in time and money.

Anticipated Additional Data Management Requirements

In addition to present needs, a number of additional data management requirements can be anticipated because of possible future groundwater programs. These are summarized in Table 6. More detailed information about possible future programs can be found in Appendix B.

VI. Required System Functions and Features

Specific system functions and features required in order to manage Maine's groundwater data are summarized in Table 7. The rationale for these can be found in the previous sections and in Appendix B. This list can be used as a checklist to evaluate possible software/hardware configurations which may come under consideration in Phase II.

VII. Conclusions and Recommendations

The State should consider taking actions to implement a groundwater newsletter, central information index, and standardized data reporting formats. In addition, information should be filed by map location whenever possible. These suggestions involve relatively little expense, but will yield significant improvements in data accessibility.

With regard to a data management system, two viable alternatives exist for the State to consider. These are (1) adopt one comprehensive data management system capable of handling most groundwater data, and phase out use of existing systems over time; or (2) continue use and development of separate data management systems, but tie them together using a GIS to index information.

A comprehensive groundwater data management system would consist of one basic software package. It would have to posess the ability to perform GIS functions and the ability to store large volumes of relational data in a variety of formats. A single system has a number of potential advantages. Since all data files could be accessed by the software, the configuration would be inherently

Additional Groundwater Data Management Requirement	Future Program(s)	Agencies
• Expandability to accomodate additional well information (i.e. additional wells, water quality parameters, well yield data, well construction and installation data, hydrogeologic descriptions, etc.)	Mandatory reporting by well drillers. Wellhead protection. Well construction regulations. Regulation of non-waste hazardous materials. Amendments to the Safe Drinking Water Act.	DEP, MGS, DHS, MDOT
• Merging groundwater data with information on land use and infrastructure, zoning and permitting, surface water, topography and other ancillary data.	Groundwater protection planning. Resource management	DEP, MGS, SPO, USGS
• Cross-referencing water quality analyses to physical descriptions of wells.	Increased precision and sensitivity of laboratory methods.	DEP, DHS
• Identification of past water analyses reports with parameters over safe standards.	Changes in state and federal safe drinking water standards.	DEP, DHS
• Tracking frequency and nature of contamination problems in different groundwater protection zones.	Groundwater protection planning.	DEP, MGS, SPO
• Modeling groundwater flow, contaminant transport, salt water intrusion, well drawdown, and surface/groundwater interactions; and ability to perform geostatistical analysis.	Resource management	DEP, MGS USGS
• Groundwater supply vs. demand analyses.	Resource management	SPO, PUC,USGS
• Economic analyses (i.e. drilling, pumping and treatment costs)	Resource development	SPO, PUC
• Areal analyses of non-point pollution	Agricultural regulation	DEP, DAFRR,
• Regional access to groundwater information and limited GIS capabilities.	Groundwater protection planning. Wellhead protection.	DEP, MGS, SPO

Table 6. Anticipated additional data management requirements that may be necessary because of possible future programs. Agencies which might be involved are also listed.

Data Management Function or Feature
• Ability to store, update, edit, and retrieve mapped information together with corresponding relational data (e.g. monitoring well locations together with corresponding water quality data).
• Ability to cross-reference relational data (e.g. water quality, yield, and construction information for the same well).
• Expandability to permit management of information from new programs and data that is generated on an ongoing basis (e.g. regular water quality monitoring).
• Ability to communicate with State IBM and Honeywell mainframe computers (State Computer Compatibility Standard).
• Operational compatibility with other State data management systems, particularly other natural resource systems, and laboratory data management systems.
• File translators that permit data exchange with WATSTORE, ARC/INFO, STORET, PCS and management systems used by neighboring states.
• Ability to incorporate NCIC digital map products which contain information on political boundaries, land use, transportation, hydrography, topography, and other data.
• Easy, accurate, efficient and localized data entry. Sampling personnel should enter sample and location information, lab should enter analysis results, etc.
• Quality assurance procedures to insure that information stored in the system is of known reliability.
• Ability to schedule acquisition of monitoring well samples, and identification of wells not sampled on time.
• Automatic updating of a central index or directory of all data in the system.
• Ability to perform queries to locate available groundwater data near or at specified locations.
• Ability to query well data for specific water quality parameters, then compare these to allowable standards, and report location and ownership of polluted wells.
• Ability to query permit and facility licensing data in order to locate point and non-point sources of pollution near wells or areas of interest.
• Ability to query and analyze multiple groundwater data layers with information on well construction, hydrogeology, well yields, water quality, etc. This might involve many combina tions of parameters from any of these layers, and also location and timeframe constraints.
• Programming tools for developing specialized functions (rating schemes, economic evaluations, lab calculations, etc.)
• Flexibility to produce custom reports, graphs, and maps, based on the results of complex queries and analyses. These should facilitate identification of spatial and temporal trends.
• Ability to link the data management system to outside software (groundwater models, statistical packages, etc.).
• Regional access points to the system, perhaps with limited GIS capabilities.
• System should be user friendly and production oriented.
• Vendor commitments to user training, continued user support, and software maintenance.

Table 7. Specific system functions and features required to fulfill Maine's groundwater data management needs.

well-suited to complicated queries and analyses. In addition, personnel would require training in the use of only one software package.

In order for a comprehensive system to effectively fulfill the State's needs, the use of existing manual and computerized data management systems would have to be phased out. Otherwise, the data base would be incomplete or data would be stored by several systems with duplication of effort. Since some agencies will be reluctant to give up use of recently implemented data management software, a relatively long transition period may be required for such a system to become fully operational .

A comprehensive data management system would require either (1) one centralized mainframe or mini-computer which could support multiple users and handle large amounts of data, or (2) several compatible mini and micro computers running the same software. Each of the smaller computers could be operated and maintained by key agencies, but still linked or networked together. From a user's point of view, the principal difference between the two hardware configurations would be the speed with which complicated sorts and analyses could be carried out. One larger computer would be considerably faster than a group of smaller computers.

An alternative to one comprehensive software package is to continue use and development of separate data management systems, and tie them together using a GIS as an "umbrella" index program. This umbrella program would store information on the availability, location, and format of groundwater data in the State, but not necessarily store all of the data itself. The exact role of the GIS might differ from project to project, but it would at minimum, serve as a tool for tying available groundwater data to a map location (e.g., UTM or lat/long) and provide information on the whereabouts and form of the data. For other projects, the GIS would be used to store this information, but in addition, it could also be used to store, analyze, and map the data itself.

This configuration has a number of advantages. Portions of the system could be implemented independently over relatively short periods of time. The overall system would be decentralized, with separate elements located at strategic locations. This would allow individual agencies control over their own data formats, and also provide greater flexibility for scheduling usage of equipment. This type of configuration would also take advantage of the effort already spent on computerizing groundwater data.

In an operational environment, users of multiple groundwater data management systems which are integrated with a GIS may find several disadvantages. First, they will require knowledge of how each system is operated. Secondly, since not all data file structures will be compatible, this configuration will be limited in its ability to efficiently perform complicated queries and analysis.

These configurations are similar in that both provide the State with GIS capabilities and computerized storage and retrieval of groundwater data. However, a single system is better suited for complex queries and data analyses. It is also easier to operate. Several systems tied by a GIS, on the other hand, would best utilize the effort that has already been made to computerize some data. This configuration would also allow agencies total control over data formats and portions of the system could be implemented quickly. In addition, we believe that a Phase II analysis will confirm that the former of these options is considerably more costly than the latter.

The distinction between the above alternatives may prove to be somewhat academic in the course of Phase II. The selection of a system may be influenced as much by the availability of suitable software as by the precise specifications of the State. No single system will satisfy all of the requirements documented in this report, and vendors' willingness to customize software generally comes at a substantial cost. Phase II should be entered with a willingness to negotiate and accept compromises between functional requirements and system configurations.

We recommend that the Phase II contractor continue to solicit involvement from the agencies and groundwater personnel involved in Phase I. Their participation was essential in development of the ideas presented in this report. It is certain that as this project proceeds, they will wish to revise some of the requirements documented here. Their participation will be essential in evaluating the ability of specific software/hardware configurations to meet these needs and in developing the compromises discussed above. All compromises should be skewed heavily to favor their needs. Finally, and most importantly, their involvement will be a necessary ingredient in gaining the cooperation of individual agencies, and commitments to a mutually accessible groundwater data management system at the user level.

