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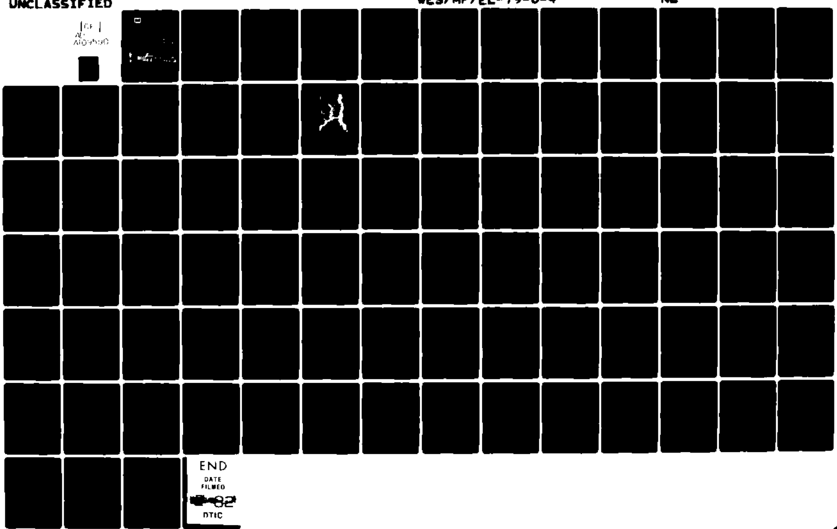

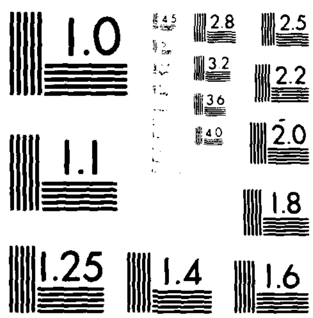

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MILITARY HYDROLOGY

Report 4

EVALUATION OF AN AUTOMATED WATER DATA BASE FOR SUPPORT TO THE RAPID DEPLOYMENT JOINT TASK FORCE (RDJTF)

by

Hugh W. Calkins, Timothy R. Johnson

Department of Geography
State University of New York at Buffalo
Buffalo, N. Y. 14260

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An automated water resources data base and associated geographic information system is needed for support of Rapid Deployment Joint Task Force (RDJTF) Engineer missions and responsibilities. A study was conducted to arrive at recommendations concerning existing, commercially available geographic information systems suitable for installation and operation at the U. S. Army Engineer Topographic Laboratories (ETL), Ft. Belvoir, Va. Data base

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specifications and RDJTF requirements were reviewed to establish geographic information system selection criteria. Criteria established pertained to four factors: (a) system technical capabilities, (b) developing organization experience and capabilities, (c) client comments, and (d) costs. Based on these criteria, seven systems were selected, evaluated, and ranked in terms of their overall suitability. Final recommendations are in two parts: (a) for a geographic information system which could be used in conjunction with hardware presently available at ETL, and (b) for a combined hardware/software system that could be acquired by ETL. Descriptions of the individual systems are included in Appendix A.

PREFACE

Work reported herein was conducted during the period January through April 1981. The effort was sponsored by the U. S. Army Engineer Topographic Laboratories, Fort Belvoir, Va., through Project Order Number 11029 for Phase 1, 2, and 3 of the Automated Information Storage/Retrieval/Synthesis System for RDJTF Water Supply needs per the U. S. Army Engineer Waterways Experiment Station (WES) Study Plan forwarded by letter dated 30 Oct 80, and by the Office, Chief of Engineers (OCE), U. S. Army, Washington, D. C., under Department of the Army Project No. 4A762719AT40, "Mobility and Weapons Effects Technology," Task Area BO, "Combat Engineering," Work Unit 030, "Military Hydrology Technology Transfer."

The study was conducted and the report written by Drs. Hugh W. Calkins and Timothy R. Johnson of the Department of Geography, State University of New York at Buffalo, Buffalo, N. Y., under U. S. Army Research Office Contract Number DAAG29-76-D-0100.

The contract was monitored technically by Dr. L. E. Link, Chief, Environmental Constraints Group (ECG), Environmental Systems Division (ESD), Environmental Laboratory (EL), WES, and Mr. J. G. Collins, ECG, under the general supervision of Mr. B. O. Benn, Chief, ESD, and Dr. J. Harrison, Chief, EL.

During the conduct of the study and preparation of this report, the Commander and Director at WES was COL Nelson P. Conover, CE. Commander and Director of the WES during the publication phase of this report was COL T. C. Creel, CE. Technical Director during the study was Mr. Fred R. Brown.

This report should be cited as follows:

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I. Purpose and Scope of Study

The purpose of this study is to review existing, commercially available, geographic information systems to identify those systems that can meet the data storage, retrieval, and analysis needs of the Rapid Deployment Joint Task Force (RDJTF) for water resource and related data. The objective of this study is to recommend one or more geographic information systems suitable for installation at the Terrain Analysis Center, Engineering Topographic Laboratory (ETL) at the earliest possible date. The Terrain Analysis Center currently produces standard overlay maps of water resouce data from aerial photographs and other sources. These overlays are produced manually on a mylar base at the scale of 1:250,000. The first objective for a geographic information system is to automate the water data base in order to provide the capability for rapid querying of this data base in support of proposed RDJTF operations. Also, computer generated maps similar to the present overlays will be produced by the system. A second objective for the geographic information system is to automate other mapping activities at the Terrain Analysis Center.

The recommendations in this report are in two parts: (1) a recommendation for a system which uses the equipment already existing at ETL; and (2) a recommendation for a combined hardware/software system that can be acquired by ETL. The recommendations also include estimates of the time it will take to install the recommended systems at ETL, and an estimate of the time and resources needed to input the water resource data bases that already exist at ETL, and the Waterways Experiment Station (WES).

II. Objective of an Automated Water Data Base and Associated Geographic Information System

The automated water data base and associated geographic information system will support the RDJTF Engineer missions and responsibilities in the planning and design of water supply systems for a contingency force. The Engineer responsibilities include the following functions:

A. Locate water sources;
B. Analyze water;
C. Develop water source site;
D. Water treatment;
E. Water storage; and
F. Water distribution.

In carrying out these functions, it is assumed the Engineer will be provided with the following information:

A. The demand for water specified in terms of location, quantity, and quality of water needed per day (24 hour period);
B. The personnel resources available for the development operation of a water supply system; and
C. The equipment available to treat, store, and transport water.

The proposed geographic information system will assist the Engineer perform two types of analysis:

A. To locate and analyze the quantity and quality of water available at a given location; and
B. To develop plans for the treatment, storage and distribution of water to meet the specified need.

The proposed geographic information system will be used by the RDJTF Engineer in the following modes:

A. Contingency Planning: To prepare maps and atlases for long range planning (base maps and overlays); to conduct planning sessions and exercises.
B. Pre-deployment: To locate and analyze water availability at a given location; plan a water distribution system.

C. Field Use: To provide on-site up-dating of the data base and to redo activities conducted under pre-deployment above.

The geographic information system will be located at ETL. At this location the system will have full capability, including data input, data base construction, data base update, data retrieval, data analysis, and data display. It is anticipated that a remote terminal to the system will be installed at McDill Air Force Base, headquarters for the RDJTF. This remote station will be capable of all data retrieval, analysis, and display functions, but not data input or data base building. The remote station will, however, need the capability to update records already in the data base. Additionally, one or more field units may be acquired, capable of being transported to any location with the RDJTF. Such field units would have full data retrieval, analysis and display capabilities for a given region of interest (approximately 10% of the data base). Also, the field units must allow for data update to records already in the data base, if economically feasible.

III. Data Base Specifications

The data required to operate the proposed system falls into four categories:

A. Map base data;
B. Water resource data;
C. Transportation data; and
D. Terrain analysis data.

Map Base Data

The map base data will be taken from the Joint Operations Graphic (JOG) maps at a scale of 1:250,000. These maps are based on the UTM* projection system. It is estimated that the initial area of interest to the RDJTF is covered by approximately 100 JOG sheets. The following information will be encoded from these map sheets:

A. Map boundaries;
B. UTM grid lines;
C. Shorelines;
D. Boundaries (international and administrative); and
E. Populated places.

Water Resource Data

The water resource data will be assembled by ETL from various sources and entered on standard overlays. The data will be digitized and encoded from these overlays and will consist of the following elements:

A. Existing water supply systems, including reservoirs and cisterns (specified as point locations):

    1. Capacity (gal/hour, storage capacity);
    2. Estimated population being served;
    3. Distribution system (pipeline, truck);
    4. Quality (temperature, salinity, pollution);
    5. Treatment (type, capability, storage).

B. Water distribution outside populated places--pipelines and ghanats (specified as a network of lines):

    1. Flow;
    2. Quality (temperature, salinity, pollution).

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* Universal Transverse Mercator.

C. Surface water--streams and rivers (specified as line segments):

1. Capacity;
2. Accessibility;
3. Flow (perennial, periodic);
4. Total yield;
5. Quality (turbidity, temperature, salinity, pollution).

D. Sub-surface water--wells (specified as points):

1. Class (capped, uncapped);
2. Quality (temperature, salinity, pollution);
3. Depth of water;
4. Sub-surface rock conditions;
5. Aquifer (type and thickness);
6. Yield.

E. Sub-surface water--ground water (specified as polygons):

1. Depth to water;
2. Sub-surface rock conditions;
3. Aquifer (type and thickness);
4. Estimated yield;
5. Quality (salinity, pollution).

The water resources overlay currently prepared by ETL also shows the location of springs. These have not been included in the data base, but they could be added as an additional point data set. On the sample map sheet supplied by ETL there are approximately 75 springs shown.

Transportation Data

The transportation data will be taken from overlays prepared by ETL and will be digitized and encoded by ETL. This data consists of the following elements:

A. Road network (specified as a network of line segments):

1. Road class (all weather, fair weather);
2. Surface material (hard, loose);
3. Width;
4. Grade;
5. Curvature;
6. Overhead clearance (for tunnels and covered passageways only);
7. Overall length in meters (bridges and tunnels only);
8. Military load classification (bridges only);
9. Bridge bypass potential (bridges only).

NOTE: Constriction points, tunnels and bridges, will probably be entered as one-dimensional segments.

B. Railroads (specified as line segments):

1. Number of tracks;
2. Gauge;
3. Class (in use, abandoned);
4. Length in meters (bridges and tunnels only);
5. Overhead clearance (tunnels only);
6. Width in meters (tunnels only);
7. Electrified (yes/no).

NOTE: Bridges and tunnels will probably be entered as one-dimensional segments.

Terrain Analysis Data

The terrain analysis data will be acquired from ETL and will consist of the following elements:

A. Obstacles (specified as line segments of polygons).

The following items are of interest but will only be added to the data base as they are available from the Defense Mapping Agency (DMA) in digital form:

B. Slope;
C. Surface Materials;
D. Vegetation;
E. Geology.

The source, scale, graphic encoding, volume of data, and number of attributes for each data item are shown on Table I, to the extent that these items are known at this time. The data volume estimates are based on the sample map sheets provided by ETL and WES. The complete data base should be reviewed by ETL personnel to verify that these volume estimates are reasonable.

It is recommended that line and polygon data be digitized at approximately 50 points to the line inch. This is adequate for analytical purposes. This is not, however, considered to be adequate for cartographic purposes, which would be about 200 points per inch. At 50 points per inch all graphic outputs of the system will show some irregularities but these will not affect the analysis. If cartographic accuracy were desired, the data volumes would increase by a factor of 4, and processing and plotting time would increase substantially.

In addition to the information shown above for each water data element and transportation data element, the RDJTF desires that the date of data collection and, if possible, a data reliability measure, be included in the data base. These two measures can be included as two more variables for each data item.

