OCEAN AND COASTAL RESOURCES
MAPPING SYSTEM AND PILOT STUDY

FEB 1985

I. INTRODUCTION

Background and Objectives

The State of Hawaii Department of Planning and Economic Development (DPED), through the Coastal Zone Management Program (CZMP) and the Ocean Resources Office (ORO), contracted with SETS, Inc., Honolulu, Hawaii, to assess the overall usefulness and feasibility of a statewide automated ocean and coastal resources mapping system. The DPED is interested in supporting research and demonstration projects aimed at improving resource planning and management and responsible economic development in the state's coastal zone. Development in the islands has been frequently constrained by competition for space and resources, and the lack of consistent and accessible information has hampered proper and timely evaluation of proposed coastal and ocean use activities.

In addition, DPED realizes that the growing availability of data digitally captured, transmitted, enhanced and distributed is making it imperative that the State of Hawaii develop a data base which can be used to integrate this new information with existing data bases. Examples include in situ sensed remotely readout buoys that are anchored or drift, and measure surface, subsurface and deep ocean temperature, current direction and velocity, and chemical composition, including salinity and dissolved gases. (See "Satellite Data Relay and Platform Locating in Oceanography," Appendix A.) Other examples are devices for collecting data on tide, wind, temperature, solar intensity, atmospheric pressure and stream flows. Also, there is information from weather satellites, Landsat and a host of proposed oceanographic satellites (see "Oceanography from Space," Appendix A).

This pilot study represents a first step by the state towards the development of a comprehensive, consistent and accessible geographic information system (GIS) to support ocean and coastal planning and economic development efforts throughout the islands. The form and implementation of this study were guided by several major objectives:

1. Identify potential users of the system and assess both data and analysis needs of these users.

2. Inventory and assess available existing data for usefulness and applicability within an automated system.

3. Develop the conceptual framework for the form and content of an automated data base of coastal and ocean resources geographic information.

4. Develop appropriate organizational model alternatives for guidance in development of an institutional structure within which the system might be implemented and maintained.

5. Provide implementation recommendations to guide system development efforts once the institutional framework has been established.

6. Develop and install in Honolulu, for two weeks, a demonstration data base of geographic information within a study area lying approximately between Kahe Point and Barbers Point on the island of Oahu to illustrate the form and capabilities of an automated GIS.

Methods Overview

The pilot study was carried out during a five-month period, from June to November 1984. SETS and Environmental Systems Research Institute (ESRI) conducted a two-week user needs assessment in July involving interviews with various federal, state, city and county, institutional and private agencies and groups involved in planning, research and economic development in the State of Hawaii. An initial list of potential interview subjects was developed by SETS and subsequently refined by DPED. Results of the needs assessment are included under separate cover in a "Report on Survey of Potential Users of a State Operated Ocean-Related Geographic Information System."

Following the first week of interviews, it was possible to begin to identify and collect data for inclusion in the demonstration data base. One consultant team member was assigned the responsibility for locating and collecting all appropriate data. This effort extended for approximately two weeks beyond the end of the needs assessment period.

SETS team members summarized and analyzed results of the needs assessment. Simultaneously ESRI staff compiled and assessed all collected data for the demonstration data base. Results of the user needs and data assessments provided the basis for the development of a conceptual data base structure and organization of "manuscripts" combining spatially related data sets in preparation for automation. All appropriate map and tabular data were rescaled and rectified as necessary, manually remapped and automated. A hard copy (pen plotter) basic data atlas was produced and selected special analyses conducted to illustrate the form and content of this data base and to demonstrate analysis and display capabilities of the system.

ESRI team members and system specialists developed the framework for a system implementation plan. The basic framework was reworked by SETS and ESRI team members to accommodate the special needs of DPED as far as these were known. A rough draft of this plan was delivered to DPED for review and comment. ESRI incorporated DPED staff input into the final form of the implementation plan included in this document.

In late October, the automated files for the demonstration data base and the ESRI ARC/INFO geographic information system software were installed on the computer system of Sam O. Hirota, Inc., in Honolulu, to begin a two-week demonstration period. Potential system users were invited to see the demonstrations and to witness, in a "hands-on" manner, the operations and capabilities of the system. Over 200 individuals attended demonstrations over the two-week period.