As with most other computer programs, the usefulness of any system adopted by the State will depend primarily on the competency of those using and maintaining it. Based on our experience, the true costs of training or hiring competent personnel are often underestimated during acquisition of GIS and other data management systems. Phase II should provide an accurate cost analysis. In addition, a cost/benefit analysis of contracting an experienced outside party to provide information management services should also be developed.

We also recommend that steps be initiated to insure the continued utility of a data management system once it has been implemented. These steps may include (1) designation of an individual to be charged with overall coordination of the system; (2) formation of a group responsible for ensuring that the system continues to meet the needs of users; (3) implementation of a Memorandum of Agreement among agencies involved with groundwater which recognizes the need for cooperation to insure the continued success of the system; and (4) funding at an adequate level to maintain the data base, coordinate groundwater data reporting, and train personnel.

APPENDIX A

KEY AGENCIES AND GROUNDWATER PERSONNEL

CONSERVATION, DEPARTMENT OF (DOC)

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William Aldrich, Geologist
Norman Marcotte, ESS IV.
James Tibbetts, ESS II.
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Florence Hoar, Senior Geologist
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Raymond Hammond, Senior Utility Engineer

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APPENDIX B

SYNOPSES OF FINDINGS LISTED BY AGENCY

DEPARTMENT OF ENVIRONMENTAL PROTECTION

Current Groundwater Programs

Bureau of Water Quality Control

- Sand and Salt Storage Pile Monitoring. Currently, there exist 763 sand and salt piles which are registered with the Bureau of Water Quality Control. On the average, two private wells are sampled near each pile. Samples are tested for high levels of sodium and/or chloride. Results are manually filed at DEP. Locations of tested wells are recorded on USGS 71/2 or 15 minute quad maps, depending on availability, and the DeLorme Maine Atlas. Location and owner of each well are stored on an IBM PC-XT micro-computer using FRAMEWORK, a data management program. Future plans include addition of water quality analysis results to this system.
[contact: Stephen Groves, William Aldrich, Peter Garrett]
- Sand and Gravel Aquifer Mapping. Fifty nine sand and gravel aquifer maps have been generated by a cooperative project between the Bureau of Water Quality Control, MGS and USGS. As part of this study, background levels of inorganic water quality parameters were determined for 100 wells. Locations of test wells are shown on sand and gravel aquifer maps available from MGS. Water quality parameters are manually filed at DEP. Results are also sent to USGS for entry in WATSTORE, and subsequently to EPA for storage in STORET. See USGS Synopsis for information on WATSTORE. While both WATSTORE and STORET allow computerized data management, both systems are slow and difficult to use. Therefore, data management functions performed by DEP remain manual.
[contact: Stephen Groves, William Aldrich, Peter Garrett]
- Waste Discharge Licenses. The Division of Licensing and Enforcement oversees thirty to forty discharge licenses which require groundwater monitoring of three to twenty wells each. Samples are analyzed for water quality parameters. Physical well descriptions, and in rare cases pumping yields are reported. All information is manually filed by town and owner at the Division's Augusta office. Periodic groundwater monitoring data is entered in the computerized Permit

at the Division's Augusta office. Periodic groundwater monitoring data is entered in the computerized Permit Compliance System (PCS).
[contact: James Tibbetts, Norman Marcotte]

• Complaint Response. Groundwater quality informa-tion is sometimes generated through the complaint response activities of the Bureau. Most investigations are conducted by regional offices, and generally involve private wells. Results are filed by well owner's name at the regional offices. All data management functions are manual.
[contact: Stephen Groves, William Aldrich, Peter Garrett]

• Other. Groundwater related information is sometimes generated by miscellaneous projects which involve DEP. Data is generaly manually filed. A radon study coordinated by the Land and Water Resources Center at the University of Maine is an example of one such project.
[contact: Stephen Groves, Willaim Aldrich, Peter Garrett]

Bureau of Land Quality Control

• Licensing and Enforcement. The Bureau of Land Quality Control generates groundwater information through its licensing and enforcement functions. Groundwater monitoring is often required near landfills, transfer stations, sludge lagoons, septic sites, and storage tanks. Water quality data, boring logs, and well installation logs are filed manually by facility operator name or municipality. The Division of Technical Services functions as a central repository.
[contact: Mark Hyland, Florence Hoar, David Dominie]

Bureau of Oil and Hazardous Materials Control

• RCRA Facilities. About a dozen industrial facilities regulated under the Resource Conservation and Recovery Act (RCRA) monitor groundwater. An average of twelve sampling wells are located at each site. Water quality results are manually filed at DEP by facility name. Facility owners also manage their own groundwater monitoring data. Some of it could be obtained on floppy discette.
[contact: George Seel]

- Superfund Sites. Over a dozen hazardous waste dumps in Maine are listed as either Federal or State Superfund Sites. Each has three or more groundwater monitoring wells which are sampled irregularly and tested for water quality parameters of interest. Results are filed manually under site name.
[contact: George Seel, Hank Aho]
- Oil Storage Sites. The Bureau of Oil and Hazardous Materials Control has developed a computerized listing (DM-IV) of oil storage sites in Maine. This consists of an interactive data base system for storage and retrieval. It will also be used by MDOT for location of tanks. Sites are identified by owner name or town in the manual files and by a code number in the computerized files. Ultimately, as many as 20,000-30,000 underground storage tanks could listed. Currently, 100 newer facilities have mandatory groundwater monitoring systems. However, facility owners are not required to submit laboratory results to DEP.
[contact: George Seel, Scott Whittier]
- Oil Spill Sites. Over 100 oil spill sites exist throughout Maine. Most sites are monitored with three to fifteen wells which are sampled irregularly by DEP. At several sites, private wells, contaminated or at risk, are sampled on a regular (monthly or quarterly) schedule. The home owner samples his own well, then sends the sample to DHS for laboratory analysis Results are sent to DEP and the homeowner. Results are indexed by site name and have in the past been filed manually at DHS and DEP. More recently these results and other related analyses have been complied in spreadsheet format on an IBM PC-XT [contact: George Seel, Cheryl Fontaine, Scott Whittier, Michael Barden]

Outside Users of DEP's Groundwater Data

- MDOT: The Location and Environment Division is a frequent user of groundwater data associated with sand and salt piles (approximately 140 of the 763 registered piles belong to MDOT). The Division also uses DEP's oils storage site data.

- MGS: Maine Geological Survey uses information on RCRA facilities and Superfund sites which are located near sand and gravel aquifers.
- EPA: Groundwater information about RCRA facilities, CERCLA sites, and waste discharge are routinely sent to EPA, Boston. Some of this data is subsequently stored in STORET.
- Attorneys and Consultants: Many forms of groundwater data are requested by attorneys and by engineers and consulting hydrogeologists. Referrals are often made to DHS and MGS.
- Public Interest Groups: Groups such as Maine People's Alliance and the Natural Resource Council of Maine occasionally request groundwater quality information.

Outside Sources of Groundwater Data Used by DEP.

- MDOT: Sand and salt storage pile water quality monitoring data generated by the Location and Environment Division
- MGS: Aquifer maps and well logs provided by drillers
- DHS: Water quality analyses for public and private wells
- USGS and EPA:

Opportunities for Improving Accessibility to Groundwater Data Among Agencies

- DHS's filing system for water quality analyses of private wells should provide easier access to data. Specific recommendations include geographic indexing of well locations, and computerization of water quality results.
- Standard "forms" for recording water analysis results should be developed and used by DEP, DHS and other agencies. At a minimum, the forms should identify location, owner, and basic water quality information (i.e. conductivity, temperature, PH, etc.). Quality assurance information such as sampling method, chain of custody, laboratory name and analytical technique should also be recorded.
- When key groundwater professionals leave MGS, DEP and DHS much information is lost (location of records, availability of maps, etc.). A scheme should be developed to minimize these losses (e.g. indexing of all available information).

- Designated personnel should be trained in use of EPA's STORET and PCS and USGS's WATSTORE data bases.