TABLE I

Data Description Table

	Data Item	Source	Scale	Graphic Coding	Est. Vol./ Map Sheet	Est. # of Attributes
I.	MAP BASE DATA					
A.	Map boundaries	JOG	1:250000	Line segments	4 seg./sheet	--
B.	UTM grid lines	JOG	1:250000	Line segments	25 seg./sheet	--
C.	Shorelines	JOG	1:250000	Line segments	3000 seg./sheet	--
D.	Boundaries	JOG	1:250000	Line segments	500 seg./sheet	1
E.	Populated places	JOG	1:250000	Points	350 pts./sheet	1
II.	WATER RESOURCE DATA					
A.	Existing water supply systems	ETL	1:250000	Points	150 pts./sheet	10
B.	Water distr. systems - pipe-lines, ghanats	ETL	1:250000	Line segments	150 seg./sheet	5
C.	Surface water - streams, rivers	ETL	1:250000	Line segments	2000 seg./sheet	10
D.	Sub-surface water - wells	ETL	1:250000	Points	100 pts./sheet	10
E.	Sub-surface water - ground water	WES	1:250000	Polygons	10000 pts./sheet	8
III.	TRANSPORTATION DATA					
A.	Road Network	ETL	1:250000	Line segments	8750 seg./sheet	10
B.	Railroads	ETL	1:250000	Line segments	1250 seg./sheet	8
IV.	TERRAIN ANALYSIS DATA					
A.	Obstacles					

IV. Geographic Information System Operations

The geographic information system functions are divided into the following categories:

A. Those functions to prepare water resource maps for contingency or long range planning, including the preparation of overlays similar to existing overlays, and the production of water potential maps;

B. Those functions to assist the Engineer to locate and analyze the water availability at a given location;

C. Those functions to assist the Engineer in planning for the treatment, storage, and distribution of water at a given location; and

D. Utility functions to build, update, and manage the data base.

Water Resource Maps

The functions to prepare water resource maps and water potential maps for contingency or long range planning will allow for the advance preparation of maps that can be used in the early stages of deployment planning. The functions required to meet this need are:

A. To prepare water resource maps:

1. Select from the data base a given area (window) described in terms of either a JOG map sheet name or number, or specified as a string of X,Y coordinates. The data selected from the data base should include the water data of interest, the map base data (items as selected only), the transportation data (if selected), and the terrain analysis data (if selected).
2. Display, on a CRT, a plotter, or both (under operator control) the data selected in number 1 above. Provision should be made to display labels (selected) for each data element to be displayed.

B. To prepare water potential maps:

1. Select from the data base a given area (window) described in terms of either a JOG map sheet number or name, or specified as a string of X,Y coordinates.
2. Convert all water resource data to a grid cell framework, with the grid cell size specified by the Engineer.
3. Calculate a water potential measure for each grid cell based on weights assigned by the Engineer to each category of water resource.
4. Display the results of number 3 above along with selected map base data on a plotter.

The preparation of water resource maps and water potential maps will be a batch operation conducted at ETL. These maps will be used by the Engineer to determine where a search will likely prove fruitful and where insufficient water is available for RDJTF operations. The product of this operation will be similar to the attached graphic (Figure 1). These maps will likely correspond to the JOG map sheets.

<u>Locate and Analyze Water Availability</u>

The functions to assist the Engineer locate and analyze the water available at a specified location are as follows:

A. To locate water available within a defined area:

1. Select from the data base an area (window) specified either by UTM coordinate or by JOG map sheet identification, and store all data for this area in working storage.
2. Display all or selected map base data for the area selected in number 1 above on a CRT (storage or refresh).
3. Accept graphic input (at CRT) of a point location or a polygon of interest as the proposed operations area of the RDJTF; and/or accept UTM coordinate descriptions of a point or polygon through a keyboard input device.

Figure 1

Example of Grid Cell Map
for Water Potential Maps

4. Generate a circle of specified radius around any point specified via the CRT or keyboard; store the circle in working storage for use as a polygon for data retrieval; and display the circle on the CRT.
5. If a polygon of interest has been specified in number 3 above, display this polygon on the CRT.
6. Search the portion of the data base in working storage on the basis of graphic criteria (circle or polygon specified above) and/or attribute criteria:
   a. Point-in-polygon - e.g., find all wells within the input circle or polygon.
   b. Line-in-polygon - e.g., find all streams within the input circle or polygon.
   c. Polygon overlay - e.g., find all ground water sources within the input circle or polygon.

   The above three search modes may be qualified by attribute data; e.g., find all wells within the input circle or polygon that produce "x" gal/hour or more; or find all stream segments within the input circle or polygon that are not saline and are accessible by truck.
7. Display on the CRT all data base items meeting the search criteria; display, at the user's option, selected labels for each data items selected and displayed; and/or transfer this display to the plotter.
8. Produce a tabular summary of attribute data for all data items selected by the search criteria, including summations of total water availability by category of quality.

B. To locate a specified quantity of water with specified quality characteristics:
   1. Select from the data base an area (window) specified either by UTM coordinates or by JOG map sheet identification, and store all data for this area in working storage.

2. Display all or selected map base data for the area selected in number 1 above on a CRT (storage or refresh).
3. Accept graphic input (at CRT) of a point location of interest as the proposed operations location of the RDJTF; and/or accept a UTM coordinate description of a point through a keyboard input device.
4. Search the water resource data base to find the closest available water that will meet the specified quantity and quality; the search should be based on airline distance and should identify the set of water data elements that are both closest and will meet the specified need.
5. Display on the CRT all data base items meeting the search criteria; display, at the user's option, selected labels for each data item selected and displayed; and/or transfer this display to the plotter.
6. Produce a tabular summary of attribute data for all data items selected by the search criteria, including summations of total water availability by category of quality.

The above functions should operate on an interactive basis allowing the Engineer to specify various point or polygon locations successively and to calculate the water availability and condition on each iteration. The Engineer will then manually compare this water availability with the expected demand and determine if the demand can be met or if additional water sources are needed. If additional water sources are needed, the Engineer should have the options to expand the original search circle or polygon, create a new search circle or polygon, or display portions of the water resource data to determine where a search might meet the requirements.

Plan and Design the Treatment, Storage and Distribution of Water

The functions to assist the Engineer to plan and design the treatment, storage, and distribution of water are divided into two categories: (1) an interactive display capability where the Engineer can selectively display the selected water sources, display the map base data, display the terrain analysis data, display the transportation data, and make judgments on the placement of personnel and equipment for developing the water supply system; and (2) a linear programming (or similar) model for automatically determining the linkages between supply and demand subject to constraints from personnel, equipment, and the connecting transportation network.

A. Interactive display capability:

1. For the specified search area, or any portion thereof, display the water sources that met the search criteria; and display selected map base data.
2. Add to the display specified portions of the road system and specified terrain analysis data, as indicated by the Engineer. The selection of the roads may be based on attribute data on the roads such as surface materials or width.
3. At the options of the Engineer, display labels for items displayed in numbers 1 and 2 above.
4. Provide the capability for the Engineer to input via the CRT a linkage between specified sources and demand points; plot on a CRT a line between each source and demand point pair.
5. Transfer the resulting display to the plotter or other hard copy unit.

B. Linear programming model for the design of the water supply systems: This will be a standard transport type model where the demand pattern is specified by the Engineer, the equipment and personnel resources are specified, and the program allocates sources to demand considering the capacity of the road system, and the equipment and personnel resources. The result of the model calculations will be output in tabular and graphic form. The model, which will be specified in detail later as a separate task, should be able to be hooked into the system as a module.

Utility Functions

The utility functions to build, update, and manage the data base should have the capability to create the digital representation of the graphic data (digitizing) and the input of the associated attribute data. The graphic data will be in the form of points, line segments, and polygons as specified in the data description table. The volume of attribute data is also specified in the data description table. It is anticipated that there will be substantial missing attribute data when the individual data items are entered into the data base. Therefore, it is important that easy updating of the attribute data be possible in both the full system at TAC* as well as in the remote terminal at McDill Air Force Base and with the field units.

The CRT displays of map data will need to be enlarged, on demand, by the Engineer. Therefore, the system should have a zoom capability to allow for the enlargement of any portion of a CRT display. Also, plotter mapping routines should be capable of producing maps at various scales, probably between 1:125,000 and 1:500,000.

* Terrain Analysis Center.

V. Criteria for the Selection of a Geographic Information System

The criteria for the selection of a geographic information system for use by ETL in meeting the needs of the RDJTF are divided into the following categories:

1. Technical capabilities--can the system perform the technical functions required by the RDJTF?

2. Organizational factors--the general experience of the organization in selling and installing their system in a user's environment, their experience in maintaining a system, and the support they provide to the user.

3. Client comments--the reputation the organization has with its clients.

4. Cost--the estimated cost of installing a system at ETL.

In addition to these criteria, general comments are included on each system when additional information is known that is relevant to the selection of a system for the RDJTF.

Technical Capabilities

The technical capabilities follow the specifications for the operations of the geographic information system as defined in the previous section, as follows:

I. Operations needed to prepare water resource maps for contingency and long range planning.

   A. Prepare water resource maps (overlays)

      1. Select an area of interest
      2. Display on a CRT or plotter

   B. Prepare water potential maps

      1. Select an area of interest
      2. Convert to a grid cell format
      3. Calculate composite measure
      4. Display on CRT or plotter

II. Locate and analyze water availability.

A. Locate water in a defined area

1. Select a window from the data base
2. Display selected map base data on a CRT
3. Accept graphic input at CRT
4. Generate a circle around the input point
5. Display circle or polygon on CRT
6. Search data base:
   a. Point-in-polygon
   b. Line-in-polygon
   c. Polygon overlay
   d. Boolean search capabilities for the above
7. Display search results on the CRT, with labels
8. Produce tabular summary of attribute data for selected items

B. Locate specified quantity of water

1. Select a window from the data base
2. Display selected map base data on CRT
3. Accept graphic input at CRT
4. Search data base to find closest available water until specifications are met
5. Display search results on CRT, with labels
6. Produce tabular summary for selected item, including summarization of water by quality category

III. Plan and design the treatment, storage and distribution of water.

A. Interactive display capability

1. For specified search area, display selected water resource data on CRT
2. Add to CRT selected portions of the road network
3. Display labels for the above items
4. Input linkage between source and demand and add to display
5. Transfer resulting display to plotter

B. Linear programming model (network calculations, e.g., minimum path, etc.)

IV. Utility functions.

A. Build data base

1. Input points with attribute data
2. Input lines with attribute data
3. Input polygons with attribute data

B. Update data base

1. Update point, line, and polygon descriptions
2. Update attribute data

Organizational Factors

The organizational factors concern mainly the experience of the organization in placing systems in users' offices and the general support provided to users. The following factors have been used to evaluate the candidate systems:

A. The number of systems sold and delivered to users

B. The arrangement for maintenance of the hardware and software

C. The release of the source code for the system

D. The training provided by the vendor

Client Comments

An important factor in the selection of a system is the general experience with the system on the part of the current users of the system. Such items as the problems that have been encountered with the hardware, the number of bugs discovered in the software, and the speed with which problems and bugs are corrected are important considerations. Also of importance is the ease with which the system can be learned and operated by the user's staff. To evaluate these factors, selected users of each system were surveyed and their comments are included in this report.

Costs and Installation Times

Of interest in this category are the costs of the hardware and software, the annual maintenance costs of each, the cost of modifications required to meet the needs of the RDJTF, and the time required to install a system after it has been ordered. The cost figures contained in the report are estimates only and are subject to revision when a firm bid is made. Every attempt has been made to express the costs in a common base; however, there are certain system differences that make cost comparisons a bit difficult. Specifically, the recommended hardware configuration for each system is sometimes above the minimum required to do the immediate job at hand. However, the larger system can probably be justified in terms of the future requirements of ETL as it develops other applications.

Specific items in this part of the evaluation are:

A. The cost of the hardware

B. The cost of the software

C. The hardware maintenance costs

D. The software maintenance costs

E. The cost of software modifications

F. The estimated time to install the system

VI. Systems Selected for Evaluation

The selection of potential geographic systems for use by the RDJTF was based on the results of two previous selection studies--one by Tomlinson Associates for the Minister of Tourism and Renewable Resources of the Province of Saskatchewan; and the other by Woodward-Clyde Consultants, San Francisco, California, for selecting a system for their own use. These two studies were conducted during 1980 and are the latest known evaluation studies of geographic information systems. The systems listed in each of these studies were used as a beginning set of systems for review in this study. The list was reviewed and systems were dropped from the list on the basis of existing knowledge of the capabilities of the listed systems and the ability of the organization to supply a system to the RDJTF.

The resulting list of potential systems was as follows:

A. Autometric Incorporated

B. COMARC Design Systems

C. Earth Satellite Corporation

D. Environmental Systems Research Institute

E. Intergraph Corporation (formerly M&S Computing)

Four out of the five above systems passed the benchmark test conducted by Tomlinson Associates during March of 1980. The other system, Autometric Incorporated, has undergone substantial development since that benchmark test was conducted.

In addition to the above systems, two other systems were added to the list of those to be considered, as follows:

A. Synercom Technology, Incorporated was added because it was known by the authors to have a system which was thought to be able to meet the defined needs.