Summary of Needs Assessment Findings

In the course of the user needs assessment, several important considerations and issues became evident. Many of these had direct bearing on how this pilot study was subsequently conducted and how initial objectives were adjusted to address important issues as they become known.

It became obvious that it would be difficult to have a GIS only for ocean resources mapping and management. First there is considerable intertwining of interests and information between the ocean and the land and, second, ocean data are not presently available in sufficient quantity or form to justify a system on its own.

Little consideration has been given to desired institutional linkages and long-term operational implications of a multiple-agency information system. In an attempt to compile as comprehensive an inventory of GIS needs as possible within the limited time frame of the pilot study, the range of potential users interviewed during the user needs assessment was very wide. Interviews conducted were necessarily limited in scope, allowing only two or three interviews per agency or group and thus recording only a partial representation of the needs of each.

The needs assessment revealed an almost universal desire by the various groups to gain access to a shared and consistent information base, but the degree of need varied greatly. Agencies or institutions involved in original oceanographic research typically indicated limited use for such a system, as most of their work involves studies which are spatially limited and temporally extensive (e.g., ocean current and thermal changes at particular points over time). This may change as people become more familiar with the capabilities of a geographic information system, although very specialized research applications will probably continue to require special programming. At the other end of the needs spectrum were groups directly involved in natural resources and development planning and coastal development permitting, who expressed frustration in dealing with geographic information as it currenly exists.

Resources mapping has typically not been coordinated between the agencies who compile and use it. Gaps were especially noticeable between levels of government, for example, between the state and the city and county. The quality of available data also varied greatly, although not necessarily by source organization.

One of the most often-stated problems was the lack of consistent and available data in usable form. Variations in the map scales used caused problems. Data from a dozen sources for the pilot study existed in twenty-two different scales. Many individuals complained that inconsistencies between various existing data were the cause of misunderstandings and time delays which affected the permitting process for coastal development projects. Researching, locating, and comparing various data or evalation consume a substantial amount of staff time in organizations dealing with the development permit process. Certain data sets used consistently during the permit evaluation process are maintained separately by different organizations. When these data are updated by the source organizaton, it becomes necessary to replace them throughout the permit review network to maintain consistency.

Several automated data bases of planning-related information are maintained by various government agencies, and although these carry much valuable information, they are not generally accessible. The Hawaii Planning Activities Support System (H-PASS) is an automated system which integrates permit information of nine state and county agencies with major land and water use management responsibilities. The H-PASS data are compiled by Tax Map Key (TMK) number, providing a direct and convenient link between this information and any future GIS. The State Division of Electronic Data Processing (EDP) apparently maintains extensive data bases of resource and land use information which might be linked to a GIS, although this has not been fully evaluated.

Generally there was a lack of understanding regarding the nature and capabilities of a geographic information system. Many of the interview subjects were familiar with or had a cursory understanding of computer mapping and drafting systems but were generally unfamiliar with the cartographic and tabular analyses made possible by a full GIS.

GIS Software Functional Requirements

The need for various software capabilities of a statewide GIS in Hawaii was derived from analysis of user needs assessment findings and examination of the content and form of geographic data currently used by interviewees. Tasks involving geographic information were dissected and generalized to generic GIS functions. Table 1 illustrates the relative importance of each generic GIS functional group to each organization interviewed and also the importance of these GIS functions to the group as a whole. It must be pointed out that this is not the total potential user group, nor is it likely that all the entities interviewed would be part of a single GIS system. The following is a brief description of each generic GIS functional group listed in the table.

TABULAR DATA - Tabular data in GIS applications refer generally to information which is in itself non-spatial, but which describes the characteristics or attributes of spatial features. In Hawaii, tabular data range from well log information, through soils descriptions and interpretations, to street names and fish catch records. This information currently exists in a variety of forms, some automated and some manual. The following are specific generic GIS tasks and functions that typically fall within the category of tabular data procedures:

- Field Measurement/Observation is the process of gathering tabular data in on-site reconnaissance visits.