Available Data Management Resources

- The Bureau of Oil and Hazardous Materials Control utilizes a Honeywell mainframe data base (DM-IV) for oil storage tank registration. The Bureau has one full time data entry person.
- EPA's Permit Compliance System (PCS) allows storage and retrieval of permit compliance information generated by the Division of Licensing and Enforcement. The system resides on EPA's IBM national computer in North Carolina. Data is entered into this system through "batching" of information. That is, data is entered on the department's Honeywell mini-computer, then electronically transferred to PCS. Data can also be entered in an interactive mode.
- EPA's water quality data management program STORET can be used via remote terminal from DEP. The Department's IBM PC-XT's can also access STORET. The system is slow and difficult to use, but offers access to vast amounts of information. The slowness and difficulty of the STORET system can be attributed to three factors: (1) STORET is an older style batch type system, (2) lack of personnel trained in the use of STORET, and (3) a poor communications link to STORET's computer.

  DEP plans to establish a dedicated link to EPA's IBM national computer at Research Triangle Park, North Carolina, to improve communication ($10-15K). This will allow one 9600 baud, one 4800 baud and one 2400 baud links to STORET and PCS. In addition, EPA has proposed revisions to make the software more interactive and user-friendly. If enacted, both measures should increase the desirability of using STORET and PCS.
- DEP's Division of Computer Services offers custom software development and data entry services. Both must be scheduled in advance and a priority system is used when necessary.

[contact: Ron Dolan, Wayne Gallant]

- DEP's Honeywell also supports it's own data management program, and additional programs MISH (data reporting) and QRP (query and reporting). The Honeywell is accessible by approximately thirty remote terminals throughout DEP.
- DEP utilizes over a dozen IBM PC-XT micro-computers. At least one is located at each regional office with no modems installed at this time. Sand and salt pile inventory program, FRAMEWORK, resides on the PCs. The PC's can also be used as terminals to access software on DEP's Honeywell, EPA's IBM and VAX, or the University of Maine's IBM computers.

Needs Met by Current Groundwater Data Management Systems

- Paper files allow manual storage and limited retrieval of groundwater information. Manipulation of manually filed data is generally necessitated by DEP's regulatory and enforcement functions.
- FRAMEWORK provides storage and retrieval of owner and location of sand and salt storage piles.
- A computerized system allows storage and retrieval of registered oil storage tanks.
- PCS provides storage and retrieval of discharge monitoring reports for sites regulated under the National Discharge Elimination System (NPDES). It is also used as source of information for mandatory reporting to EPA.
- EPA's STORET provides storage and retrieval and sorting of water quality data. This system has been in existence for over ten years but is used very little by DEP for reasons stated earlier.
- USGS's WATSTORE is used for storage (not retrieval) of groundwater quality data related to the State's sand and gravel aquifer mapping project.

Needs Not Being Met By Current Data Management Systems

- Many departmental, interagency, and outside inquiries for groundwater information cannot be satisfied because of the difficulty of locating and manually sorting files (particularly within the Bureau of Water Quality Control).

- Long term monitoring for groundwater contamination around sand and salt piles is needed. Currently, monitoring results are not stored in a format that lends itself to easy trend analyses.
- Current data management methods do not lend themselves to monitoring performance of NPDES pollution abatement systems or remedial containments for oil and hazardous substances. Detection of a failing system requires regular trend analysis of water quality parameters.
- In general, there is a lack of accurate information on what groundwater quality information is available from various state agencies. In some instances, regional DEP offices are unaware of each others data. This sometimes results in duplication of effort.
- Efficient and timely emergency response to hazardous materials spills which may contaminate groundwater resources requires immediate access to accurate information on hydrogeology, land use, well locations, utilities, etc.
- The Clean Water Act (Section 305-B) requires statements on regional and statewide trends in groundwater quality biannually. Manual filing and retrieval of information makes formulation of such statements very difficult.

Desirable Data Management Functions and Features

- Any data management system should allow easy, accurate and efficient data entry. Sampling personnel should enter sample information, lab personnel should enter analysis information, etc..
- Computerized laboratory calculations and direct reporting of results.
- Locating wells and corresponding data by geographic coordinates and geographic proximity: for example, a system user should be able to determine what type of groundwater data is available within a mile radius of a given site.
- Scheduling acquisition of monitoring well samples, and identification of wells which have not been sampled on time.

- Sort records by water quality parameter, location, or geologic setting to determine trends.
- Comparison of water quality parameter concentrations to safe drinking water standards.
- Determination and display of spatial and temporal trends in groundwater information (e.g. contaminant plume maps, histograms, etc.).
- A system should provide programming tools for developing limited but specialized functions such as statistics, ratings, etc.
- Compatibility with USGS'S WATSTORE system (to whatever degree possible)
- Quality assurance procedures to insure that information in the system meets specified standards.
- Any system should be accessible from DEP's field offices.
- User training, continued user support, and software maintenance.

Additional Requirements Due to Anticipated Future Programs

- Wells having parameter concentrations over safe drinking water standards should be easily identified and flagged along with corresponding owner information. This is especially important when changes in safe drinking water standards warrant examination and evaluation of old records. EPA or State safe drinking water standards should also be maintained in the system.
- Mandatory reporting of physical well information (logs) by drillers might necessitate additional data management requirements.
- Wellhead protection programs will require accurate inventories wells and potentially threatening past and present land use activities.
- Anticipated saltwater intrusion problems in southern Maine might require modeling of groundwater flow and well drawdown.

- Non-point pollution problems from agricultural and sludge

disposal activities might require areal rather that site specific analyses.

- Future regulation of non-waste hazardous materials will require groundwater quality monitoring near storage facilities.
- A need to consider groundwater and surface water resources together might necessitate analytical tools within the database for modeling the interaction between the two resources.
- Laboratory testing techniques are capable of detecting many water quality parameter concentrations in parts per trillion. Such small concentrations are easily affected by physical well characteristics such as method of construction, inner casing material, type of grout and filter pack material. In order to account for these interactions, physical information about individual wells will have to be stored together with lab results.

Contractual Bounds on Data Management

- DEP is not under any formal contractual bounds with regard to data management. However, the Department is honoring Agreements of Understanding with EPA and UGSG which necessitate some degree of compatibility with STORET, PCS and WATSTORE. DEP must also adhere to State computer compatibility standards.

Cost of Maintaining Current Data Management Systems

- The costs of maintaining current manual groundwater data files are impossible to evaluate because of a lack of record keeping. Likewise, it is impossible to estimate costs associated with poor decision-making or duplication of effort resulting from lack of accurate knowledge about what groundwater data is available.
- EPA's STORET is used at no charge, but data entry and equipment costs must be considered. An anticipated cost of $10,000-15,000 for a direct data link with EPA should also be considered.

- The Bureau of Water Quality Control utilizes one person, one-third to one-half time, for groundwater data entry. The Bureau of Oil and Hazardous Materials Control also employs one person, full time, for data entry on underground oil storage tanks and quality control.

Other

- EPA has selected Georgia for development of a "model" data base integration system. The purpose of this project is to demonstrate that different data management programs can be tied together by an "umbrella" system. Maine has recently been selected to be a model State for EPA's Region I.