B. Battelle Pacific Northwest Laboratories was added to the list as a result of a submission by Battelle to the authors.

Thus, a total of seven systems were reviewed and evaluated during the course of this study.

VII. Evaluation of Selected Systems

The process of evaluation of the geographic information systems selected for this study consisted of the following steps: (1) contact the organization and request documentation about the system; (2) submission of the specifications prepared during this study to each vendor; (3) site visits to either the vendor's home office or to a location where the system could be demonstrated (only for five of the systems); (4) telephone interviews with all vendors; and (5) telephone interviews with selected clients of each vendor, where possible. The evaluation is based on information obtained from the system documentation, interviews with vendor personnel, demonstrations of the system (in four cases), and a survey of clients of each system. Benchmark tests were not conducted during this study because the data are not presently organized in a fashion to allow for a benchmark test, there was not sufficient time for such a test, and the resources of the study were limited. The review of system documentation focused on the technical capabilities of each system, but did not include an examination of the source code to determine if the system is well designed and programmed.

The evaluation of the geographic information systems considered in this study is presented in table form as follows:

1. Table II - Technical Capabilities
2. Table III - Organization Factors
3. Table IV - System Costs.

The Battelle Pacific Northwest Laboratories system (CIRMIS) is not evaluated in detail, in this and subsequent sections of this report, because adequate information was not received from Battelle. From the information that was received it did not appear that Battelle's system could meet the technical requirements and it was apparent that the system has not been organized and packaged for transfer to another user. Also, Battelle does not have a standard hardware configuration for their system and it appears that any transfer of their system would require substantial software conversion.

TABLE II

Technical Capabilities

Function	Autometrics	COMARC	EarthSat	ESRI	Intergraph	Synercom
I. Prepare water resource maps						
A. Water resource maps						
1. Select area of interest	Yes	Yes	Yes	Yes	Yes	Yes
2. Display on CRT/ plotter	Yes	Yes	No	Yes	Yes	Yes
B. Water potential maps						
1. Select area of interest	Yes	Yes	Yes	Yes	Yes	Yes
2. Convert to grid cells	Yes	Poly-only	No	Yes	Yes	Poly-only
3. Calculate composite measure	Yes	No	No	Yes	No	Yes
4. Display on CRT/ plotter	Yes	Yes	No	Yes	Yes	Yes
II. Locate and analyze water						
A. Locate water						
1. Select window	Yes	Yes	Yes	Yes	Yes	Yes
2. Display map base data on CRT	Yes	Yes	No	Yes	Yes	Yes
3. Accept graphic input at CRT	Yes	No	No	No	Yes	Yes
4. Generate circle	Yes	No	No	No	Yes	Yes

TABLE II (continued)

Function	Autometrics	COMARC	EarthSat	ESRI	Intergraph	Synercom
5. Display circle or polygon on CRT	Yes	Yes	No	Yes	Yes	Yes
6. Search data base						
a. Point-in-polygon	Yes	Yes	No	Yes	Yes	Yes
b. Line-in-polygon	Yes	Yes	No	Yes	Yes	Yes
c. Polygon Overlay	Yes	Yes	Yes	Yes	Yes	Yes
d. Boolean search	Yes	Yes	Yes	Yes	Yes	Yes
7. Display results on CRT	Yes	Yes	No	Yes	Yes	Yes
8. Produce tabular summary	Yes	Yes	No	Yes	Yes	Yes
B. Locate specified quantity of water						
1. Select window	Yes	Yes	Yes	Yes	Yes	Yes
2. Display map base data on CRT	Yes	Yes	No	Yes	Yes	Yes
3. Accept graphic input at CRT	Yes	No	No	No	Yes	Yes
4. Search data base to find closest water	Yes	No	No	No	No	Yes
5. Display results on CRT	Yes	Yes	No	Yes	Yes	Yes
6. Produce tabular summary	Yes	Yes	No	Yes	Yes	Yes

TABLE II (continued)

Function	Autometrics	COMARC	EarthSat	ESRI	Intergraph	Synercom
III. Plan and design water system						
A. Interactive display capability						
1. For search area, display selected data	Yes	Yes	No	Yes	Yes	Yes
2. Add road network to CRT	Yes	Yes	No	No	Yes	Yes
3. Add labels	Yes	Yes	No	Yes	Yes	Yes
4. Input linkage between source and demand	Yes	No	No	No	Yes	Yes
5. Transfer to plotter	Yes	Yes	No	Yes	Yes	Yes
B. Linear programming model	No	No	No	No	No	No
IV. Utility functions						
A. Build data base						
1. Input points	Yes	Yes	Yes	Yes	Yes	Yes
2. Input lines	Yes	Yes	Yes	Yes	Yes	Yes
3. Input polygons	Yes	Yes	Yes	Yes	Yes	Yes
B. Update data base						
1. Update points, lines & polygons	Yes	Yes	Yes	Yes	Yes	Yes
2. Update attribute data	Yes	Yes	Yes	Yes	Yes	Yes

TABLE III

Organizational Factors

Factor	Autometrics	COMARC	EarthSat	ESRI	Intergraph	Synercom
1. Number of systems sold and delivered to users	6	>10	0	>15	>10	>10
2. Hardware maintenance arrangement	w/venders	w/venders	w/venders	w/venders	w/Inter-graph	w/syner-com
3. Software maintenance arrangement	subscrip. service $3500/yr.	subscrip. service $3600/yr.	subscrip. service $10,000/year	subscrip. service $5000/yr.	subscrip. service	subscrip. service
4. Release of source code	Yes	No	Yes $10,000 extra	Yes	Yes $40,000 extra	Yes $40,000 extra
5. Training provided by vendor	3 weeks	4 weeks	1 week	5 weeks	6 weeks	4 weeks

TABLE IV

System Costs

Cost Category	Autometrics	COMARC	EarthSat	ESRI	Intergraph	Synercom
1. System Acquisition Costs						
A. Hardware	$155,000	}$200,000	$190,000	$175,000-200,000	}$300,000	}$273,000
B. Software	20,000		60,000	50,000-75,000		
2. Software Modifications						
A. Modification costs	$10,000	Time & Materials	Time & Materials	$5,000	N/A	N/A
3. Total Acquisition Cost	$185,000	~$225,000	~$275,000	$230,000-280,000	$300,000	~$273,000
4. Installation Time						
A. Estimated time for installation	90-120 days	90 days	60 days	60 days	120 days	180 days
5. Maintenance Costs						
A. Hardware	$24,000/yr.*	$27,000/yr.*	$35,000/yr.*	$36,000/yr.*	$ 30,000/yr.	$32,000/yr.
B. Software	3,500/yr.	3,600/yr.	10,000/yr.	5,000/yr.		

*Figures here are based on an estimate of 1.5% of purchace price per month.

VIII. Findings and Recommendations

This section presents the overall findings of this study and the recommendations for the installation of a geographic information system at ETL. The recommendations are in two parts: (1) a recommendation of which system would be best if current equipment at ETL were to be utilized; and (2) a recommendation of which system would be best if a completely new system were to be acquired. This section also contains recommendations regarding the staffing requirements to operate a geographic information system at ETL, a specification of what work should be done to set up an information system at ETL, and estimates of the time required to input the estimated data volumes of the water data base.

A summary statement of findings for each system is presented below.

Autometric Incorporated

The AUTOGIS System marketed by Autometric Incorporated has most of the technical capabilities needed by the RDJTF. The system does not have any modeling capability and has limited capability in the areas of logical search, tabular summaries, and linking source and demand points for water allocation. The input system is considered to be somewhat weak in that the system stops when it cannot make a successful edgematch and requires resolution of the problem before digitizing can continue. This sometimes requires the participation of additional people, takes time, and therefore slows down a production digitizing operation.

Organizationally, the system is relatively young. Autometric Incorporated has been in the geographic information system business less than two years, with their oldest installation just over a year old. Many users are still working with AMS, the input subsystem, and have not extensively tested or used MOSS, the analytical subsystem. Their support has been good to date. Autometric Incorporated will release their source code (it is already in the public domain) and this should not pose any problem. This will be particularly important when additions are made to the system, for example, when a linear programming model is added.

Comments received from clients indicate that the support provided by Autometric Incorporated is relatively good, with software problems being handled quickly and efficiently.

Costs of the Autometric Incorporated system range between \$145,000-\$165,000. The lower figure is for a micro-computer based system and the higher figure is for a mini-computer. The micro-computer version is just now being implemented and has unknown performance qualities and is not recommended primarily because of the small difference in price between the systems. As ETL moves into other applications a micro-computer could become a limiting factor.

COMARC Design Systems

The technical capabilities of the COMARC Design Systems' COMPIS System is fairly good. They can either currently meet the needs or can do so with minimal modifications. The system has a reputation as being technically good. However, the system may be somewhat difficult to modify because of the overall design structure of the system. The system appears to have evolved in response to various user needs as they have occurred rather than the system being designed as an integrated whole. This may make the system difficult to modify.

Organizationally, COMARC has had some problems. Users report that system personnel have changed often and new people have not been totally familiar with the system, making user service difficult. COMARC will not release the source code to their users, except for an additional charge, and then they are not happy about it.

Comments from selected clients are generally not favorable. Specific comments include: (1) the system does not run well; (2) COMARC tends to blame users for problems; (3) COMARC does not provide satisfactory service; (4) the system is not user friendly, is hard to learn, and the manuals are very poor; and (5) training is limited and COMARC does not provide any continuing training for new staff persons. One client is now in the process of acquiring the Autometric Incorporated AUTOGIS System to supplement the capabilities of COMPIS.

The COMARC system is marketed as a combined hardware/software package. The approximate price for RDJTF use would be $200,000 plus modifications on a time and materials basis. The hardware would be maintained by the various vendors with COMARC maintaining the software for $3,600/year.

Earth Satellite Corporation

Earth Satellite Corporation markets the LANDPAK System. Technically this system cannot meet the interactive graphics capabilities required by the RDJTF. Previous tests have concluded that this system is also quite slow.

Operationally, Earth Satellite Corporation is not set up to install and maintain a geographic information system. They have not sold the system yet and have no experience in installation and maintenance. Their staff is quite small, with their computer experts being in a different firm, which was located in the same offices until recently but has moved to a new location. It is unclear at this time how this might affect the support of the LANDPAK System.

As the system has not been sold to anyone, it was not possible to obtain feedback from users.

The costs of the LANDPAK System are somewhat high, being approximately $250,000. This does not include the modifications that would be required to meet the needs of the RDJTF, which would be done on a time and materials basis. Hardware maintenance would be with the manufacturers and software maintenance from Earth Satellite Corporation would be $10,000/year.

Environmental Systems Research Institute

The technical capabilities of the Environmental Systems Research Institute's (ESRI) geographic information system do not meet fully the needs of the RDJTF at this time. Specifically, the system does not have an interactive graphics capability as needed to locate and analyze water availability. However, in response to the specifications prepared during this study, ESRI has decided to write an interactive graphics module based on the RDJTF specifications. Therefore, ESRI will be able to demonstrate a system that has most of the required capabilities by the middle of April 1981. It is therefore concluded that the ESRI system qualifies for consideration by the ETL as meeting the needs of the RDJTF.

Organizationally, ESRI has the most experience of any company surveyed in the sale and installation of geographic information systems for planning and spatial analysis purposes. Other firms have distributed systems for engineering drawing and urban tax mapping functions but these systems do not have a data structure suitable for cartographic applications and are therefore considered inferior for the purposes of the RDJTF.

A review of the client experience reveals that ESRI has an excellent reputation for delivering services. They are particularly strong in dealing with user problems and in following up on user applications. With one exception, ESRI users are very satisfied with the service provided.

The costs of the ESRI system are somewhat higher than the cheapest system. The estimate from ESRI is somewhat flexible with the best guess at about $230,000 for a combined hardware/software package to meet the specified needs.

Intergraph Corporation

The system marketed by Intergraph Corporation has all the technical capabilities required except the modeling capabilities. There would not be a problem in adding a model or other additions to the system later on as long as the work was done by Intergraph Corporation. Intergraph Corporation uses a PDP 11/70 but makes modifications to both the hardware and operating system. This means that all maintenance must be done by Intergraph Corporation and that all system additions must go through them. Also, to understand the system it is necessary for a systems analyst to know the PDP 11/70 assembly language. The Intergraph System was originally designed for engineering drawing. Because of this, its applications for geographic or cartographic data do not function as well as engineering applications.

Organizationally, Intergraph Corporation is a large firm; however their geographic applications staff is relatively new and somewhat small. Intergraph Corporation does not like to give the source code to the users, but will distribute it for an extra charge.