	Tabular Data	Cartographic Data: Generation/Storage	Cartographic Data: Manipulation/Analysis: Geometric Analysis	Cartographic Data: Manipulation/Analysis: Network Analysis	Cartographic Data: Manipulation/Analysis: Digital Terrain Modelling	Cartographic Data: Manipulation/Analysis: Query	Cartographic Data: Display: Composition	Cartographic Data: Display: Presentation	Bibliographic Data
	Field Measurement/Observation, Retrieve Existing Tabular Data, Compilation on Forms, Data Entry/Edit, Update, Storage/Management, Data Manipulation, Statistical Analysis, On-Line Query, Report Generation	Air Photo Interpretation, Gather Existing Map Data, Field Survey (Sampling), Drafting/Compilation on Maps, Digitize/Edit, Traverse Entry/Cogo, Cartographic Data Update, Map Join/Edge Match, Storage/Management	Polygon Overlay, Line in Polygon, Vector/Cell Conversion, Polygon Dissolve, Point in Polygon, Polygon to Point Analysis, Transformations, Buffer/Corridoring, Windowing, Coordinate Filtering, Proximal Analysis, Line Length Calculation, Area/Perimeter Calculation, Aggregation/Districting, Contiguity Analysis	Distance Accumulation, Area to Network Accumulation, Optimal Path Selection, Flow Simulation, Time/Distance Computation	Spatial Interpolation, Contouring, Slope/Aspect, Sun Intensity, Viewshed, Road Engineering Design, Volume Calculation, Cross Sectioning, 3-D Viewing	Spatial Query, Attribute Query	Generalization, Scale Change, Modify Features/Text, Graphic Superimposition	Symbolize Points, Symbolize Lines, Symbolize Polygons, Text/Annotation, Display Legends, Modify/Update Features/Text	Indexing, Storage, Retrieval
USGS	15	50	5	2	2	5	5	10	6
Army Corps	8	40	5	0	2	10	5	5	25
DPED Ocean Resources	15	10	25	0	5	10	5	5	25
Coastal Zone Management	5	15	15	5	5	30	5	5	15
DPED Land Use Commission	5	10	10	5	0	25	15	20	10
DPED Land Use Division	2	2	35	0	0	35	8	8	10
Division of Land Management	10	15	5	0	0	40	5	5	20
DLNR Division of Aquatic Resources	20	5	3	0	0	40	3	3	26
DOT Harbor Division Planning	15	35	0	0	0	25	5	15	5
Department of Health OEQC	0	0	5	0	0	45	10	15	25
U.H. Oceanography	0	0	20	0	5	25	5	5	40
U.H. Look Laboratory	5	3	10	0	0	15	6	6	55
C & C Public Works	10	30	25	10	2	10	5	5	3
C & C Civil Defence	10	15	35	35	0	3	1	1	0
HECO	15	10	30	0	5	10	5	10	15
Sierra Club	2	3	0	0	10	30	5	10	40
Private Developers and other Special Applications	10	15	30	5	5	5	5	10	15
Percent of Total	9	15	15	4	2	21	6	8	20

Table 1

Demand for Software Capabilities

(Values Expressed in Percent of Total Need by Organization)

- Retrieve Existing Tabular Data includes the accumulation of tabular data which may be stored in a variety of manual or automated files and formats.

- Compilation on Forms involves the recording of tabular data on designated reporting forms for use primarily as spatially related component information. This procedure can be done manually or by machine, and may be supplemented by field work or other collected information.

- Data Entry/Edit is a process of entering tabular data into a structured file. This is typically accomplished by key entering data using a CRT terminal with a formatted screen.

- Update is a process of revising stored tabular data in a manual or an automated system. Automated updates are best performed using an alphanumeric screen editor with well-defined software procedures to control the process.

- Storage/Management involves the orderly storage, management and retrieval of tabular data. It includes storing a sequence of records or files in an efficient structure for space management, indexing capabilities, and means for easy access and manipulation, as well as restoration of the records or files to their original file location. This procedure may also involve an archival process for the storage and retrieval of data in file cabinets or on magnetic tapes, including back-up files.

- Data Manipulation includes the ability to perform various arithmetic and logical operations on tabular data, as well as to sort and relate different data sets to each other. This is normally done within the context of a model, process or procedure. There are three levels of data manipulation: the file level, the record level and the algorithmic level. The processing is concerned with the operations of a set of entities within a file. Record processing is concerned with the retrieval of specific records from a file and the subsequent manipulation of fields within the record, using arithmetic or logical functions. At the algorithmic level, procedures are used to manipulate individual values for a particular purpose.

- Statistical Analysis is concerned with computations and the aggregation of data according to well-defined statistical procedures, in order to provide the user with a better perspective on the collection of data. The parameters prescribed regarding data collection itself are very meaningful for interpreting the data in the aggregate rather than individual data items.