DEPARTMENT OF CONSERVATION
MAINE GEOLOGICAL SURVEY

Current Groundwater Programs

- Sand and Gravel and Significant Aquifer Mapping. Fifty-nine sand and gravel aquifer maps have been generated by a cooperative project between MGS, DEP and USGS. The map series (1:50,000 scale) depicts known deposits of coarse-grained surface material that in all probability can supply useful volumes of groundwater. Predicted well yields are also shown. Corresponding to each map is a report with information pertaining to wells, springs, test borings, test pits and other geologic information. Maps and reports are manually filed by index number. Recently, MGS has begun digitizing maps covering York County, as part of a demonstration project of the Maine Geographic Information System (MEGIS).
[contact: Walter Anderson]

- Bedrock Aquifer Mapping. MGS has begun a bedrock aquifer mapping project in conjunction with USGS. Locations of wells are determined from the Delorme Maine Atlas. Each wells is assigned an identification number (attribute). The ID numbers are associated with yield, depth to bedrock and other physical parameters stored using Burroughs DataManager. Ultimately, maps showing aquifer boundaries will be generated from this data.
[contact: Walter Anderson, Marc Loiselle]

- High Groundwater Transmissivity Mapping. Potential zones of high bedrock aquifer transmissivity have been delineated on nine USGS 7.5 minute quadrangle maps. Also shown are bedrock linear features and high and low yield wells.
[contact: Walter Anderson, Marc Loiselle]

- Regional Lineament Maps. Bedrock linear features, locations of high yield wells, and zones of groundwater recharge are being delineated on 1:250,000 scale maps of Maine. This project will be completed in October, 1986.
[contacts: Walter Anderson, Marc Loiselle]

- Well Driller's Information. MGS acts as a central repository for well information voluntarily provided by drillers. More than 20,000 records exist with information about aquifer characteristics and well yields. The location of each well is determined on the Delorme Maine Atlas. Location, driller, well number, well type, depth, estimated yield, and other information are stored on a Burroughs Mini-Workstation using Burroughs Data Base.
[contact: Walter Anderson]
- Miscellaneous Projects. MGS is frequently a consultant on projects administered by other agencies. For instance, MGS has worked with DEP on salt and sand storage pile studies, with DAFRR on a pesticide study, and with DHS on numerous water quality studies. Information generated by these projects is usually managed by the administrating agencies.
[contact: Walter Anderson]

Outside Users of MGS's Groundwater Data

- State Agencies. DEP, DHS, PUC, SPO, DARFF, LURC and other state agencies are frequent users of MGS's groundwater data. Sand and gravel aquifer maps are perhaps the most often used source of information.
- Federal Agencies. USGS relies heavily on hydro-geologic data gathered by MGS. Other federal agencies also utilize MGS data.
- Consultants. Engineers and consulting hydrogeologists are frequent users of all forms of groundwater data.
- Land Use Planners. Municipal and Council of Government planners use sand and gravel aquifer maps for land use zoning.
- Others. MGS is a source of groundwater information to universities, hospitals, public interest groups, and many others.

Outside Sources of Groundwater Data Used by MGS

- Maine Geologic Survey uses relatively little groundwater information outside of what is generated through its own programs.

Opportunities for Improving Accessibility to Groundwater Data Among Agencies

- Groundwater data could be made more accessible if programs were formulated to include a GIS component. The exact role of the GIS might differ from project to project, but should, at minimum, serve as a tool to geographically index groundwater information. Then future data users would be able to make inquiries about availability of information by providing the coordinates of an area of interest and a search radius.
- MGS and USGS work closely on many projects. Both would benefit if groundwater information could be easily transferred between MEGIS and Arc/Info, a GIS used by the U.S. Department of Interior. Currently, a file translator is being developed at University of Maine to partially satisfy this need. The software will enable MEGIS to read and write NCIC Digital Line Graph (DLG) data file structures which can already be handled by Arc Info and a number of other systems. However, the DLG format permits translation of mapped information only. Relational information will still have to be manually transferred [contact: Thomas Brann, UM].
- Both MSG and USGS would also benefit if groundwater data was easily transferable between Burroughs Data Base and WATSTORE. However, there are no immediate plans to develop this link.

Available Data Management Resources

- Maine Geological Survey's greatest data management asset is MEGIS. The system is comprised of several software modules which support digitizing, editing, and map making. Polygon, line and point information can be digitized from existing maps or aerial photographs. The digital files can be edited to correct mistakes, and updated to include new or additional information. Later, when a "hardcopy" is desired, the system can be used to produce high quality maps of resources or areas of interest.

  MEGIS also allows assignment of identifiers, or attributes, to mapped information. Often, just a number is used. Attributes

allow system users to distinguish between features, such as lines that are roads and lines that are streams, or polygons that are aquifers and polygons that are not. Attributes can also be used to cross-index mapped features to additional information stored in an outside relational data base. For instance, a map polygon delineating geographic extent of a sand and gravel deposit can be indexed to aquifer characteristics such as transmissivity, expected well yield, and water quality parameters stored in another data management system.

It should be pointed out that because MEGIS is not directly connected to a relational data base, the system is not a true GIS. It lacks classification schemes and other basic analytical tools needed to manipulate relational information. This software is not adequate for analysis of complex data sets.

All digitizing, editing and mapping functions are performed at DOC in Augusta, but MEGIS software resides on an IBM 3033 at the University of Maine. The system utilizes Tektronix graphics terminals, a Talos digitizer, and a Houston DP8 drum plotter. One experienced operator is dedicated full-time to the system [contacts: James Rea, Marc Loiselle].

- MGS utilizes five Burroughs B-26 Mini-Workstations. Each workstation supports Burroughs Data Base, a relational information management system. Currently, MGS is using this system to store relational data corresponding to geographic information stored on MEGIS.
- USGS offers cooperative programs through which MGS could gain access to WATSTORE. Currently, MGS does not participate in this program.
- Data entry personnel are occasionally available.

Needs Met by Current Data Management Systems

- Paper files allow manual storage and limited retrieval of groundwater information. Manipulation of manually filed data is generally necessitated by MGS projects and outside requests for information.

- MGS generates a great deal of mapped information. The agency is exploring and demonstrating the utility of MEGIS for developing and updating maps related to groundwater resources.
- Burroughs Data Base allows storage, retrieval, and sorting of well information provided by drillers. This data base contains a wealth of data which will be utilized in future groundwater projects.

Needs Not Being Met By Current Data Management Systems

- Current data management systems, particularly manual files, do not allow quick data entry, easy updates, or timely transmittal of information.
- MGS data management systems need to be compatible with USGS. The current lack of compatibility is most acute when the two agencies are involved in cooperative projects which require mutual access to information.
- Development of maps from information stored in a GIS requires classification schemes and other analytical tools to manipulate relational information. MEGIS does not provide for this. In addition to limitations in its ability to manage relational information, the system is difficult to use. Currently, it is unclear if MEGIS will satisfy long term needs of MGS.

Desirable Data Management Functions and Features

- Compatibility with USGS and neighboring state data management systems.
- A system should be simple but flexible enough to permit development of software for specific applications.
- Efficient data entry, easy updating, and timely information retrieval.
- Quality assurance procedures to insure that information in the system meets specified standards.
- Sort by hydrogeologic parameter, location, or geologic setting to permit inquiries and determination of spatial and temporal trends.
- Polygon to grid to polygon conversion.
- Ability to analyze multiple data layers simultaneously.

- GIS capability to incorporate NCIC digital map information such as land use, hydrography, elevation, etc.
- User training and software maintenance and service commitments from vendors.

Additional Requirements Due to Anticipated Future Programs

- Future sand and gravel aquifer projects might necessitate groundwater flow modeling or contaminant transport modeling.
- A geostatistical analysis capability might be needed at some point.
- A statewide aquifer protection planning project, if implemented, would utilize a GIS for information processing and mapping.

Contractual Bounds on Data Management

- MGS has contracted with the University of Maine to provide maintenance of MEGIS software.

Cost of Maintaining Current Data Management Systems

- The costs of maintaining current manual groundwater data files are impossible to evaluate because of a lack of information. Likewise, it is not possible to estimate the cost of using Burroughs Data Base for managing water well information provided by drillers.
- MEGIS operates on an annual budget of $60,000 per year. This figure accounts for maintenance, computer time, communications, supplies, and one full-time operator. The cost of using the system is approximately $41 per hour.

Other

- The State should consider acting to improve its position on USGS's priority list for development of 7.5 minute cultural and hydrographic DLG products. These digital map layers delineate transportation, land use, streams, lakes, ponds and other features of interest to many within State government. If made

available, DLG's would be a valuable source of information which could easily be incorporated in a state geographic information system.

- MGS should have some control over who has immediate access to its information. Its obligation to provide such access differs between state and federal agencies and the public.