The client comments indicate that support is generally good; however there have been some problems with the polygon overlay routine.

The costs of the system, combined hardware/software package, start at $296,000. They have a new implementation on a micro-computer that sells for $145,000 but this is not recommended as future expansions would be limited.

Synercom Technology, Incorporated

The INFORMAP system produced by Synercom provides the required technical capabilities for the RDJTF project with the exception of modeling capabilities. INFORMAP operates on either a PDP 11/44 or PDP 11/70. The system has been specifically designed to serve the needs of utility companies and municipalities in information management and mapping. With this orientation, it is difficult to assess its performance in a project environment such as that planned for RDJTF.

Organizationally, Synercom appears to serve more of an engineering clientele than those concerned with cartographic applications. Additionally, the source code for the INFORMAP system has a substantial release price associated with it.

Clients are generally satisfied with the performance of the hardware and software of the Synercom system. The clients interviewed were particularly pleased with the service provided by Synercom.

The costs of the total hardware/software system quoted by Synercom is approximately $273,000. At this level, the Synercom system is offered at a higher price than most.

Ranking of the Systems Investigated

The geographic information systems reviewed in this study are ranked below in the order of those best able to meet the requirements of the RDJTF. This is primarily based on the technical capability of the system and the support service provided by each organization. The rankings are as follows:

1. Environmental Systems Research Institute
2. Autometric Incorporated

3. COMARC Design Systems

4. Intergraph Corporation

5. Synercom Technology, Incorporated

6. Earth Satellite Corporation

Earth Satellite Corporation is ranked in the last place because their system cannot currently meet the technical capabilities required and, more importantly, the organization has no experience in selling, transferring, or maintaining a system at another location. Earth Satellite Corporation has not sold their LANDPAK system to anyone yet and thus has no experience in the transfer and maintenance of the system at another installation. Their organizational base for support appears to be weak and it is questionable whether or not they will continue to market and support the system in the future. For the above reasons it is recommended that this system not be acquired.

The next two systems on the list are Synercom Technology Incorporated and Intergraph Corporation. Both of these systems appear to have the technical capabilities required; however, this is known only to the extent that the representatives of each organization verbally indicate the systems have these capabilities. It must be emphasized that no benchmark tests have been conducted during this study and therefore it cannot be known for certain if these systems have the needed capabilities. Of greater significance in the evaluation of these two systems is the fact that both systems were designed for different applications than that needed for the RDJTF. Intergraph Corporation's system is basically an engineering drawing system designed for low data volumes and straight line segments. Tests to date, conducted by others, indicate that this system does not perform efficiently with moderate to large data volumes of cartographic data. The system marketed by Synercom Technology, Incorporated is designed for urban engineering applications, such as assessment mapping, utility company mapping, etc. The cost of both of these systems is considerably higher than the other systems evaluated. In their favor, however, each organization is a large well established firm having considerable experience in the sale, installation and maintenance of systems at other locations. One factor regarding Intergraph Corporation is the fact that they have solved the problem of establishing efficient remote terminalsto their systemwhereas the other organizations investigated have either not attempted or have failed to successfully implement remote operations. Finally, Intergraph Corporation has modified the hardware and operating system they use and thus any user of this system is totally dependent on Intergraph Corporation for maintenance, support and modifications. In the final analysis, both of these systems are possible but are ranked lower than other systems because of their basic design and cost.

The COMPIS system of COMARC Design Systems is next on the list. This system does not have all the technical capabilities needed but it is estimated that the modifications needed could be made fairly easily. As an organization COMARC has a poor record of support and service to its users. Many of the existing clients contacted are unhappy, with one user currently in the process of acquiring the Autometric Incorporated system to supplement or replace the COMARC system it acquired first. Also, COMARC is extremely reluctant to release the source code so that their users are completely dependent on the COMARC organization for service and support. In the final analysis, COMARC is a possible system but with reservations because of its poor service record.

The two remaining systems, ranked first and second, are Environmental Systems Research Institute (ESRI) and Autometric Incorporated. In terms of technical capability the ESRI system is being modified in response to the specifications prepared under this study and should be ready for testing by mid-April 1981. The Autometric Incorporated system appears to have all the needed technical capabilities, except for the modeling package (which no one has) but once again the system has not been tested. Both organizations have good reputations for service and support; however Autometric Incorporated has been selling their system for less than two years, and has fewer clients. Autometric Incorporated is the least expensive system found in this study. Both of these systems can be recommended for possible acquisitions by ETL for the RDJTF processing needs; however, ESRI is ranked first because of its excellent record of service and support and because they were willing to prepare an interactive graphics module designed specifically around the RDJTF specifications, while other organizations would do this only on a time and materials basis. Both of these systems could be tested within a matter of a few weeks.

Recommendations for System Acquisition

The recommendations are provided in two parts: 1) a recommendation which assumes use of existing equipment at ETL; and 2) a recommendation for the acquisition of a combined hardware/software package.

Using Existing ETL Equipment

The existing equipment of ETL which is suitable for the RDJTF needs is limited to two systems: 1) Autometric Incorporated; and 2) Intergraph Corporation. Each of these systems currently resides at ETL in a research mode and could potentially be used for the RDJTF assuming organization matters could be worked out. Presently, each system resides in a non-classified area which might have to be changed to process the classified water resource data. In reviewing the potential for transferring any other system to the existing hardware, it was concluded that this is not feasible within reasonable time and cost constraints. Thus, the options are to use either the Autometric Incorporated system or the Intergraph Corporation system. If one of the existing systems were to be utilized for the RDJTF, it is recommended that the Autometric Incorporated system be used. However, it should be pointed out that the existing Autometric installation is considerably larger than required and is also designed for research purposes. Discussions with Autometric Incorporated personnel revealed that they do not feel that this particular configuration is most efficient for a production operation and it would be difficult for the RDJTF processing to co-exist with research users.

A second option is to utilize one of the existing systems until a new system can be acquired. In this case, it might be better to use the Intergraph Corporation system because it has a better input subsystem and a data structure that is more compatible with other systems. This .sumes, of course, that the system to be acquired is other than the Autometric Incorporated system.

Acquiring a New System

The recommendation for acquiring a new system is to first consider the ESRI system. This organization has the most experience with this type of application, has the best performance record, and can presumedly meet the technical specifications. If it were decided to acquire this system, the Intergraph Corporation system could be used in the interim to start data input from the existing maps. Before this course of action is taken, the conversion from the Intergraph Corporation data structure to the ESRI data structure would have to be investigated.

Program for Acquiring a System for TAC

Whichever course of action is decided upon with respect to acquiring a system for the RDJTF, the following actions are recommended:

1. Verification of data volumes: the data volumes derived during this study (Table I) should be verified by examination of the complete set of water resource maps. This verification can be done by ETL personnel.
2. Benchmark test: the system or systems under consideration should be subjected to a benchmark test designed specifically around the RDJTF requirements. This is the only way to know for sure that a system can reasonably input, store, and process the data needed for RDJTF operations. Such a test should be designed by an independent consultant in cooperation with ETL personnel.
3. Data format compatibility: if one of the existing systems at ETL is to be used on an interim basis, the compability of the data formats between the existing system and the system to be acquired must be investigated. This would best be done by personnel from the organization from which it is proposed to acquire a system. Alternatively, this could be done by an independent consultant.
4. Software review: the system or systems under consideration should have their software structure reviewed in detail to determine if there are any potential problems in the struc-

ture of the software, the specific algorithms used to perform spatial manipulations, and the ease with which modifications can be made. This task should be done by an independent consultant.

5. Data Base design: this task is the detailed design of the data files needed to meet the RDJTF needs and should be done by the organization who will provide the system in association with ETL personnel.
6. Data input process design: the detailed steps of the data input process need to be specified. This includes possible modifications to the existing maps, preparation of special maps for input, and the design of the input process (digitizing), including editing. This should be done by the organization providing the system in association with ETL personnel.
7. Summary report format design: the summary reports called for in the specifications need to be designed. This can be done by the organization providing the system in association with ETL personnel.
8. Detailed design of interactive design capability: this task is to provide the detailed design of the interactive planning and design of the water distribution system. ETL personnel, in conjunction with the RDJTF Engineers, need to specify, in detail, the planning and design process and then convert that process into a set of interactive operations with the help of the organization providing the system.
9. Specification of the linear proramming model: the linear programmging model should be specified by an independent consultant with experience in this area.

Personnel Required to Operate the System at ETL

The minimum personnel requirements to operate the proposed system at ETL are: 1) a system supervisor familiar with current mapping procedures; 2) a systems analyst familiar with geographic information systems; and 3) a skilled operator for data input and system use. It is assumed that existing ETL personnel will be used to supervise the system. The person for system input and system use can probably be trained from existing ETL cartographic personnel or someone with comparable skills transferred to ETL. No previous computer experience would be required. The systems analyst position would be responsible for maintaining the system, interfacing with the organization providing the system, and coordinating additions to the system. This person should have prior experience with geographic information systems at the systems design and programming levels. Also, depending on the systems acquired, this person may be required to know machine language coding.

Data Input Time Estimates

Table V contains estimates of the time required to input the data into a data base. These estimates are general and may vary somewhat between systems. The estimates are based on the data volumes contained in Table I.

For digitizing, the following rates have been used:

1. For point data: 150 points/hour.
2. For line data: 2.5 line inches/minute for polygons and irregular lines
   5.0 line inches/minute for straight lines.

The estimated time for digitizing the initial 100 JOG sheet area is 21.5 weeks. The key entry of attribute data will vary with the system. A rough estimate for this is approximately 10 weeks.

The editing of the input data can run as long as the original input times, so that a conservative estimate for editing the digitized data would be 21.5 weeks, with about 5 weeks for the editing of the attribute data.

TABLE V

Data Input Estimates (Digitizing)

Data Type	Time/Map Sheet	Time/100 Map Sheets	Total Elapsed Time
I. Map base data			
A. Map boundaries	5 min		
B. UTM grid lines	10 min		
C. Shorelines	24 min		
D. Boundaries	10 min		
E. Populated places	140 min		
Total	189 min	~ 315 hours	~ 8 weeks
II. Water resource data			
A. Existing water systems	60 min		
B. Distribution systems	60 min		
C. Surface water	20 min		
D. Wells	40 min		
E. Ground water	80 min		
Total	260 min	~ 433 hours	~ 11 weeks
III. Transportation data			
A. Road network	45 min		
B. Railroads	10 min		
Total	55 min	~ 100 hours	~ 2.5 weeks
Total digitizing			~ 21.5 weeks

Appendix A

Individual System Descriptions

Autometric Incorporated
One Drake Park
Suite 130
333 West Drake Road
Ft. Collins, Colorado 30526
(303)226-3282

Dr. Carl N. Reed

I. Summary of Vendor's Product

AUTOGIS is the system marketed by the AUTOMETRIC corporation. The system was designed to aid groups in meeting information needs for a natural resource management and environmental impact assessment. AUTOGIS is an interactive system with one major subsystem for data entry and edit and a second major subsystem for data storage, manipulation, retrieval, and display. Installations housing AUTOGIS can be found in several locations within the U.S.

II. Description of System

A. Data Input

The Analytical Mapping System (AMS) is the AUTOGIS subsystem that handles data input and edit functions. Through the use of menus, the user digitizes point, line, and polygon data. Points are entered as nodes while line data are recorded as a "stream" of points. Polygon data are handled in AMS as nodes with adjoining line segments.

Input maps can be of any scale; AMS converts differing scales to a common scale, if necessary. Data from maps are recorded in latitude and longitude. Transformations can be made from this initial referencing system to UTM coordinates, State Plane coordinates, and several other projection systems.

Descriptor information can be readily entered and associated with each cartographic element (point, line, or polygon). A maximum of 200 descriptors can be assigned to a given cartographic element.

Editing operations are included in AMS for updating cartographic and descriptor data. Data verification procedures are performed to ensure integrity of data. Verification occurs before digitized data is entered into the data base.

B. Data Storage

The Map Overlay and Statistical System (MOSS) is the subsystem used for storage of digitized data. MOSS can store point, line, polygon, raster, elevation point, and elevation grid data. A map sheet is the basic storage unit within the MOSS data base framework. Up to 16,000 point, line, or polygon features can be stored for any one map; 2,000 maps may be stored in a data base.

C. Data Manipulation and Retrieval

The MOSS subsystem also handles manipulation and retrieval operations in AUTOGIS. Various manipulation capabilities exist including polygon overlay, polygon-to-grid conversion, area and distance calculations, and zone generation around features of interest.