Statistical analysis includes a number of clearly defined functions, such as standard deviation, mean, average, regression, correlation, factor analysis, principal component analysis, and others. In each of these examples the data are viewed as a collection rather than as individual entities. Statistical analysis is usually defined in terms of a library of functions. It is important to understand what is being done by the functions in order to properly interpret the results of the analysis.

- On-line Query is the process by which one selects items of interest according to certain criteria. The criteria are normally based on arithmetic and Boolean connectives. This process typically results in a list of data items which can be displayed via manual or automated means in a report or stored in another file to be operated on by other functions. The output is a set of items which satisfy the condition specified.

- Report Generation is a mechanism by which information is systematically identified, extracted, ordered and displayed in tabular form, based upon access from a single file or a set of files. The user specifies output formats on the file or files. A user may also define operations to be performed on the data items, such as summarization, average or any logical operations in a standard form.

CARTOGRAPHIC DATA GENERATION AND STORAGE - Cartographic data generally refer to information which is spatial, that is, having a real extent or location. This might be the boundaries of a coral reef inventory unit, a political/administrative boundary, a coastline, or the location of an observation well. Nearly all spatial data used by interviewees exist in a manual form as maps. In isolated cases very simple maps have been automated for special applications. One exception is SeaMARC data currently being collected by the University of Hawaii. Through highly refined sonar technology, the SeaMARC device compiles information about the ocean bottom in an automated form. This information is then further interpreted and manipulated to make maps depicting various characteristics of the ocean floor, such as bathymetry and surface geology. The following are specific generic GIS tasks and functions that fall within the category of cartographic data generation and storage.

- Airphoto Interpretation is the interpretation of features from aerial photography. The procedure is typically conducted using a stereoscope and various types and scales of remotely sensed imagery; for example, black and white photography or color infrared.

- Gather Existing Map Data involves the retrieval of map data from storage for use.

- Field Survey (Sampling) includes the sampling of environmental characteristics through field observation, measurement, reporting and related collection procedures.

- Drafting/Compilation on Maps is the conversion of both image and tabular data into spatially related information, typically as plotted on a map. It can be done manually or by a machne, such as in stereo compilation from aerial photographs or topographic mapping. It may be supplemented with field work and existing maps as well as with data retrieved from tabular reports. This process includes the compilation of horizontal control geometric data by Coordinate Geometry (COGO).

- Digitize/Edit is the digital encoding of compiled map data, including points, lines and polygons. Editing of digitized data is simply the elimination of errors created during digitizing, the replacement or displacement of line segments to the proper position, and the correction of other errors generally cartographic in nature.

- Traverse Entry/COGO (Coordinate Geometry) is a set of mathematical tools and functions for encoding and converting bearings, distances, angles, and other measurements into coordinate information. This operation is normally done on an alphanumeric screen into which data is entered and the geometry is determined analytically.

- Cartographic Data Update is the capability which permits the revision or addition of information to reflect changes that have taken place in the data since compilation was last performed.

- Map Join/Edge Match is the process of removing inconsistencies at the edges of maps from compiled map data so that the features match across map sheets. Edge match, map join and merge constitute one function. A map join is putting maps together, and merge implies a global joining of a group of maps. Map joining compiles the physical and logical joining of map entities (features) from one map sheet to the adjacent sheet. While features may not be physically connected, they are logically connected. For example, a utility crossing several map sheets may not physically connect to itself at map edges, but its segments will be logically connected through pointers in a digital file. In a manual system, map joining simply requires ensuring that lines and features match at sheet edges where map sheets join. Map sheets, however, may also be physically connected as in the continuous map.

- Storage/Management invokes the orderly storage, management and retrieval of geographical data and maps in an efficient structure for space management, access and retrieval.

CARTOGRAPHIC DATA GEOMETRIC ANALYSIS PROCEDURES - Geometric analysis procedures refer to a host of spatial manipulations of map features to derive some conclusion about geographic interrelationships. Most geometric analysis procedures are difficult and cumbersome to implement in a manual form and thus are generally underutilized when automated tools for performing these are not available. Many organizations interviewed expressed the feeling that although their applications of geometric analyses are now limited, their use of these procedures would increase if the tools were available to do so in a cost and time-efficient manner. The following are specific generic GIS functions that fall within the category of cartographic data geometric analysis procedures.