DEPARTMENT OF HUMAN SERVICES

Current Groundwater Programs

- Public Water Supply Development. Public water supplies are defined as those which serve more than twenty-five people or those which provide fifteen or more service outlets. New public groundwater supplies must be tested for turbidity, coliform bacteria, hardness, volatile organic compounds, radioactivity, and a number of inorganic parameters prior to source approval. Safe yield and cone of influence must be determined for gravel wells, using preliminary and prolonged pump tests. This information is manually filed. Physical well descriptions, when available, are also filed.
[contact: Donald Hoxie, Charles Rossoll, Kenneth Meyer]

- Public Water Supply Monitoring. Over 2000 public water supplies exist in Maine. Many of these depend on groundwater. The Safe Drinking Water Act requires that the quality of these sources be tested on a regular basis. All public supplies must be tested annually, some are required to test for bacteria more frequently. Annual tests are done for sodium and nitrate. Tests for organic and inorganic parameters are done every three years, while radioactivity is checked every four years. There is little quality control on this data.

  Laboratory results were, at one time, stored on the State's IBM mainframe computer. That program has since been discontinued and the old records are archived on computer tapes.

  Currently, laboratory results are manually filed and microfilmed. However, administrative information is stored on an IBM PC-XT. This data includes ownership, town name and map location (manual files only), sampling rates, what parameters are tested, and what parameters are found to be in excess of safe drinking water standards. All violations are reported to EPA. Hazardous waste violations are also reported to DEP.
[contact: Donald Hoxie, Charles Rossoll, Kenneth Meyer]

- Private Water Well Analyses. The agency performs 7000-8000 private water analyses each year. Samples are taken by well owners, who also provide a limited description of the well. Primary parameters of interest include nitrate and bacteria. There is no quality control on this data since well owners are not trained in proper sampling procedures and seldom provide accurate information on physical well characteristics.

  Laboratory results are manually filed and microfilmed, first by town name where the well is located, then by owner. Administrative information, such as owner and address, is stored on an IBM PC-XT.

  [contact: Donald Hoxie, Charles Rossoll, Kenneth Meyer]

Outside Users of DHS Groundwater Data

- State Agencies. DEP receives, under a protocol involving the Division of Health Engineering and the Public Health Laboratory, copies of reports which show detection of hydrocarbons or volatile organic compounds. MDOT depends on DHS for laboratory analysis of groundwater samples thought to be contaminated by road salt and for pre-construction evaluations. PUC, MGS and DAFRR are occasional users of DHS files.
- Federal Agencies. EPA receives and computerizes notices of public water supplies not meeting safe drinking water standards. USGS uses water quality data in their biannual water resource reports on Maine.
- Consultants, Real Estate Agents, Bankers, Lawyers. As additional focus is put on groundwater quantity and quality, more requests are made each year for information on wells. DHS is required by law to make this information available to the public.

Outside Sources of Groundwater Data Used by DHS

- DHS often uses MGS's sand and gravel aquifer and bedrock aquifer maps. The agency also uses DEP's information on possible pollution threats, e.g. sludge spreading programs, hazardous waste sites, etc.

Opportunities for Improving Accessibility to Groundwater Data Among Agencies

- Currently, anyone wishing to obtain groundwater information from DHS must spend considerable time manually searching files. An ability to carry out computerized sorts and retrieval of well analysis records would greatly enhance the Agency's ability to provide timely access to data.
- The Agency is searching for a systematic method of obtaining more precise well locations from owners, but an adequate procedure has not yet been developed. The current lack of precise geographic reference greatly limits the utility of any future data management system, regardless of its sophistication.
- Results of groundwater investigations which are conducted by DEP as follow-up to violation reports are rarely circulated back to DHS. The Agency's files are therefore incomplete.

Available Data Management Resources

- DHS Public Health Laboratory utilizes a Honeywell Level 6 mini-computer. It has not yet been decided how or if this computer will be integrated into a data management system.
- IBM PC-XT micro-computers are used to manage public and private water supply administrative data.
- DHS has one full-time and two part-time data entry personnel working on water supply information.

Needs Met by Current Data Management Systems

- Paper files and microfilm allow manual storage and retrieval of groundwater quantity and quality data, and physical well information. The effect of physical well characteristics on samples is an important element in the interpretation of water quality results.
- Microfilm is being used as a long term storage media in the likely event of future EPA laboratory audits. Microfiche will replace microfilm sometime in the future.

- IBM micro and mainframe computers are used for storage and retrieval of administrative information used for billing and mailing and, in the case of public supplies, for reporting water quality violations.

Needs Not Being Met by Current Data Management Systems

- Manual files do not allow timely retrieval of groundwater information. This problem is made worse by the lack of precise data on private well location.
- Regional analysis of groundwater can be very difficult and expensive if files must be searched manually for relevant information. This limits the State's ability to manage safe pumping yields and groundwater in general.

Desirable Data Management Functions and Features

- DHS has been conceptualizing possible data management arrangements for some time. Overall, a desirable system would consist of two components: one for managing data collected six months prior and another for long term archiving and retrieval. The first component would involve at least one mini-computer at the Public Health Laboratory. The computer would be used to track test kits, track laboratory samples, and manage laboratory results. Information not more than six months old would be kept on-line and thus immediately accessible from remote terminals or through a micro-computer.

The second component would involve microfiching, and long term storage on computer media which could be accessed by different agencies through the State's IBM mainframe. Data need not be immediately accessible, but the system should have the capability of satisfying inquiries within a reasonable period of time.

Data management functions which would be most useful include (1) storage of quality assurance information along with laboratory results; (2) sorts by water quality parameter, hydrogeologic setting, well type, and geographic proximity; (3)

comparisons of water analysis results to safe drinking water standards; (4) determination of spatial and temporal trends in water quantity and quality; (5) and ability to produce customized reports.

- GIS capabilities would be useful for reviewing proposed development activities near watersheds and aquifers which feed public and private water supplies.

Additional Requirements Due to Anticipated Future Programs

- Amendments to the Safe Drinking Water Act will increase the number of water quality parameters for which public wells are tested. Regulatory changes like this necessitate the use of flexible formats for coding information in data management systems.
- Future wellhead protection programs will require accurate inventories of wells and their locations.
- Private well construction practices might be regulated by the State sometime in the future. If so, physical well information will be generated. Subsequently, this information will have to be managed by the State.
- Classification schemes designed for groundwater protection might necessitate incorporation of physical well data and groundwater quality results in a State GIS.

Contractual Bounds on Data Management

- There are no formal contractual bounds which might restrict data management options.

Cost of Maintaining Current Data Management Systems

- The costs of maintaining manual data management systems are impossible to evaluate because of a lack of information.
- Use of IBM mainframe and PC-XT computers for management of administrative information involves one full-time and two part-time data entry personnel. Computer costs are not available.

MAINE DEPARTMENT OF TRANSPORTATION

Current Groundwater Programs

- Sand and Salt Storage Facility Ranking. Currently, MDOT stores road sand and salt at 140 locations throughout Maine. These storage facilities are being ranked in terms of their impact on the environment. As part of the ranking procedure, water samples are taken by MDOT technicians from wells near storage facilities and tested for sodium and chloride by DHS. Conductivity measurements are also made. Well type and location relative to storage facility are carefully noted. All field and lab records are manually filed. Much of this information is also managed on an IBM PC-XT with LOTUS, a commercially available spreadsheet program.
  [contact: William Reid, Chris Olson]
- Preconstruction Information. Prior to many road construction projects, MDOT conducts groundwater quality studies to establish existing water quality. Sodium and chloride concentrations are of prime concern. Most laboratory analyses are done by DHS. Laboratory reports, together with available well construction details and well location are manually filed by town name and job number.
  [contact: William Reid, Chris Olson]
- Pollution Claims. MDOT responds regularly to private claims for compensation for wells polluted by construction and maintenance activities. The Agency's response to such claims often involves groundwater monitoring to confirm or establish source(s) of contamination. All records are manually filed by name of well owner.
  [contact: William Reid, Chris Olson]
- Exploratory Borings. Much geologic information is generated by MDOT's exploratory soil borings. Depth to groundwater is routinely recorded. All information is manually filed by town name and project number.
  [contact: Melvin Morgan]

- Special Projects. Groundwater data are sometimes generated by special projects administered by MDOT. Information is manually filed by title of study and by location.
[contact: William Reid, Christine Olson]

Outside Users of MDOT Groundwater Data

- DEP. The Bureau of Water Quality Control is a user of DOT's sand and salt storage facility monitoring data.
- Consultants and Attorneys. Engineers, hydrogeologists, and attorneys are frequent users of all types of groundwater data.