Data retrieval is possible based on: (1) descriptor criteria, (2) size criteria, (3) proximity, and (4) geographic windowing. Though MOSS does not provide true Boolean searching (i.e., using AND, NOT, OR, etc.), searches combining data items are possible. Qualitative data value ranges serve as the bounds for these searches. Results of these and other retrieval operations can be stored in the user's data base for future use.

In addition to the functions cited above, MOSS performs other, more specialized, manipulation and retrieval activities. These include suitability analysis, road corridor selection, trend analysis, and proximity analysis. To aid these and other data analysis efforts, MOSS interfaces with the Statistical Package for the Social Sciences (SPSS).

D. Data Display

The interactive nature of AUTOGIS and the MOSS subsystem allows the user to display information on the graphic CRT as well as in hard copy format. Plotting, mapping, and report generation can be displayed in either form.

Plotting and mapping options available in MOSS include color mapping, contour mapping, various shading and symbologies, and three-dimensional plotting. Report generation using the MOSS software allows the display of summary statistics for descriptor data within geographic areas of interest.

III. Description of Hardware

AUTOGIS software operates on the Eclipse line of Data General minicomputers with 64K bytes of central memory. The host computer language for AUTOGIS is FORTRAN as provided by Data General.

IV. Evaluation of System Based on Project Specifications

A. Technical Evaluation

1. Prepare water resource maps for contingency or long range planning.

   a. Prepare water resource maps

1)	Select area of interest	yes
2)	Display on CRT or plotter	yes

   b. Prepare water potential maps

1)	Select area of interest	yes
2)	Convert to grid cell format	yes
3)	Calculate composite measure	yes
4)	Display on CRT or plotter	yes

2. To locate and analyze water availability

   a. Locate water in a defined area

1)	Select window from data base	yes
2)	Display selected map base data on a CRT	yes
3)	Accept graphic input of CRT	yes
4)	Generate a circle around input point	yes
5)	Display circle or polygon on CRT	yes
6)	Search data base	
	a) Point-in-polygon	yes
	b) Line-in-polygon	yes
	c) Polygon overlay	yes
	d) Boolean search	yes
7)	Display search results on CRT, with labels	yes
8)	Produce tabular display of attribute data for selected items	yes (up to 6 attributes)

   b. Locate specified quantity of water

1)	Select window from data base	yes
2)	Display selected map base data on CRT	yes
3)	Accept graphic input at CRT	yes
4)	Search data base to find closest set of items that meet demand specifications	yes
5)	Display search results on CRT, with labels	yes

6) Produce tabular display for selected data items, including summations — yes

3. Plan and design the treatment, storage and distribution of water

   a. Interactive display capability

      1) For specified search area, display selected water resource data on CRT — yes
      2) Add to CRT selected portions of road network — yes
      3) Add labels to items displayed in 1 and 2 above — yes
      4) Input linkage between source and demand and add to display — yes (airline distance node to node)
      5) Transfer resulting display to plotter — yes (Tektronics hard copy unit only)

   b. Linear programming model (network calculations, e.g., minimum path) — no (could be interfaced)

4. Utility functions

   a. Build data base

      1. Input points with descriptor data — yes
      2. Input lines with descriptor data — yes
      3. Input polygons with descriptor data — yes

   b. Update data base

      1. Update points, lines, polygons — yes
      2. Update descriptor data — yes

C. Organizational Evaluation

AUTOMETRIC offers a truly interactive system to the user. This adds to its flexibility as a user-oriented system. The company is willing to release the source code to its clients. One advantage for AUTOMETRIC in the current evaluation is that their system has been installed already at ETL, in a research mode.

D. Cost and Time Estimates

1. Hardware Costs

   a. ECLIPSE S/140
   b. disk (192 megabyte) = $80,000
   c. tape drive (800-1600 bpi)
   d. digitizer (Summagraphics) = 20,000
   e. printer = 12,500
   f. plotter (Calcomp 1051) = 24,000
   g. graphics CRT (Tektronix with hard copy unit) = 18,000

2. Software Costs

   a. $20,000 for basic software and an additional $10,000 for modifications

3. Maintenance Costs

   a. Hardware - negotiable with Data General
   b. Software - a subscription service is provided for $3,500 per year; this includes system updates and consultation if problems arise.

4. Delivery Time Estimates

   a. 4 weeks with Data General hardware in-house; otherwise 3-4 months

5. Installation and Training Time Estimates

   a. Installation--between 5 weeks and 1 year is the range given (dependent upon hardware configuration of individual user).
   b. Training--3 weeks following installation.

E. Client Experience

1. Eric Strand
   U.S. Fish and Wildlife Service
   Ft. Collins, Colorado
   (303) 226-9100

   a. Hardware - generally satisfied
   b. Software - some problems; data volume exceeds data structure limitations; weakest area is interactive display capability; good manipulation of polygons.
   c. Support - client does his own support work

2. Todd Stille
   Bureau of Land Management
   Portland, Oregon
   (503) 231-6948

   a. Hardware - no major problems; interface dificulty with Analytical Mapping System (AMS).
   b. Software - some problems; Zeta software has labelling problems; problems with polygon overlay in MOSS.
   c. Support - good training and service by AUTOMETRIC; system is easy to learn.

3. Nick Faust
   Georgia Institute of Technology
   Atlanta, Georgia
   (404) 894-3357

   a. Hardware - Eclipse S/250 was not working when received.
   b. Software - user friendly and well-structured.
   c. Support - no contact with AUTOMETRICS.

4. Robert Ader
   National Coastal Ecosystem Team
   U.S. Fish and Wildlife Service
   Slidell, Louisiana
   (504) 255-6511

   a. Hardware - difficulty with delivery
   b. Software - currently setting up system; not used yet.
   c. Support - currently good.

COMARC Design Systems
315 Bay Street
San Francisco, California
(415) 392-5300

Mr. James Bailey

I. Summary of Vendor's Product

COMARC offers its COMPIS system which runs on Data General minicomputers. COMPIS is in a modular format to allow expansion and enhancement as needed. Interaction with COMPIS occurs either at a terminal or from a digitizing station through the use of menus for achieving data handling tasks including graphic display.

COMPIS has been used extensively by COMARC to address planning and natural resource management issues in the past decade. In addition, the whole system has been installed in several locations.

II. Description of System

A. Data Input

A data base implementation driver controls data input activities of COMPIS. Data collected at different scales can be digitized and converted to a common scale; this eliminates the need for reformatting original source maps. Coordinate conversions between State Plane, latitude-longitude, and UTM are possible since COMPIS requires no common projection system. In the data input process spatial information of the point or line varieties can be treated as "arcs". Area features can be recorded either as whole polygons or as a series of arcs. The whole polygon method entails that common boundaries between polygons are digitized--once for each polygon. Complex polygonal structure such as land use types are recorded by the arc method. COMPIS assembles the digitized arcs into polygons with associated centroids. Labels are assigned to the centroid to identify the polygon.

Descriptor information associated with each cartographic element (point, line, or polygon) is assigned during the digitizing process. A maximum of 32 descriptors can be used to identify each cartographic element in the data base.

Menus associated with the ARC, POLYGON, LINES AND POINTS and TOPOGRAPHY drivers are used for editing digitized map products. These menus give users such options as interactively thinning lines, creating polygons, and correcting errors in digitized files.

B. Data Storage

Information is stored in the data base as one of several different files: (1) ARC, (2) POLYGON, (3) LINES AND POINTS, (4) TOPOGRAPHY, or (5) GRID. Data are not limited to one projection system for storage. The coordinate conversion driver maintained by COMPIS readily performs transformations between State Plane, UTM and latitude-longitude reference systems.

C. Data Manipulation and Retrieval

Manipulation and retrieval of data using COMPIS works on a file basis. Files are manipulated according to the types identified in II.B. The system is capable of performing: (1) POLYGON OVERLAY, (2) POLYGON-TO-GRID CONVERSIONS, (3) GRID-TO-POLYGON CONVERSIONS, (4) PROXIMITY ZONE GENERATION among other manipulations. For instance, the polygon driver through its menu of functions allows the user to overlay two polygon files to determine unique intersections between the two sets of polygons.

Polygon-to-grid conversions are completed using the polygon driver. A polygon file is accepted and transformed to grid cell format (of any cell size). Grid-to-polygon conversions use the grid driver to create a polygon file from a file digitized to grid format.

Additionally, the polygon driver can be used to generate lines of a specified distance around the polygon of interest; likewise, lines and points driver can perform similar proximity zones around lines or points specified by the user.

Manipulations associated with files of topographic data are accomplished using the topography driver. An example of its functions is the calculation of slope and aspect for locations in a topography file.

The COMARC system operating with COMPIS provides for interactive sessions at graphic CRTs for manipulation and retrieval of spatial information. Menus appear on the screen such that the user may select amoung several manipulation options, depending on the type of file being accessed.

D. Data Display

Within the menu of the representative drivers (ARC, POLYGON, LINES-POINTS, TOPOGRAPHY, GRID) options exist for producing output in the form of interactive plots and reports as well as hard copy plots and reports. Display of files can be either done at some point to edit files or to achieve a final screen or hard copy of desired files.

Tektronix (storage CRT) plot programs and Zeta (hard copy) plot modules are resident in each of the major drivers in COMPIS. Plotting with labels is possible for both the graphic CRT and hard copy plots.

Report writing options are capable of providing summary statistics for several files at one time. For example, cell values for up to 17 grid files can be summarized using an option in the grid driver. Likewise, acreage and linear distance figures can be obtained for polygons and lines, respectively.

III. Description of System Hardware

The COMARC system is tied exclusively to Data General hardware. The Eclipse line of minicomputers is specifically used to operate the COMPIS software which is written entirely in FORTRAN.

IV. Evaluation of System Based on Project Specifications

A. Technical Evaluation

1. Prepare water resource maps for contingency or long range planning

a. Prepare water resource maps

1)	Select area of interest	yes
2)	Display on CRT or plotter	yes

b. Prepare water potential maps

1)	Select area of interest	yes
2)	Convert to grid cell format	polygon-grid only
3)	Calculate composite measure	no
4)	Display on CRT or plotter	yes

2. To locate and analyze water availability

a. Locate water in a defined area

1)	Select window from data base	yes
2)	Display selected map base data on a CRT	yes
3)	Accept graphic input at CRT	no
4)	Generate a circle around input point	no
5)	Display circle of polygon on CRT	yes
6)	Search data base	
	a) Point-in-polygon	yes
	b) Line-in-polygon	yes
	c) Polygon overlay	yes
	d) Boolean search	yes
7)	Display search results on	

CRT with labels yes

8) Produce tabular summary of attribute data for selected items yes

b. Locate specified quantity of water

1) Select window from data base yes
2) Display selected map base data on CRT yes
3) Accept graphic input at CRT no
4) Search data base to find closest set of items that meet demand specifications no
5) Display search results on CRT, with labels yes
6) Produce tabular display for selected data items, including summations yes

3. Plan and design the treatment, storage and distribution of water

a. Interactive display capability

1) For specified search area, display selected water resource data on CRT yes
2) Add to CRT selected portions of road network yes
3) Add labels to items displayed in 1 and 2 above yes
4) Input linkage between source and demand and add to display no
5) Transfer resulting display to plotter yes

b. Linear programming model (network calculations, e.g., minimum path) no

4. Utility functons

a. Build data base

1) Input points with descriptor data yes
2) Input lines with descriptor data yes
3) Input polygons with descriptor data yes

b. Update data base

1) Update points, lines, polygons yes
2) Update descriptor data yes

B. Organizational Evaluation

COMARC packages a hardware/software system; one part cannot be purchased without the other. In that regard, the buyer is making a substantial commitment. Personnel at COMARC seem to be adamantly against releasing their source code unless the client is willing to pay a large price.

C. Cost and Time Estimations

1. Hardware costs

a.	Eclipse S/140 ($\geq$ 1 megabyte)	= $30,000
b.	disk (277 megabyte)	= 38,000
c.	tape drive	= 16,000
d.	digitizer (Talos 36 x 48)	= 10,000
e.	printer (300 lines/min.)	= 15,000
f.	plotter (Zeta 3653)	= 20,000
g.	CRT (alpha-numeric)	= 2,000
h.	graphic CRTs (Tektronix 19")	= 15,000

2. Software costs

a. Software is not sold separately; total cost for hardware/software is $200,000 at least (based on Eclipse S/140).