- Polygon Overlay is a function which allows the processing of one or more sets of polygons which have been overlaid to form a combined set of polygons. This results in a common set of values for the sets involved. There are different combinations of polygon overlays. One is used in update where it only takes on the attributes of one of the previous sets, and is a process for cartographic analysis. Polygon overlay can be broken down into several other techniques, such as line intersection, point in polygon and cellular overlay. These are all techniques used to carry out the polygon overlay function.

- Line in Polygon involves the intersection of line and polygon features for determining their relationships (e.g., the type and length of lines falling within a given polygon).

- Vector Cell/Cell to Vector Conversion is a process for the conversion of X,Y coordinate data expressed as vectors, points, lines and polygons into a cellular structure, and also the conversion of cellular data into an X,Y coordinate format. The grid cell is a title of an arbitrary two-dimensional ruling of the surface of the earth. The vector conversion requires the transferral of cartographic files from an X,Y coordinate form to a cellular form. Cells can be of any size, orientation or shape.

- Polygon Dissolve is the capability to merge two or more polygons which share common attributes by eliminating the shared boundaries.

- Point in Polygon is the procedure which determines if certain points lie within a given polygon. This capability can be enhanced so that the attributes of the polygon are assigned to points that fall within it.

- Polygon to Point Analysis involves the analysis of a coordinate point relative to the geometric boundary of a polygon. This can be used for calculating distance.

- Transformation involves mathematical expressions used to convert coordinate data within one frame of reference to coordinate data in another frame of reference. It is used for a variety of applications, including changing from one map projection to another map projection, or converting from one set of coordinates captured on a digitizer to another coordinate system.

- Buffering or Corridoring is a process whereby a polygon or zone of fixed size is created around a point, line or polygon. These polygons are sometimes created based on the attributes of given cartographic features.

- Windowing is a function allowing the user to define a specific geographic area which is used to delimit a piece of a map or cartographic area. This process involves maintaining the attributes with the cartographic features. The cartographic features and the associated attributes can be retrieved, using a window for subsequent display, analysis and manipulation.

- Coordinate Filtering is the process of weighing out superfluous coordinates. It is used to generalize maps and to reduce requirements for computer storage.

- Proximal Analysis is a procedure which involves the creation of polygons or areas around randomly spaced point locations. It is carried out by dividing equally the distance between paired points, then generating perpendicular lines to the mid-way points, which are then extended to intersect and form areas. This process is used for creating polygons, mapping and analyzing qualitative data where a continuous coverage map is desired, but where contouring is not appropriate. It is possible to obtain pictorial displays of discontinuous data with this method.

- Line Length Calculation is a procedure for computing the distance between successive coordinate pairs forming a straight line or following an irregular path.

- Area/Perimeter Calculation is a procedure for geometrically computing the area or perimeter of polygon features.

- Spatial Aggregation/Districting is a procedure which allows the user to semi-automatically determine districts. It provides the capability to aggregate polygonal data into larger units of polygonal data. Polygon dissolve is used as an operation of polygon aggregation. Districting is the process whereby areas may be interactively aggregated by utilizing topological boundary information around a set of entities (e.g., the ability to spatially aggregate polygons into larger polygons, including the aggregation of the attributes by using topological identification of boundary features or by using a graphic function like polygon overlay). This procedure may be performed via manual or automated means.

- Contiguity Analysis is concerned with adjacency relationships between any given polygon and its neighbors. Typically this procedure involves summarizing and relating the attributes of neighboring polygons to the polygon being examined.

CARTOGRAPHIC DATA NETWORK ANALYSIS PROCEDURES - Network analyses involve the creation and manipulation of spatial and characteristic relationships typically along such flow networks as road, streams and utility service nets. The following are specific GIS functions that usually fall within the category of cartographic data network analysis procedures.

- Distance Accumulation is the process of aggregating spatially distributed data within a specified distance from a feature. This procedure is used to summarize or enumerate geographic features, such as points, lines or polygons and their attributes within a user-specified distance of a particular geographic location. This is typically done with a grid cell-by-grid cell summarization with user specified distances.

- Area to Network Accumulation involves the association of area quantities (e.g., volumes of water or population attributes) of polygons to a network (e.g., stream or road) and calculates the time/distance or friction relationship of these polygon attributes to a selected point on the network.