Outside Sources of Groundwater Data Used by MDOT

- DEP. The Bureau of Water Quality Control has its own sand and salt storage pile monitoring program. Data generated as part of this program is also used by MDOT.
- MGS. Well driller's information and sand and gravel aquifer maps are used regularly by MDOT.

Opportunities for Improving Accessibility to Groundwater Data Among Agencies

- DHS's filing system for water quality analysis of private wells should provide easier access to data. Specific recommendations include geographic indexing of well locations, and computerization of water quality results. Laboratory results also suffer from lack of quality control. Uncertainties are largely due to well sampling irregularities which are beyond the Agency's control. In addition, all private well records should indicate if the data can be used for public information.
- The creation of a central groundwater information index and a "key contact" position would improve accessibility to data among agencies. It would also provide an element of continuity to knowledge about the State's groundwater data. Currently, when a key groundwater professional leaves state employment, knowledge about availability of data and its location is lost.

Available Data Management Resources

- MDOT utilizes approximately twenty-five IBM PC-XTs or compatibles. These support D-BASE III data base management and LOTUS spreadsheet programs.
- The agency is installing AT&T mini-computers in each of its regional offices. These run under UNIX operating systems and will be tied to the State's IBM mainframe.
- DOT's Computer Services Division employs several analysts who are available for software development. The Agency also employs college students knowledgeable in computers during summers and holidays for programming and data entry.

Needs Met by Current Data Management Systems

- Paper files allow manual storage and retrieval of groundwater data and well construction details.
- LOTUS is used on an IBM PC-XT for storage and spreadsheet analysis of sand and salt storage facility data.

Needs Not Being Met by Current Data Management Systems

- Manual files do not allow timely retrieval of groundwater information. The cost of manually sorting files greatly limits the Agency's ability to establish regional background water quality conditions and extent of groundwater contamination problems. In addition, these files are very susceptible to "mix-ups" that result in loss of information.

Desirable Data Management Functions and Features

- Sort data by location, type of pollution, and timeframe.
- Identify potential point and non-point sources of pollution near wells.
- Form data summaries and statistics.
- Determine and display spatial and temporal data trends.
- Any system must be user-friendly.

Additional Requirements Due to Anticipated Future Programs

- An underground storage tank inventory and monitoring program is anticipated sometime in the near future. The program will involve groundwater quality monitoring near tanks located on MDOT maintenance lots and rights-of-way. The resulting laboratory data will require management.
- Unanticipated special studies will necessitate flexibility in any data management system.

Contractual Bounds on Data Management

- There are no formal contractual bounds which might restrict data management options.

Cost of Maintaining Current Data Management Systems

- The costs of maintaining manual data management systems are impossible to evaluate because of a lack of information. Agency personnel spend a lot of time helping others locate groundwater information.
- Use of an IBM PC-XT computer for management and analysis of sand and salt storage facility data involves one part-time student position. Computer costs are unavailable.

PUBLIC UTILITIES COMMISSION

Current Groundwater Programs

- Water Utilities. Approximately 150 publicly and privately owned water utilities depend on groundwater to some extent. Annual reports submitted by these utilities to PUC contain information on total groundwater usage and individual well production. These figures are computerized on an IBM PC-XT using Water Utility Data Base, a customized version of D-BASE III. Much of this information is of questionable quality because of reporting irregularities. Currently, the Agency is contacting utilities in order to verify reported well yields.
  [contact: Raymond Hammond]
- Other. Among other miscellaneous groundwater information, PUC files contain reports on old groundwater favorability studies. These discuss the suitability of subsurface sources as new drinking water supplies. Reports are manually filed.
  [contact: Raymond Hammond]

Outside Users of PUC Groundwater Data

- SPO. Water utility reports are used as a source of information for reports on Maine's resources.
- USGS. Data on surface water and groundwater usage is used to compile biannual reports on Maine's water resources.
- Water Associations. Maine Water Utilities Association and Maine Rural Water Association utilize water usage data.

Outside Sources of Groundwater Data Used by PUC

- DEP, DHS, MGS. Water quality information and sand and gravel aquifer maps are used for groundwater favorability studies.
- USGS. Water usage information is exchanged regularly between the two agencies.

Opportunities for Improving Accessibility to Groundwater Data Among Agencies

- Standardization of well terminology will lead to better communication regarding groundwater between agencies.
- Direct access to WATSTORE would improve accessibility to USGS's groundwater information.

Available Data Management Resources

- PUC has a network of IBM PC-XT and PC-AT computers. D-BASE III is available for data management.
- Two full-time programmer analysts are available for software development.

Needs Met by Current Data Management Systems

- Manual files provide storage of annual reports and groundwater favorability studies.
- Water Utility Data Base (D-BASE III) supports the Agency's efforts to regulate utilities and manage groundwater supplies. This system provides summary and reporting functions.

Needs Not Being Met by Current Data Management Systems

- DHS data management procedures do not allow an efficient way in which to monitor water quality trends. In many cases, early identification of contamination problems can lead to more timely remedial response and lower cleanup costs.
- In order to effectively regulate water utilities, accurate information is needed on groundwater usage, well drawdown, specific yield, and numbers of people served by water utilities.

Desirable Data Management Functions and Features

- A system should allow data sorting and economic analysis. For example, the Agency is often interested in consumption per customer and investment per customer. In one report these might be needed for a six month period, in another report for a one year period, or a ten year period in still another. A system should be flexible enough to provide these types of statistics.

Additional Requirements Due to Anticipated Future Programs

- Many utilities will increase their future dependence on groundwater. The decision to do so will be based on the economics of treating surface water vs. drilling wells and pumping. Accessibility to all available information on groundwater will be needed for these analyses.
- As subsurface sources increase in importance, proper allocation of groundwater will be needed. The State will play a key role in this. Accurate information on usage, specific yields, well drawdown, and water quality will be required in order to effectively manage this resource. In short, this will necessitate a statewide groundwater information system.

Contractual Bounds on Data Management

- There are no formal contractual bounds which might restrict data management options.

Cost of Maintaining Current Data Management Systems

- Information was entered into PUC's Water Utility Data Base at a cost of about $600. Computer costs are unavailable.

DEPARTMENT OF AGRICULTURE, FOOD, AND RURAL RESOURCES

Current Groundwater Programs

- Site Location Application Review. DAFRR's Soil and Water Conservation Commission is one of a number of review agencies for site location permit applications. These are received by DEP's Bureau of Land Quality Control and circulated for review and comments. Though these applications address potential impact on groundwater, no new data is generated by DAFRR.
[contact: Frank Ricker, Paul Beers]

Outside Users of DAFRR Groundwater Data

- Outside users of groundwater data are referred to MGS, DEP or other agencies.

Outside Sources of Groundwater Data Used by DAFRR

- Groundwater data needed for site location reviews is included with permit applications. This information is provided to DEP, and subsequently DAFRR, by the permit applicant.

Opportunities for Improving Accessibility to Groundwater Data Among Agencies

- Standardization of data collection procedures would improve accessibility to groundwater information.

Available Data Management Resources

- The Department utilizes a Burroughs mainframe computer with a number of remote terminals. The Burroughs supports R-Base, a commercially available data base management program.

- DAFRR's Board of Pesticides Control has access to Purdue University's National Pesticide Registration System (NPRS). This is a central repository for information on pesticide solubilities, health risks, and other factors related to groundwater pollution.

Needs Met By Current Data Management Systems

- The Agency does not manage groundwater data.

Needs Not Being Met By Current Data Management Systems

- The Agency does not manage groundwater data.

Desirable Data Management Functions and Features

- DAFRR's recommendations for specific functions include sorting of groundwater data by geographic proximity; sort by sodium ion concentration, biological oxygen demand, and PH; and map generation.
- A groundwater data management system should be compatible with other natural resource data systems.