3. Maintenance costs

a. Hardware - negotiable with Data General, Tektronix, Zeta, and other vendors
b. Software - $3,600 per year for software subscription service; available for consultation and distribution of new revisions

4. Delivery time estimates (90 days)

5. Installation and training time estimates

a. 4 weeks of training provided by COMARC

D. Client Experience

1. Karen Siderelis
   Land Resources Information Service
   Department of Administration
   116 W. Jones St., Room B-44
   Raleigh, NC 27611
   (919) 733-2090

   a. Hardware - some problems; disk failed twice; cursor and wire problems with Talos digitizer; service by Data General, Talos, and Zeta is good.
   b. Software - isn't 100% reliable; problems with polygon overlay and grid-polygon conversion; some topography functions are not actually programmed
   c. Support - fair to poor service from COMARC; revisions are sent once every several months

2. Sondra Manning
   International Paper Company

   a. Hardware - good performance with few problems since installation 2-1/2 years ago.
   b. Software - problems initially; data base management is poor, editing functions are weak; problems with functions; good analysis capability, lots of changes in software during past 2 years
   c. Support - service on hardware is very good; service on software from COMARC is generally good

3. Ralph Bunn
   Bureau of Land Management
   Sacramento, California 95825
   (916) 484-4008

   a. Hardware - system does not work on Eclipse C/330
   b. Software - digitizing is a problem in the new version; various other features do not work well
   c. Support - organizational problems in COMARC; sales people change frequently; they blame users for problems that arise; no follow-up help after initial training program

4. Joanne Williams
   Planning Department
   Gunnison County
   Gunnison, Colorado 81230
   (303) 641-4100

a. Hardware - wiring problems with Zeta; otherwise system is working satisfactorily
b. Software - initial problems because system is not user friendly; manuals are useless; training is poor
c. Support - fairly good; problems with management not backing systems people

5. Douglas Mutter
Alaska Department of Natural Resources
323 East Fourth Ave.
Anchorage, Alaska 99501
(907) 279-5577

   a. Hardware - no problems
   b. Software - programming modifications are being done in-house; response on problems has been slow from COMARC
   c. Support - training is good; workshops good, support for software is limited--not enough personnel

Earth Satellite Corporation (EARTHSAT)
2150 Shattuck Ave.
Berkeley, California
(415 845-5146

Dr. Philip Langley

I. Summary of Vendor's Product

LANDPAK is the geographic information system marketed by EARTHSAT. It operates on a PRIME minicomputer and handles cartographic data in the form of points, lines, or polygons, along with descriptor information pertaining to each piece of cartographic data. Data is accessible from the data base through an easy to use query language. Maps resulting from these queries can be produced with a wide variety of color and shading options.

LANDPAK was primarily designed to help meet information needs in natural resource management, particularly forestry.

II. Description of System

A. Data Input

Only lines are digitized in the LANDPAK system. Polygons are formed through construction of line segments or arcs.

The <u>line extraction</u> subsystem requires that lines be digitized only once, as arcs. Redundant points are eliminated and projection transformations can be performed to obtain map registration in the UTM coordinate system. A <u>polygon extraction</u> subsystem creates polygons from digitized arcs. Polygons are assembled from intersecting lines, loose ends are eliminated, and the polygons are automatically numbered. Entire polygons are stored rather than chains or line segments. "Slivers" are not a problem because adjacent boundaries are assembled from the same arcs.

<u>Descriptive record compilation</u> is the third subsystem used for data input. LANDPAK refers to each point, line, or polygon as a resource unit (RU). Descriptor records can be associated with each RU. Each record may contain information in the form of character strings, dates, real numbers, integers, or entire matrices. A maximum of 1500 descriptor records can be associated with a single resouce unit.

The <u>update</u> and <u>operational insertion</u> subsystems are used for editing information contained in the data base. To update a map, lines defining new RU's are all that need to be digitized. The system inserts new data into the existing file map, removes obsolete lines, and updates the map to its new form. If old units are split into two or more new units as a result of updating, associated descriptor records are reassigned to their respective RU's automatically.

B. Data Storage

Two storage areas are used in operating LANDPAK--the data base and the work file. Results of user queries are contained in work files. These files remain in storage until they are deliberately deleted.

LANDPAK used a B-tree data structure. There are three types of information units making up the data structure used with LANDPAK.

1. Control Units - areas of land called up by number or name, e.g., a map sheet

2. Layers - examples include vegetation, soils or topography layers; layers can be of a "primary" nature which are those stored in the data base and "secondary" layers which are specific combinations of primary layers (such as those that result from queries); there is a limit of 32 layers per control unit.

3. Resource Units - these units can be a single point, line, or polygon and are present within layers; resource units have cartographic and descriptor records associated with them (maximum of 1500 descriptors per resource unit); cartographic data are stored on a UTM coordinate basis.

C. Data Manipulation and Retrieval

LANDPAK is operated by a "transaction" method. A transaction corresponds to a work session using the LANDPAK system. Each transaction initiated is identified by a name and date performed; these are input by the user at the CRT. Transactions remain in the system indefinitely to allow for update, review, and reference by the user.

Once a transaction is initiated or called up (if it is already in the system), the user formulates a query statement to extract the information necessary for solving a problem. Query statements use Boolean operators (AND, OR and NOT) to combine multiple layers of data from the data base. Data items appear on both sides of the operator to indicate the particular information desired. For example, the following statement attempts to combine all areas of "SOIL TYPE A" and "TIMBER DENSITY B" into a data base query:

SOIL TYPE A AND TIMBER DENSITY B

One query statement may use more than one layer of data. "Secondary" layers (layers derived from transactions) can also be manipulated in query statements.

The zone generator is a manipulation subsystem that creates features such as streams or roads and around RU's of the polygon variety.

Polygon overlay is achieved using the overlay processor. The query statement selects desired characteristics between layers. Boundaries are dissolved to yield new units if desired.

D. Data Display

Plotting, mapping, and report writing subsystems can be executed at any time during the LANDPAK transaction. This permits the user to inspect cartographic and descriptor data in its current state within the workfile.

The plotting subsystem allows the user to display a maximum of 10 data items within plotted polygons. Data item values are arranged into labels which are automatically positioned inside the plotted polygon. If the label does not fit inside the polygon, the RU number is plotted instead and the label appears in the legend with the key associating it with the RU.

Mapping is completed through an interactive subsystem where the user can compose multi-color maps at the alpha-numeric CRT. Additionally, a variety of cross-hatching and labelling options allow for creative map design. Once the mapping options are selected, the resulting map can be produced on the plotter.

Report writing involves a subsystem for generating tabular reports to show results of a query. Multiple layers of data can be integrated to obtain totals of various kinds for particular spatial areas of interest. Reports are keyed to output maps generated by a transaction.

III. Description of System Hardware

LANDPAK currently requires a 32-bit system for operation. Specifically, either the PRIME 450 or 550 minicomputer is capable of supporting the LANDPAK system. The PRIME 450 contains 256K bytes of memory and runs under the PRIMOS operating system. LANDPAK itself requires 600K bytes of memory for operation.

IV. Evaluation of System Based on Project Specifications

A. Technical Evaluation

1. Prepare water resource maps for contingency or long range planning

   a. Prepare water resource maps

1)	Select area of interest	yes
2)	Display on CRT or plotter	no

   b. Prepare water potential maps

1)	Select area of interest	yes
2)	Convert to grid cell format	no
3)	Calculate composite measure	no
4)	Display on CRT or plotter	no

2. To locate and analyze water availability

   a. Locate water in a defined area

1)	Select window from data base	yes
2)	Display selected map base data on CRT	no
3)	Accept graphic input at CRT	no
4)	Generate a circle around input point	no
5)	Display circle of polygon on CRT	no
6)	Search data base	
	a) Point-in-polygon	no
	b) Line-in-polygon	no
	c) Polygon-overlay	yes
	d) Boolean search	yes
7)	Display search results on CRT with labels	no
8)	Produce tabular display of attribute data for selected items	no

   b. Locate a specified quantity of water

1)	Select window from data base	yes
2)	Display selected map base data on a CRT	no
3)	Accept graphic input at CRT	no
4)	Search data base to find closest set of items that meet demand specifications	no
5)	Display search results on CRT with labels	no

6) Produce tabular display for selected data items, including summations — no

3. Plan and design the treatment, storage and distribution of water

   a. Interactive display capability

      1) For specified search area, display selected water resource data on CRT — no
      2) Add to CRT display selected portions of road network — no
      3) Add labels of items displayed in 1 and 2 above — no
      4) Input linkage between source and demand and add to display — no
      5) Transfer resulting display to plotter — no

   b. Linear programming model (network calculations, e.g., minimum path) — no

4. Utility functions

   a. Build data base

      1) Input points, with descriptor data — yes
      2) Input lines, with descriptor data — yes
      3) Input polygons, with descriptor data — yes

   b. Update data base

      1) Update points, lines, polygons — yes
      2) Update descriptor data — yes

B. Organizational Evaluation

There is a possibility of reaching an agreement with the Washington office to tie into the system for temporary use with an option to purchase the system at a later date. Presently though, LANDPAK is not in the Washington office.

C. Time and Cost Estimations

1. Hardware costs

a.	PRIME 450 (750 bytes)	= $90,000
b.	disk (300 megabyte)	= 23,000
c.	tape drive	= 18,000
d.	digitizer	= 10,000
e.	printer	= 13,000
f.	plotter (Zeta 3653)	= 20,000
g.	CRTs (alpha-numeric)	= 1,500
h.	graphic CRTs (Tektronix)	= 15,000

2. Software costs

   a. LANDPAK is $50,000 (or $60,000 with high speed polygon extractor)

3. Maintenance costs

   a. Hardware - negotiable with PRIME
   b. Software - $5,000-10,000 per year or 10-20% of purchase price

4. Delivery time estimates

   a. 45-60 days (based on PRIME delivery times)

5. Installation and Training Time Estimates

   a. Generally, <u>days</u> rather than <u>weeks</u> of training appear to be the norm

Environmental Systems Research Institute
380 New York Street
Redlands, California
(714) 793-2853

Mr. Jack Dangermond

I. Summary of Vendor's Product

The ESRI system is designed to meet information needs of groups concerned with planning and environmental impact assessment. It operates on a PRIME minicomputer, though ESRI documentation suggests that it is applicable to other computers as well. ESRI has developed the system for more than a decade into its present modular format. Numerous installations of ESRI software exist in the U.S. and in foreign countries.

II. Description of System

A. Data Input

The Interactive Digitizing Subsystem (IDS) handles the input and edit functions for point, line, and polygon data. IDS software operates with a coordinate digitizer which can be interfaced with a graphic CRT for interactive editing.

For polygon input, the polygon/intersection chain (PIC) technique or the double digitizing method are the options. Using the former, common boundaries between polygons are digitized only once whereas with the latter, the boundary between two polygons is digitized twice, once for each polygon. Point and line features are digitized as points and lines using the IDS software subsystem.

Descriptor information for points, lines, or polygons can be added to their respective cartographic elements during digitization or at a later time. As many as 40 descriptors can be assigned to a given cartographic element.

Editing of digitized points, lines, and polygons is provided by the IDS software. Options within this subsystem include: (1) removal of erroneous chains, (2) moving an X,Y coordinate location to a new location, (3) adding or deleting X,Y coordinate locations, and (4) enlarging a specified window of digitized data for a graphic CRT display (a hardware function). These edit functions aid in the creation of an error free cartographic data base.

B. Data Storage

Two storage modes constitute general data storage in the ESRI system--the master data base file and the temporary data base file. The latter subset of the data base results from a query of the entire data base. Query results can also be inserted into the data base as a permanent addition (e.g., polygon overlay results).

C. Data Manipulations and Retrieval

Manipulation and retrieval of data stored in the data base is performed through the following subsystems: (1) polygon information overlay system (PIOS), (2) GRID system, and (3) topographic analysis system (TOPO).

PIOS performs several manipulation functions on data that are referenced by X,Y coordinates. Conversions between UTM, State Plane, and latitude-longitude are accomplished by PIOS. Additionally, PIOS includes modules for polygon overlay and polygon modeling. Overlay of polygon files uses point-in-polygon and line intersection techniques to construct the interaction polygons. Through the polygon model program, an examination of polygons in a given study area can be completed. PIOS software also includes a route evaluation module. This manipulation function allows the user to select a route (e.g., for a transmission line) and perform an overlay of this route upon multiple data sets. Specific variables may be weighted relative to the expected impact of route intrusion upon them. Finally, the PIOS subsystem maintains a module for transferring data from polygon-to-grid format. Point-to-grid and line-to-grid conversions are possible within this subsystem.