- Optimal Path Selection is the process of using a network data base of road and road intersections to select the optimal path based on specified time/distance relationships.

- Flow Simulation is the ability to dynamically simulate movement of a collection of entities through a network. The technique is typically used to simulate such movements as vehicle flow on a street, pedestrian movement through a pedestrian network, water moving through a pipe network or electricity moving through an electrical network.

- Time/Distance Districting is the ability to measure time/distance, to accumulate time/distance data through a network radiating out from a given point, and to associate these time/distance values to the points through which the measurements are taken. This procedure is used to define contour distances away from known points, and to determine districts which are created from a variety of such processes. It may be considered as proximal mapping on a network time/proximity/districting basis rather than on a distance basis.

CARTOGRAPHIC DATA DIGITAL TERRAIN MODELING PROCEDURES - Digital terrain modeling procedures involve a variety of applications related generally to sun intensity calculations, volume calculations and a host of other applications as described in the following:

- Spatial Interpolation is the capability to interpret proportions between points of known elevation for the purposes of establishing contours or elevation values between these points. This is typically done using random point data which are interpolated into a grid or triangulated surface of facets.

- Contouring is the capability to derive lines of constant elevation or given values of elevation by photogrammetric means, using interpretive techniques or vertical survey traverses. It may be used to fit a line through a series of randomly distributed or regularly distributed points of known elevation.

- Slope/Aspect is the capability to calculate the topographic slope for each aspect of a given area. The term "slope" addresses the steepness of an area, while "aspect" relates to the direction in which an area is oriented. The average slope has eight surrounding neighbors, and there are six different ways to calculate slope on a regular elevation basis. The calculation of the angle of the topographic slope may be based on a manual or digital frame file with a grid of polygons, and the classification of that surface of slope variation into slope ranges by which each is stratified (e.g., 5 to 10 percent or 10 to 15 percent). The calculation of the direction of those slopes may also be broken into facets (e.g., north, northeast or northwest).

- Sun Intensity is the calculation of the potential sun intensity measured in British thermal units, based on the angle of slope, direction of slope and location of the sun relative to that slope. The calculation is based on sun estimates and angles according to time of year and hour of day, and comprises the angle of incidence of the sun with the surface at a particular time.

- Viewshed is the capability of calculating and displaying the land site across the top of a reference surface for one or more selected view points.

- Road Engineering Design is a set of drafting-related construction drawings, generated staking diagrams, and analytic functions for generating horizontal and vertical road profiles and calculating related cut and fill volumes.

- Volume Calculation is a computation of volume based on the overlay of two surfaces of topographic data and the distance between them. This is achieved by subtracting one surface from the other.

- Cross Sectioning gives the capability to extract a 2-D profile from a 3-D surface, allowing any user-defined path to be produced.

- 3-D Viewing provides the ability to display a topographic surface by producing a 3-D graphic. A 3-D representation of a digital terrain model is created in the procedure.

CARTOGRAPHIC DATA QUERY PROCEDURES - Data query is the capability of extracting or examining geographic information by area or characteristic. The ability to perform this type of function was the single most stated need of interviewees. It has applications from permit review to inventory and research functions. The two general types of query are as follows:

- Spatial Query allows the extraction of cartographic data based on user-defined windows, such as circles or other regular and irregular shapes.

- Attributes Query offers the ability to select data items from a file system based on the values of specific attributes or combinations thereof, defined by arithmetic, relational and logical expressions.

CARTOGRAPHIC DATA COMPOSITION PROCEDURES - The application and/or presentation of map information for different purposes often requires that base data be manipulated, generalized or otherwise changed to meet specific needs. The following are GIS functions generally falling under this category:

- Generalization is the process of weighing coordinates and unnecessary data, such as in the delegation of polygons based on mineral size or the elimination of certain minerals. This process concerns maintaining information content consistent with the skill with which it is being represented.

- Scale Change provides the ability to plot or display data at a user-defined scale. With this capability, scale is not confined to the input scale. This procedure may involve generalization techniques.

- Modify Features and Text offers the capability of adding or moving text and cartographic symbology by automatic or manual means to improve the presentation of a graphic product.

- Graphic Superimposition is the integration of two or more graphics in a consistent manner over the same area.