Additional Requirements Due to Anticipated Future Programs

- Pesticide and animal waste pollution problems might result in additional groundwater monitoring requirements sometime in the future. These would necessitate additional data storage capabilities, and probably a capacity to manage data at the county level.
- A proposed agricultural irrigation study for Aroostook County would also necessitate additional data storage capacity.
- Growing interest in the effectiveness of spreading sludge wastes on agricultural land (land treatment) might warrant accessibility to DEP groundwater quality data.
- A groundwater classification system is currently being developed as part of the State's natural resource protection efforts. This classification scheme could be most effectively

implemented if a GIS is used for data storage and retrieval, updating, analysis and map generation. In addition, implementation of a groundwater protection plan will necessarily start at the local level. Thus, the State should consider the need to provide municipalities and other interested groups some type of remote accessibility to GIS capabilities.

Contractual Bounds on Data Management

- There are no contractual bounds which might restrict data management options.

Cost of Maintaining Current Data Management Systems

- There are no costs since DAFRR does not manage groundwater data.

DEPARTMENT OF FINANCE AND ADMINISTRATION
BUREAU OF DATA PROCESSING

NOTE:

The Bureau of Data Processing is not directly involved with groundwater data. However, the Agency does offer a number of data management resources which are relevant to this study. These are discussed below. [contacts: Val Wood, Bernard Beaulieu].

Current Groundwater Programs

- None

Outside Users of the Bureau's Groundwater Data

- None

Outside Sources of Groundwater Data Used by the Bureau

- None

Opportunities for Improving Accessibility to Groundwater Data Among Agencies

- The Bureau of Data Processing could act as a centralized access point to computerized groundwater information.

Available Data Management Resources

Honeywell System

- Hardware -- 3 DPS 8/52 CPU's, 4 communication processors, 25 disk drives, 16 tape drives, 3 1200 LPM printers, 5 job entry computer systems, and 450 remote terminals throughout the State.
- Operating System -- GCOS-8
- Data Management Software
  * Data Manager (DMIV) - Data base accessible from remote terminals.

    * Integrated Data Store (IDS-II) - Allows an integrated data base to be accessed by many users.
- Data Summarization and Report Generation
    * Query and Reporting Processor (QRP) - Designed retrieval and report generation software.

IBM System

- Hardware -- 1 4381 Model 3 CPU, 4 communication processors, 17 disk drives, 6 tape drives, 1 high speed printer, 2 job entry computers, and over 400 terminals throughout the State.
- Operating Systems -- VM/XA SF, VM/SP, MVS/XA, OSVS1
- Data Management Software
    * Scientific Information and Retrieval System (SIR)- An integrated hierarchical data base management system with an easy to learn, integrated programming language.
    * The Bureau is committed to acquiring a relational data base sometime in the future.
- Statistical Analysis and Reporting Software
    * Easytrieve Plus - A report generation and sorting system
    * Statistical Analysis System (SAS) - An integrated system for data management and statistical analysis.
- The State's IBM mainframe has the capability of supporting MEGIS.

Other Computers

- Northern Telecom (Data100) mini computers
- IBM PC, PC-XT, and PC-AT personal computers
- Burroughs B25 personal computers
- AT&T 7300 Unix personal computers

Relevant Services

- Custom development of data management and application software
- Software Support
- Training

- Microcomputer Rental
- Resource Library
- Data entry
- Magnetic Tape Storage

Needs Met By Current Data Management Systems

- The Bureau does not manage groundwater data.

Needs Not Being Met By Current Data Management Systems

- The Bureau does not utilize groundwater data.

Desirable Data Management Functions and Features

- The State's computer compatibility standards require that all new equipment be compatible with the State's IBM and Honeywell mainframes (e.g. Model 3270 terminals). Furthermore, the Bureau feels that a groundwater data management system should be housed on one of these computers, so that it can be accessed through the many remote terminals already in place throughout the State. The Bureau would not be receptive to the addition of a third computer specifically for groundwater data management.

Additional Requirements Due to Anticipated Programs

- There is a trend toward increased public utilization of state information. This will necessitate consideration of technical features which provide accessibility and at the same time some degree of privacy.

Contractual Bounds on Data Management

- The Bureau has contracted the Computer Center, located in Falmouth, Maine for long term data entry services.

Costs of Maintaining Current Data Management Systems

The following are 1986 unit costs for services provided the Bureau of Data Processing.

- Personnel --

*Sr. Computer Programmer	$ 19.25
*Programmer Analyst	21.25
*Systems Analyst	23.75
*Systems Project Leader	26.00
*Systems Group Manager	28.50

- Personal Computer Rental

*IBM PC/XT with color monitor	$375./month
*IBM PC/XT with monochrome	325./month
*IBM 3270PC	375./month
*Burroughs B25	450./month
*Burroughs B25 with graphics	525./month

- Data Entry

*Per hour keypunch or Data100 data entry computer	$ 15.00

- Computer Hardware

*Session Connect Time	$ 0.00
*Dial up access	0.00
*Dedicated Communication Ports	350.00/month
*Electronic Mail	0.00
*Page Printing per page	.025
*Printing per line - Honeywell	.00107
*Printing per line - IBM	.0012
*Disk Storage - Honeywell	2.54/MB
*Disk Storage - IBM	3.697/MB

*Usage rates for other items such as CPU time and tape drives can be obtained by calling 289-3631.

Other

- Additional information can be found in a User Reference Guide, 1986, available from the Bureau of Data Processing.

STATE PLANNING OFFICE

Current Groundwater Programs

- Statewide Coordination of Groundwater Programs. SPO is charged with coordination of interagency groundwater programs. This involves one full-time "State Groundwater Coordinator" who works with professionals and committees to promote interdepartmental cooperation and communication between professionals. This individual also acts as a central source of information on groundwater laws, zoning, variances, etc. [contact: Paul Dutram]
- Groundwater Protection Planning. Development of a planning process for groundwater protection is currently underway at SPO. A draft methodology for community level aquifer protection planning consists of (1) formation of a groundwater committee, (2) informing the public, (3) gathering existing data, (4) inventorying well locations and potential contamination sources, (5) data evaluation, (6) public education, (7) selection of groundwater protection plan options, (8) identification of land use conflicts, (9) identification of regulatory conflicts, and (10) protection plan implementation. The proposed planning process depends largely on existing forms of groundwater information.
[contacts: Paul Dutram, Holly Dominie]
- State Groundwater Data Management System. This report is the first phase of the State's effort to establish a groundwater data management system. The project is administered by the Data Management Committee of the Maine Land and Water Resources Council through the State Groundwater Coordinator. The purpose of this study is to determine and document what groundwater data management practices are being used in Maine, analyze existing and future groundwater data management needs, develop general recommendations for a mutually accessible State groundwater data management system, and to serve as a model for other natural resources data management systems. Phase II, as proposed, will consist of development of specific data management options which meet the needs documented in this

report. Phase III will be the implementation of a system. [contact: Paul Dutram, Karen Massey]

Outside Users of SPO Groundwater Data

- SPO does not act as a source of groundwater quality or quantity data. Outside users are referred to MGS, DEP, or other agencies.

Outside Sources of Groundwater Data Used by SPO

- SPO utilizes information on groundwater programs and projects carried out by virtually all other State agencies. Actual figures on yield or water quality of specific wells are rarely used. Rather, the Agency is interested in statewide or regional summaries.

Opportunities for Improving Accessibility to Groundwater Data Among Agencies

- Improved accessibility to EPA's STORET system would be of benefit.
- DHS data should be indexed by geographic location and stored on computer in order to facilitate sorting and information retrieval.
- A State groundwater newsletter would enhance communication and cooperation between groundwater professionals.

Available Data Management Resources

- Access to the State's IBM and Honeywell mainframe computers
- Five Victor model 9000 micro-computers
- Eight AT&T model 6300 IBM-compatible micro-computers
- One Apple Macintosh personal computer

Needs Met by Current Data Management Systems

- No groundwater data management systems are utilized by SPO.

Needs Not Being Met by Current Data Management Systems

- Accurate knowledge of what groundwater data exists in the State is critical to the Agency's coordinating and planning efforts. Currently, no index exists.
- SPO is unable to incorporate accurate information on Maine's groundwater quality or quantity in its biannual natural resource reports. This is principally due to the lack of a management system which permits analysis of all available groundwater data.
- A data management system would also enable SPO to set priorities for providing assistance to towns for aquifer protection planning. This could be accomplished by sorting existing information to identify towns with water supplies already affected by pollution and those that are very susceptible to contamination.