The GRID subsystem provides manipulation capabilities for merging single variable grid files into a multi-variable file for further analysis. Additionally, the GRID subsystem enables the user to conduct weighted and unweighted searches, location of corridors that are most suitable for actions such as mining activities, area calculations for particular variables, and grid modeling similar to the polygon modeling previously discussed.

Several manipulation activities are performed by the TOPO subsystem. Slope calculations, cut/fill calculations, sun intensity calculations, watershed calculations, and viewshed analysis are a few examples of TOPO's capabilities. Conversion from contours to grid format is also accomplished using a module in TOPO.

Finally, ESRI offers the Command Interactive Graphics Package (CIGP) for direct, interactive use of the total system. CIGP is a menu-type of package that allows the user to communicate with PIOS, GRID, and TOPO modules in creation/editing of Boolean models and program execution, among other capabilities.

D. Data Display

Several options exist within PIOS, GRIS and TOPO subsystems for display of spatial data. PIOS includes modules for polygon plots of study areas. The AUTOMAP routines in PIOS produce "line printer" maps of choropleth and contour/proximal varieties. Statistical reports are also available through the PIOS subsystem. Area calculations and polygon summaries for single or multiple polygon layers can be completed with routines in this subsystem.

In the GRID subsystem, display capabilities include plotting of grid files with a pen plotter. Grey tone shading represent the data on the output map. Another graphic output routine uses an electrostatic printer for hardcopy. Color graphic output is provided via a digital image recorder.

Using routines in TOPO, the user can produce a variety of topography maps and plots. Two-dimensional contour plots are possible for display of continuous surface information. Further plotting routines are associated with the manipulation functions of TOPO defined earlier (i.e., cut/fill analysis, aspect analysis, slope analysis, etc.).

III. Description of System Hardware

The ESRI software operates primarily on a PRIME minicomputer system with 64K of central memory. ESRI documentation suggests that the software is operative on a variety of computers (e.g., IBM, HP3000, UNIVAC, CDC, and BURROUGHS). FORTRAN IV is the host programming language for ESRI software.

IV. Evaluation of System Based on Project Specifications

A. Technical Evaluation

1. Prepare water resource maps for contingency or long range planning

a. Prepare water resource maps

1) Select area of interest	yes
2) Display on CRT or plotter	yes

b. Prepare water potential maps

1) Select area of interest	yes
2) Convert to grid cell format	yes
3) Calculate composite measure	yes
4) Display on CRT or plotter	yes

2. To locate and analyze water availability

a. Locate water in a defined area

1)	Select window from data base	yes
2)	Display selected map base data on a CRT	yes
3)	Accept graphic input at CRT	no
4)	Generate a circle around input point	no
5)	Display circle or polygon on CRT	yes
6)	Search data base	
	a) Point-in-polygon	yes
	b) Line-in-polygon	yes
	c) Polygon-overlay	yes
	d) Boolean search	yes
7)	Display search results on CRT with labels	yes
8)	Produce tabular display of attribute data for selected items	yes

b. Locate specified quantity of water

1)	Select window from data base	yes
2)	Display selected map base data on CRT	yes
3)	Accept graphic input at CRT	no
4)	Search data base to find closest set of items that meet demand specifications	no
5)	Display research results on CRT with labels	yes
6)	Produce tabular display for selected data items, including summations	yes

3. Plan and design the treatment, storage and distribution of water

a. Interactive display capability

1)	For specified search area, display selected water resource data on CRT	yes
2)	Add to CRT selected portions of road network	no
3)	Add labels to items displayed in 1 and 2 above	yes
4)	Input linkage between source and demand and add to display	no
5)	Transfer resulting display to plotter	yes

b. Linear programming model (network calculations, e.g., minimum path) no

4. Utility functions

a. Build data base

1) Input points w/ descriptor data	yes
2) Input lines w/ descriptor data	yes
3) Input polygons w/ descriptor data	yes

b. Update data base

1) Update points, lines, polygons	yes
2) Update descriptor data	yes

B. Organizational Evaluation

ESRI has a substantial amount of modeling software connected with its system. From the documentation, the CIGP driver appears to give a user-friendly entry to and exit from the system through the menu structure.

C. Time and Cost Estimations

1. Hardware costs

a. PRIME 550 (.5 megabyte memory)	= $85,000
b. disk	= 42,000
c. tape drive	= 19,500
d. digitizer (Talos 30"x40")	= 10,000
e. printer	= 14,500
f. plotter (Houston)	= 13,000
g. CRT	= 1,500
h. graphic CRT	= 14,000
i. Princeton hardcopy unit	= 8,000

2. Software costs

a. $60,000-75,000
b. new developments for this project total $5,000

3. Maintenance costs

a. Hardware - $25,000-35,000
b. Software - $3,000-5,000

4. Delivery Time Estimates

a. 60 days

5. Installation and Training Time Estimates

   a. 5 weeks in addition to above time

D. Client Experience

1. Dennis Smith
   Woodward-Clyde Consultants
   Three Embarcadero Center
   Suite 700
   San Francisco, CA 94111
   (415) 956-7070

   a. Hardware - generally happy; Princeton terminal needs more software for interactive editing
   b. Software - more problems than expected; polygon overlay is not working; labeling problems with polygon plotting
   c. Support - support for software is poor; some routines are not well documented for modifications and additions

2. Bob Puterski
   Division of Planning
   Colorado Department of Local Affairs
   Room 520, Centennial Bldg.
   1313 Sherman St.
   Denver, CO 80203
   (303) 866-3170

   a. Hardware - satisfied with hardware; Princeton display is better than Tektronix but has poor documentation
   b. Software - problems in interactive editing; software descriptions are too brief for the layman
   c. Support - training was good; ESRI people "really care"; good availability of ESRI staff; Dangermond keeps in touch with progress of client

3. Pete Croswell
   Lands Unsuitable Project
   DNREP
   Capital Plaza Tower, Room 407
   14th Floor
   Frankfort, KY 40601

   a. Hardware - satisfied
   b. Software - no major problems; learning to use some of the software; handles point, line and polygon information well
   c. Support - satisfactory

4. Les Maki
   State Planning Agency
   Metro Square Bldg.
   7th and Roberts
   Room LL45
   St. Paul, MN 55101
   (612) 296-1202

   a. Hardware - pleased with hardware; no equipment problems
   b. Software - adequate; could be more user oriented; major use is data capture technique
   c. Support - excellent; good response to software problems

5. Bill West
   Southern California Edison Company
   Planning Department
   2244 Walnut Grove Ave.
   Box 800, Rm. 493
   Rosemead, CA 91770

   a. Hardware - Not Applicable
   b. Software - generally satisfied; some redesign of system; not a total turn-key operation
   c. Support - very cooperative attitude by ESRI

6. Mike Burnham
   U.S. Army Corps of Engineers
   Hydrologic Engineering Center
   609 2nd Street
   Davis, CA 95616
   (916) 440-3285

   a. Hardware - Not Applicable
   b. Software - very satisfied; used in 30 studies
   c. Support - satisfied with ESRI's assistance

7. Dave Cowen
   Geography Department
   University of Southern Carolina
   Columbia, SC 29204
   (803) 777-6803

   a. Hardware - Not Applicable
   b. Software - generally satisfied
   c. Support - usually solve problems themselves rather than contact ESRI

Intergraph Corporation
One Madison Industrial Park
Huntsville, Alabama 35807
(703) 790-9750

Mr. Joe Pilonero

I. Summary of Vendor's Product

Intergraph (formerly M&S Computing) produces a system composed of two subsystems for handling geographic information. The Interactive Graphics Design Software (IGDS) subsystem provides functions for creation and manipulation of cartographic elements. Another subsystem, the Data Management and Retrieval System (DMRS) is responsible for handling descriptor elements.

The system marketed by Intergraph was designed as a multipurpose system to serve a wide variety of applications. Some of these applications are architectural design, civil engineering, drafting, topographic mapping, and many other types of engineering activities. The system has been under development and improvement since 1969. It operates on Digital Equipment Corporation's PDP-11 computer.

II. Description of System

A. Data Input

The IGDS subsystem handles input of cartographic elements into the data base. Point, line, and polygon features are entered by the user through a menu structure. Lines and polygon data are digitized at between 10 and 40 points per inch.

Descriptor data management is provided through the DMRS subsystem. Linkages are maintained with the IGDS subsystem to associate each cartographic element with its corresponding descriptor values. System defined verbs (such as INSERT) are used for descriptor data input via the DMRS subsystem.

For input and editing of cartographic data, four types of menu structures are available: (1) command menus, (2) application menus, (3) cursor menus, and (4) function-key menus. These options add to the flexibility of the IGDS subsystem for entering and updating cartographic data.

Editing of descriptor data is performed with several system-defined verbs. Commands to FIND, INSERT, CHANGE, and DELETE allow update of descriptor data.

B. Data Storage

Cartographic and descriptor data elements are stored separately. Linkages exist between cartographic elements and their respective descriptor values. There is no "temporary data base" structure in the system marketed by Intergraph. When the user accesses information, he or she is interacting directly with the data base.

C. Data Manipulation and Retrieval

Queries of the data base are performed using the various types of user menus described earlier. Intergraph has a unique dual display graphics workstation. An advantage of this structure lies in its file manipulation capabilities. Users can specify three "reference files" in addition to the current working file. Reference files may be adjoining coverages or they may share characteristics with the currently used file, for example. Desired data can be modified for the current file but not for the reference files.

Several manipulation and retrieval activities can be enacted with the IGDS and DMRS software subsystems including: (1) polygon-to-grid conversions, (2) grid-to-polygon conversions, (3) polygon overlay, (4) distance measurements, and (5) multidescriptor queries. Searches of the data base operate on a descriptor data selection process. The query language allows the user to combine desired characteristics to extract required cartographic and descriptor data. Polygon overlay using the IGDS and DMRS subsystems uses combinations of AND, OR and NOT functions for obtaining required data from the data base. Results of the polygon overlay process can also be used for further queries.

D. Data Display

Manipulation and retrieval of data from the data base can be displayed through plotting, mapping, and summary reports. The MAPGEN software, for instance, is used to map the results of data base queries. These maps can be produced interactively on the graphics screen or as hard copy plots. A variety of colors can be used for hard copy plots.

The DMRS subsystem contains a report generation function. Combinations of cartographic and descriptor data are used to produce graphics and tabular reports with summary statistics.

III. Description of System Hardware

Intergraph's software currently operates on a PDP-11 computer manufactured by Digital Equipment Corporation. It maintains an on-line storage capacity for up to 16 workstations.

IV. Evaluation Based on Project Specifications

A. Technical Evaluation

1. Prepare water resource map for contingency or long range planning

a. Prepare water resource maps

1)	Select area of interest	yes
2)	Display on CRT or plotter	yes

b. Prepare water potential maps

1)	Select area of interest	yes
2)	Convert to grid cell format	yes
3)	Calculate composite measure	no
4)	Display on CRT or plotter	yes

2. To locate and analyze water availability

a. Locate water in a defined area

1)	Select window from data base	yes
2)	Display selected map base data on a CRT	yes
3)	Accept graphic input at CRT	yes
4)	Generate a circle around input point	yes
5)	Display circle or polygon on CRT	yes
6)	Search data base	
	a) Point-in-polygon	yes
	b) Line-in-polygon	yes
	c) Polygon-overlay	yes
	d) Boolean search	yes
7)	Display search result on CRT with labels	yes
8)	Produce tabular display of attribute data for selected items	yes

b. Locate specified quantity of water

1)	Select window from data base	yes
2)	Display selected map base data on CRT	yes
3)	Accept graphic input at CRT	yes
4)	Search data base to find closest set of items that meet demand specifications	no
5)	Display research results on CRT with labels	yes

6) Produce tabular display for selected data i ms, including summations	yes

3. Plan and design the treatment, storage and distribution of water

a. Interactive display capability

1) For specified search area, display selected water resource data on CRT	yes
2) Add to CRT selected portions of road network	yes
3) Add labels to items displayed in 1 and 2 above	yes
4) Input linkage between source and demand and add to display	no
5) Transfer resulting display to plotter	yes

b. Linear programming model (network calculations, e.g., minimum paths)	no

4. Utiltity functions

a. Build data base

1) Input points with descriptor data	yes
2) Input lines with descriptor data	yes
3) Input polygons with descriptor data	yes

b. Update data base

1) Update points, lines, polygons	yes
2) Update descriptor data	yes

B. Organizational Evaluation

The system produced by Intergraph was designed primarily to serve engineering drawing functions. As a result, various geographic queries and manipulation capabilities are not present in the system. Some of these shortcomings are being rectified at the present time. Intergraph has been offering the system since 1973; thus, it does have marketing experience in producing geographic information systems.