CARTOGRAPHIC DATA PRESENTATION PROCEDURES - Graphic presentation of base data or analysis results is necessary for nearly every application requiring communication of these features. The following are generic GIS functions generally falling under this category:

- Symbolize Points involves the depiction of attributes with graphic symbols or alphanumeric values as per user specifications.
- Symbolize Lines provides cartographic display of linear features by means of X,Y coordinate pairs.
- Symbolize Polygons involves the cartographic display of regularly or irregularly shaped polygons and their attributes. Typically this capability includes shading, symbology and numeric labeling as well as a variety of other map cosmetic functions for generating alphanumeric labeling of polygons.
- Text/Annotation is the positioning of actual textual data, including graphical symbology for place names, feature names, legends and others.
- Display Legends involves the preparation and layout of informational legends for graphic displays.
- Modify/Update Features/Text involves the revision of text and cartographic features for presentation purposes.

BIBLIOGRAPHIC DATA PROCEDURES - The indexing, storage and retrieval of geocoded bibliographic data was another much-described GIS need stated by interviewees. This capability is especially important to persons involved in research about specific subjects and/or specific areas of land or ocean. The three functional areas of this category are briefly described below:

- Indexing involves the creation of topological structure to facilitate access to large collections of data entities (records).
- Storage is the process of maintaining information over time.
- Retrieval is the ability to locate and provide on demand the information associated with a data item.

II. SYSTEM DESIGN: OPERATIONAL ALTERNATIVES AND CONCEPTUAL DATA BASE STRUCTURE

Findings of the user needs assessment and an evaluation of information collected for the demonstration data base provided the basis for the development of a conceptual system and data base design and implementation plan for a State of Hawaii Ocean and Coastal Resources Geographic Information System. The system design and implementation plan were conceptually developed around assumptions regarding ultimate institutional and operational parameters. Since no desired framework for the system was specified, two alternatives describing operational considerations, hardware configurations and associated costs were developed to provide DPED with a range of issues to consider. The conceptual data base structure described here and implemented in the demonstration data base was founded on an assessment of collected data and application needs described by the potential system users who had been interviewed. Although the interviews conducted could not totally represent the needs of all potential system users, it is felt that the subjects represent a sufficient cross-section to make possible the development of the conceptual data base structure and system alternatives described in this section.

A. OPERATIONAL ALTERNATIVES

Two operational alternatives were developed and are described here as a means of illustrating a range of operational and cost considerations. The two alternatives described are: 1) a Service Bureau approach wherein the organization operating and maintaining the system acts as a centralized entity providing system services to other organizations; and 2) a User Network approach involving a decentralized network of users, each responsible for the development and maintenance of a central archive data base. A variety of possible combinations exist between these two examples, and ultimately the final operational system will probably involve components of each. Personnel and hardware requirements specified for each alternative are based on certain critical assumptions regarding the scope and operational/institutional parameters of a state-run, multiple-user geographic information systm. These assumptions are stated for each alternative.

Service Bureau Alternative

Description and Issues

The first operational alternative described here for consideration by the state can be conceptually labeled a "Service Bureau" approach. Generally this approach would involve the organization of a centralized Service Bureau within the state, or the establishment of an autonomous or semi-autonomous entity outside the state, to act as a multiple-agency, multiple-user service center for ocean, coastal and related geographic information in the State of

Hawaii. This organization would be responsible for all system and data management and would respond to user application requests upon demand. In some cases, long-term arrangements for automation, maintenance and updating of participant agency data sets could be established. Financially a Service Bureau might be supported partially through one-time project applications contracts and partially through ongoing data base development and maintenance.

There are several advantages and disadvantages inherent in this approach. A centralized facility can take advantage of certain economies of scale and focus. Hardware, software and personnel which would not be fully utilized by any single user organization can be used as shared resources by many. A greater degree of quality control can be maintained by a central organization (Service Bureau) whose primary mandate is the production, application and maintenance of the GIS system and data base. This Service Bureau would consist of highly trained system and application technicians able to respond technically to a wide variety of needs. One danger is that GIS technicians may become highly specialized in their understanding of system capabilities and lose touch with basic analysis application needs. Conversely, persons with little technical or hands-on knowledge of GIS system capabilities may not be able to communicate their needs to a system technician, or they may be unaware of certain system capabilities which might provide adequate alternative solutions to application problems. System resource allocations can be complicated by conflicting demands for personnel and computer time. This can cause time delays and inconvenience, which to some extent can be alleviated through careful project planning and establishment of resource allocation procedures and standards.