Desirable Data Management Functions and Features

- Sort by hydrogeologic parameter, location, or geologic setting to permit inquiries and determination of spatial and temporal trends. For example, sorting of data to determine how many wells are going out of circulation within a certain region
- Identification and flagging of water quality reports that indicate possible contamination problems within certain geographic areas
- Correlation of land use and population statistics, and other useful data with groundwater resource information

Additional Requirements Due to Anticipated Future Programs

- SPO's proposed groundwater protection planning methodology largely consists of analysis of mapped hydrogeologic and land use information. The result will be a set of groundwater resource maps, land use classification maps, and threat maps. Incorporating a GIS component in the State's groundwater data management system will facilitate this process, particularly if the data base can be linked to existing permit and regulatory activities (e.g. site location permits, RCRA facilities, etc.).
- Groundwater protection planning will be implemented at the town level. Therefore, accessibility to groundwater information must be decentralized. Regional planning or conservation commissions or regional DEP offices could well provide remote access to a State groundwater information system.
- SPO will be a repository for hydrogeologic and land use data generated by towns in the course of local groundwater protection planning.
- After groundwater protection plans have been implemented, ongoing efforts should be made to gauge their effectiveness. This should include tracking the frequency and nature of contamination problems that occur in different protection zones.

Contractual Bounds on Data Management

- There are no contractual bounds which may restrict data management options.

Costs of Maintaining Current Data Management Systems

- There are no costs since SPO does not manage groundwater data.

UNITED STATES GEOLOGICAL SURVEY
WATER RESOURCES DIVISION, AUGUSTA, MAINE

Current Groundwater Programs

- Basic Data Collection Network. USGS performs long term monitoring of groundwater throughout the nation. The Agency's primary objectives are to gage the effects of climate, terrain, and man-made stresses on groundwater availability. Depth to water and well drawdown are of primary interest. The Maine monitoring network presently consists of about twenty wells. Ultimately, it will be expanded to forty wells. This program utilizes the Agency's Water Data Storage and Retrieval System (WATSTORE) for information management.

  Water levels at most wells are monitored continuously for the entire period of record. However, only five day high values are retained on WATSTORE for long term storage. Measurement frequencies of wells placed to gage the effects of terrain are sometimes reduced to twice monthly.

  Groundwater quality monitoring is a secondary objective. However, at least two chemical analyses are performed on each well: one at high and the other at low water level. Results of these also are stored in WATSTORE.

  [contact: Derrill Cowing, Thomas Maloney]

- Well Information. Information from three to four thousand wells inventoried during hydrologic studies is being entered into WATSTORE. Included are parameters such as aquifer type, depth of well, depth to water, well type, and pumping yield. When completed, this data base will be a valuable source of groundwater information.

  [contact: Derrill Cowing, Thomas Maloney]

- Hydrologic Studies Program. USGS, MGS, and DEP cooperate on a variety of groundwater related projects, including the sand and gravel aquifer mapping program. Information collected for these projects include seismic and other geophysical data, test hole logs, and water level
  and water quality data from observation wells. Maps, data and

interpretative reports resulting from projects are published, distributed and filed manually, but numerical and descriptive information is entered into WATSTORE whenever possible. [contact: Derrill Cowing, Thomas Maloney]

Outside Users of USGS's Groundwater Data

- USGS groundwater data is utilized by federal agencies, state agencies, regional planning groups, commercial interests, consultants, and private citizens. Generally, the information requested by outside users, if available, can be found in appendices to water resources reports and on maps.

Outside Sources of Groundwater Data Used by USGS

- MGS. Many projects are done in cooperation with MGS.
- DEP. Groundwater quality data is sometimes generated by joint USGS/DEP/MGS projects.
- DHS. Public and private water analysis results contain information particularly useful to USGS. However, these are seldom used because of a lack of adequate site location information.

Opportunities for Improving Accessibility to Groundwater Data Among Agencies

- DHS water quality files should be geographically indexed and computerized.
- Laboratories should have the capability of delivering analytical results in formats readily accessible by STORET and WATSTORE.
- A central geographic index to groundwater data availability would greatly improve accessibility.
- Accessibility could also be improved through better communication between groundwater professionals.

Available Data Management Resources

- USGS's Boston Prime computer supports WATSTORE. The system consists of several files which are grouped and stored by common characteristics. A site information file is maintained for all sites which have data stored in the system. Currently, files are maintained for the storage of (1) surface-water, quality-of-water, and groundwater data measured on a daily or a continuous basis, (2) annual peak values for streamflow stations, (3) chemical analyses for surface or groundwater sites, (4) water data parameters measured more frequently than daily, (5) geologic and inventory data for groundwater sites, and (6) summary data on water use. Additional data files can be added as needed.

  WATSTORE allows extensive statistical analyses of data to be performed with PSAT, a statistical system developed at Princeton University, or the Statistical Analysis System (SAS). Sorts are also possible. Data can be displayed in computer printed tables and graphs, and also in the form of two-dimensional contour plots.

- WATSTORE is based on INFO, a proprietary relational data base management program. USGS also utilizes ARC/INFO, an integrated geographic information management system. ARC/INFO is also based on INFO, but the program includes many mapping functions not found in WATSTORE. Since both ARC/INFO and WATSTORE utilize INFO formats, relational data files can be shared by the two systems.

  The Water Resources Division Augusta office has one direct line to the USGS Prime computer in Boston. This line provides remote access to both WATSTORE and ARC/INFO. However, most GIS functions must be performed in Boston because of mapping hardware requirements.

  Recently, the Augusta office has made a request for an IBM PC-AT based version of ARC/INFO. If purchased, the PC version would act as a satellite workstation to the Boston ARC/INFO system. This arrangement would provide the office with in-house analytical and mapping capabilities.

- Another important groundwater data service provided by USGS is the National Water Data Exchange (NAWDEX). NAWDEX is a national confederation of water-oriented organizations

working together to improve access to water data. No data is stored in NAWDEX. Rather, its objective is to assist users of water data in the identification, location, and acquisition of needed data.

NAWDEX consists of member organizations from the water data community. These organizations are linked so that their water data holdings may be readily exchanged for maximum use. A central Program Office coordinates this linkage and provides overall management of the program.

The Program Office encompasses four major areas of operation: (1) maintaining an internal data center, including access to automated data processing facilities for maintenance and use of its information files; (2) indexing water data held by participating organizations; (3) providing facilities and personnel for responding to requests for data; and (4) formulating recommended water data handling and exchange standards.

- In addition to having access to the above, the Augusta office has an IBM PC-AT computer and a Hewlett Packard plotter.

Needs Met By Current Groundwater Data Management Systems

- WATSTORE is used for storage and retrieval, statistical analyses, and sorting by geographic proximity. WATSTORE water quality file data are readily accessible through STORET.
- ARC/INFO is used for geographic information management and mapping.

Needs Not Being Met By Current Data Management Systems

- WATSTORE and ARC/INFO seem to satisfy current needs.

Desirable Data Management Functions and Features

- See above discussions of WATSTORE and ARC/INFO.

Additional Requirements Due to Anticipated Future Programs

- USGS involvement in Maine's bedrock aquifer mapping project will necessitate some degree of data format compatibility between ARC/INFO and MEGIS (or visa versa).
- Availability of surface and groundwater will be a future resource management issue that will necessitate better water usage information.
- Determination of the contribution of groundwater to surface water networks during low flow periods and draughts will require accurate delineation of subsurface recharge areas, flow patterns, discharge areas, and water usage.

Contractual Bounds on Data Management

- The U.S. Department of Interior is committed to using Prime computers and ARC/INFO.

Cost of Maintaining Current Data Management Systems

- The Water Resources Division in Augusta spends $60,000 annually on WATSTORE. This figure accounts for data storage, retrieval, and analyses costs for 50 stream gages, 20 wells, 20 water quality stations, data management and computer analysis for all project activities, and a historical data base. It also includes capital costs and system maintenance.

Other

- Groundwater information stored in a data management system should be of known reliability.
- Training of water sample collection personnel and regular quality control reports from State laboratories are desirable.