C. Cost and Time Estimations

1. Hardware-Software Option A

   a. PDP 11/44 (.75 megabyte memory)
   b. disk (2 160-megabyte disks) = $177,000
   c. tape drive
   d. graphics software
   e. DMRS software = 20,000
   f. FORTRAN IV = 5,000
   g. graphics work station = 43,000
      1) 36" x 48" digitizer
      2) dual 19" x 19" raster display
   h. hard copy output options
      1) Versatec V80 (11" x 17") = 8,000
      2) Calcomp 960 = 35,000

2. Hardware-Software Option B

   a. LSI 1123 (1 megabyte memory)
   b. disk (80 megabyte)
   c. type drive = $140,000
   d. controller-printer
   e. work station
   f. DMRS software = 20,000
   g. FORTRAN IV = 5,000
   h. graphics work station = 43,000
      1) 36" x 48" digitizer
      2) dual 19" x 19" raster display
   i. hard copy output options
      1) Versatec V80 (11" x 17") = 8,000
      2) Calcomp 960 = 35,000

3. Additional software costs

   a. Polygon intersection software = $7,500

4. Maintenance costs

   a. Hardware - through Intergraph
   b. Software - comes as a package with hardware maintenance; the package is usually 10% of total hardware/software cost

5. Delivery time estimates

   a. approximately 120 days

6. Installation and training time estimates

   a. approximately 6 weeks

D. Client Experience

1. Bruce Rowland
   Geographic Data Center
   Tennessee Valley Authority
   Norris, Tennessee
   (615) 494-9800

   a. Hardware - satisfied; very little maintenance
   b. Software - polygon overlay did not meet expectations; still developing grid routines; interactive graphic query works well
   c. Support - Intergraph is very responsive; good support of system.

2. Larry Wright
   Engineering Topographic Laboratories
   (703) 664-1851

   a. Hardware - still delivering (color terminal)
   b. Software - some is still under development
   c. Support - good response to inquiries about using system

3. Mike Keveny
   Housing and Urban Development
   Washington, D.C.
   (202) 755-6170

   a. Hardware - Not applicable
   b. Software - good for maintaining engineering maps; weak in interactive graphics and polygon operations
   c. Support - good

4. Mike Domerantz
   National Mapping Division
   U.S. Geological Survey
   Reston, VA
   (703) 860-7764

   a. Hardware - no comment
   b. Software - good interfaces; data transfer problems
   c. Support - software support is weak

Synercom Technology, Incorporated
500 Corporate Drive
Sugar Land, Texas 77478
(713) 491-5000 Ext. 200

Mr. William Folchi

I. Summary of Vendor's Product

The INFORMAP system is the geographic information system produced by Synercom. INFORMAP consists of two major subsystems - the Mapping Interactive Graphics Digitizing System (MAP/IN) and the Information System for Automated Mapping and Distribution Facilities Management System (INFORM). The former subsystem handles data acquisition from source materials and maintains the data base; conversely, the latter subsystem is a management information system that is used to produce reports, displays, and plots of selected data.

In total, INFORMAP was designed by Synercom to meet the information management needs of utilities and municipalities. Several installations of the INFORMAP exist throughout the U.S.

II. Description of System

A. Data Input

Data input is accomplished through the MAP/IN subsystem. Point, line, and polygon data are encoded using the following data kinds defined in the INFORMAP system: (1) primary annotation, (2) lines and curves, (3) symbols, (4) smooth curves, and (5) expandable lines and curves. Under this set of data kinds, polygon data are formed via line intersections (vertices) at a minimum of three points.

Descriptor data corresponding to a specific cartographic element are entered before the actual cartographic representation (i.e., point, line, or polygon) is digitized. If descriptor data are unknown at the time of digitization, they can be filled in at a future edit session.

Editing cartographic elements is possible using several commands in the INFORMAP system. Interactive graphic editing requires that the user select an "edit tolerance" or an area around which he or she wishes to potentially modify. Various deletion or modification commands can then be used to alter cartographic elements within the specified area. Simple commands are also found in the INFORMAP system for altering or inserting descriptor data.

B. Data Storage

The data base structure used in INFORMAP is a hierarchical tree structure. It has been designed to optimize system performance for utilities and municipalities applications.

The basic storage unit contained in INFORMAP is called a "facet". Facets result from the division of the entire user study area into a grid of regularly shaped elements. Size of the facet is user-defined. All data associated with each facet are stored in one location. Thus, a user query need only search the particular facet of interest rather than the entire study area. Bringing in facets to satisfy data manipulation, retrieval, and display functions utilizes the "working storage-permanent storage" philosophy of the INFOMAP system. Operations on user data files are done in working storage which is of a temporary nature. The user does not interact directly with the data base.

C. Data Manipulation and Retrieval

Data Manipulation and Retrieval is user-oriented in structure. Menus are created entirely by the user through INFORMAP utility commands. A particular menu is accessed by name for use in a manipulation/retrieval session. INFORMAP provides two types of menus: (1) a list of commands with selection from the keyboard, and (2) a list of commands with cursor selection. The first type of menu commands the user to key in his choice from the list provided; the second menu type gives a graphic list of commands where the user selects his or her choice by "pointing" with the cursor.

The menu structure within INFORMAP allows the user to interactively select data from the data base. A variety of capabilities exist for manipulation and retrieval of data. Various types of display windows can be selected to view portions of the data base. Scaling, rotation, and other transformations of graphic displays are achieved using INFORMAP-supplied functions. Among the more complex operatons performed are polygon overlay and Boolean searches. The latter operation combines data items with specified values yielding composite information for geographical areas of interest.

In addition to the operations cited above, INFORMAP currently performs coordinate conversions between State Plane and UTM systems. Distance and area measurements for geographical areas may be calculated using INFORMAP utilities.

D. Data Display

Display of data using the INFORMAP system is controlled by the INFORM subsystem. Selective window displays enable the user to view particular areas directly at the graphic CRT. Plotting of cartographic data can be performed either on the graphic CRT or transferred to a hard copy plotting unit. Several options exist to add symbols, shading, cross hatching, and other characteristics to these forms of graphic display.

Report generation is another display capability offered via the INFORM subsystem. Various utility commands can be used to generate summary statistics for descriptor data items.

III. Description of System Hardware

The INFORMAP system operates either on a DEC PDP 11/44 or 11/70. Memory on the PDP 11/44 can be expanded to one megabyte while memory for the PDP 11/70 can be expanded to four megabytes.

IV. Evaluation Based on Project Specifications

A. Technical Evaluation

1. Prepare water resource maps for contingency or long range planning

a. Prepare water resource maps

1) Select area of interest	yes
2) Display on CRT or plotter	yes

b. Prepare water potential maps

1) Select area of interest	yes
2) Convert to grid cell format	Poly-only
3) Calculate composite measure	yes
4) Display on CRT or plotter	yes

2. To locate and analyze water availability

a. Locate water in a defined area

1) Select window from data base	yes
2) Display selected map base data on a CRT	yes
3) Accept graphic input at CRT	yes
4) Generate a circle around input point	yes
5) Display circle or polygon on CRT	yes
6) Search Data base	
a) Point-in-polygon	yes
b) Line-in-polygon	yes
c) Polygon-overlay	yes
d) Boolean search	yes
7) Display search results on CRT with labels	yes
8) Produce tabular display of attribute data for selected items	yes

b. Locate specified quantity of water

1) Select window from data base — yes
2) Display selected map base data on CRT — yes
3) Accept graphic input at CRT — yes
4) Search data base to find closest set of items that meet demand specifications — yes
5) Display search results on CRT, with labels — yes
6) Produce tabular display for selected data items, including summations — yes

3. Plan and design the treatment, storage and distribution of water

a. Interactive display capability

1) For specified search area, display selected water resource data on CRT — yes
2) Add to CRT selected portion of road network — yes
3) Add labels to items displayed in 1 and 2 above — yes
4) Input linkage between source and demand and add to display — yes
5) Transfer resulting display to plotter — yes

b. Linear programming model (network calculation, e.g., minimum paths) — no

4. Utility functions

a. Build data base

1) Input points with descriptor data — yes
2) Input lines with descriptor data — yes
3) Input polygons with descriptor data — yes

b. Update data base

1) Update points, lines, polygons — yes
2) Update descriptor data — yes

B. Organizational Evaluation

The fact that Synercom has developed INFORMAP specifically to serve utilities and municipalities may be limiting factor in its applicability for other types of projects. In addition, the release price on the system source code is $40,000.

C. Cost and Time Estimations

1. Hardware-Software costs

a.	PDP 11/44 (> or = 1 megabyte)	
b.	disk (2 80-megabyte disks)	
c.	tape drive (800-1600 bpi)	= $139,700
d.	MAP/IN software	
e.	2 graphic work stations	
	1) graphic CRT	
	2) alphanumeric CRT	= $ 75,000
	3) digitizer	($37,500 each)
f.	plotter (Calcomp 960)	= $ 36,400
g.	printer (8 1/2" x 11" size)	= $ 5,800
h.	INFORM software	= $ 15,000
i.	FORTRAN IV	= $ 880
	TOTAL COST	= $272,780

2. Maintenance Costs

a. Hardware and software are handled jointly in the maintenance agreement; typically, hardware/software maintenance per <u>month</u> is 1% of purchase price.

3. Delivery Time Estimates

a. 180 days after contract is agreed upon

4. Installation and Training Time Estimates

a. 4 weeks of training initially and a period of 2 weeks for refresher training at no additional cost; there is a 6-month follow-up visit after system is installed.

D. Client Experience

1. Bob McDonald
   P.O. Box 1551
   Carolina Power and Light Company
   Raleigh, NC 27602
   (919) 836-6274

   a. Hardware - good experience thus far with system hardware
   b. Software - no serious problems
   c. Support - Synercom is eager to help in solving problems with the system

2. Saul Miller
   Mid-States Engineering
   Indianapolis, IN
   (317) 634-6184

   a. Hardware - satisfactory performance since installation in August 1980
   b. Software - digitizing system is very satisfactory in meeting data input needs
   c. Support - good service by Synercom

3. Ken Niles
   Utility Data Corporation
   Houston, TX
   (713) 681-6671

   a. Hardware - no major problems with any component of the hardware configuration
   b. Software - initially, some routines were too slow in response time; this has been improved recently with new software revisions
   c. Support - during Synercom's growing stages, their service left much to be desired; support for clients has improved significantly in the past 6 months; there is also a Synercom system users group that meets periodically

4. Ken Strange
   Turner, Collie, and Braden Engineers
   Houston, TX
   (713) 780-4100

   a. Hardware - performance is good about 75% of the time
   b. Software - generally satisfactory; installation of new capabilities causes some problems until bugs are worked out; good software maintenance
   c. Support - response to problems is generally good

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Calkins, Hugh W.
Military hydrology : Report 4 : Evaluation of an automated water data base for support to the rapid deployment joint task force (RDJTF) / by Hugh W. Calkins, Timothy R. Johnson (Department of Geography, State University of New York at Buffalo). -- Vicksburg, Miss. : U.S. Army Engineer Waterways Experiment Station ; Springfield, Va. : available from NTIS, 1981.
80 p. in various pagings ; ill. ; 27 cm. -- (Miscellaneous paper / U.S. Army Engineer Waterways Experiment Station ; EL-79-6, Report 4)
Cover title.
"November 1981."
"Prepared for U.S. Army Engineer Topographic Laboratories and Office, Chief of Engineers, U.S. Army under Project No. 4A762719AT40, Task Area BO, Work Unit 030."
"Monitored by Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station."

Calkins, Hugh W.
Military hydrology : Report 4 : Evaluation : ... 1981.
(Card 2)

1. Automatic data collection systems. 2. Hydrology. 3. Military geography. 4. Water resources development. I. Johnson, Timothy R. II. State University of New York at Buffalo. Dept. of Geography. III. United States Army Engineer Topographic Laboratories. IV. United States. Army. Corps of Engineers. Office of the Chief of Engineers. V. U.S. Army Engineer Waterways Experiment Station. Environmental Laboratory. VI. Title VII. Series: Miscellaneous paper (U.S. Army Engineer Waterways Experiment Station) ; EL-79-6, Report 4.
TA7.W34m no.EL-79-6 Report 4