Over time the Service Bureau personnel will develop a high degree of familiarity with the contents of the archive data base, automation and processing methods, and data base and system maintenance procedures. Consistent procedures will in turn be more likely to result in a higher level of data consistency throughout the archive data base.

It would appear that a Service Bureau approach has a great deal of merit. However, the ultimate success of a GIS is closely tied to the ease with which the end user can interact with the system. A Service Bureau system will probably inhibit this interaction and ultimately reduce the true usefulness and efficiency of the system.

For the purpose of describing hardware and personnel requirements, several key assumptions have been made. It is assumed that at least initially the system will be made up of key departments within the state government and will not be used solely for ocean resources mapping and management. The reasons for this assumption are spelled out in the implementation portion of this study. In addition, the archive data base will consist mostly of the data these groups use regularly, as indicated in Table 2.

	Variable
State	
	Solar Regimes
	Beach Change Transects
	Fisheries Chart
	Median Annual Rainfall
	DLNR Observation Wells
Federal	Shore Type
	Detailed Coastline
	Offshore Bottom Type
	Existing Use
	Bibliography of Surveys/Studies
	Shoreline Inventory
	Water Sampling Points
	Zooplankton Sampling Points
	XBT Sampling Points
	Streams (Major)
	Streams (Detailed)
	Topography
	Transportation
	Nearshore Bathymetry
	Generalized Coastline
	Gauging Stations
	Observation Wells and Water QualSampl[illegible]
	Geology
	Bathymetry
	Soils
	NOAA (State Map)
City and County	Development Plan Public Facilities
	Development Plan Land Use Zoning
	Zoning Map
	Existing Land Use
	Special Management Areas
	Beach Parks and Right of Ways
	Floodways
	Flood Insurance Rate Maps
	Flood Map Index
	Tsunami Inundation
	Parcel Maps
Institutional	Meteorology Station Locations
	Land Surface Form
	Annual Average Wind Power
	Seasonal Wind Power
	Tsunami Wave Runup Heights
	DSV Turtle Dive Tracks
Private	Sediment Test Rod Locations
	Benthic Recording Locations
	Coral Reef Changes
	Algal Abundance
	Coral and Algae Test Stations
	Temperature Plumes
	Sediment Profile Locations
	Nearshore Surface Temperatures
	Nearshore Bathymetry
	Natural Color Aerial Photographs

Table 2
Pilot Study Data List

Given the likely scope and complexity of the initial archive data base development effort, it is assumed for cost computation purposes, that much of the initial data entry will be contracted out by the state to an independent contractor. Equipment and personnel requirements are based on this assumption and the Service Bureau would take primary responsibility for all subsequent data base maintenance, automation and application.

It is anticipated that special project applications initially will be numerous but generally small in scope. Clients for this service will typically consist of various state, county, and private agencies requiring access to the data and capabilities of the GIS on a one-time or sporadic basis. Some of these projects will require the application of information not previously automated and will provide ongoing opportunities for expansion of the data base.

Personnel Requirements

Projections for the number and types of GIS personnel required to run the operational Service Bureau are difficult to define without a comprehensive assessment of user needs. The scope of this pilot study allowed only a broad-stroke assessment of needs, including, in many cases, an assessment of the needs of only a single division within a multi-division department. As a result, the personnel requirement projections represented here are based on a qualitative assessment of professed data and application needs and a translation of those needs into GIS terms. These projections are not definitive estimates, but rather represent a model by which to compare operational alternatives and a tool for the state to use as system planning and implementation progress.

A list of the personnel that will be required to operate a GIS Service Bureau, given what is currently known regarding system needs, is represented in Figure 1. Following is a brief description of each staff position:

System manager - The system manager has primary responsibility for all administrative matters relating to the operation, maintenance and application of the GIS system and data base and the direction and overseeing of all other GIS staff. This person should have a comprehensive understanding of GIS applications and operations, a strong background in business administration and experience in regional planning or related fields. Experience in data base design and maintenance of a multiple-user operational data base would also be desirable.

Hardware/Software Administrator - Responsibilities of the hardware/software administrator include periodic maintenance and upkeep of all hardware system components, on-call hardware and software troubleshooting, acquisition and installation of additional peripheral components as needed, and regular back-ups of current system data. This person would also be responsible for maintaining records regarding all hardware warranties, license agreements, software update agreements and other documents germane to

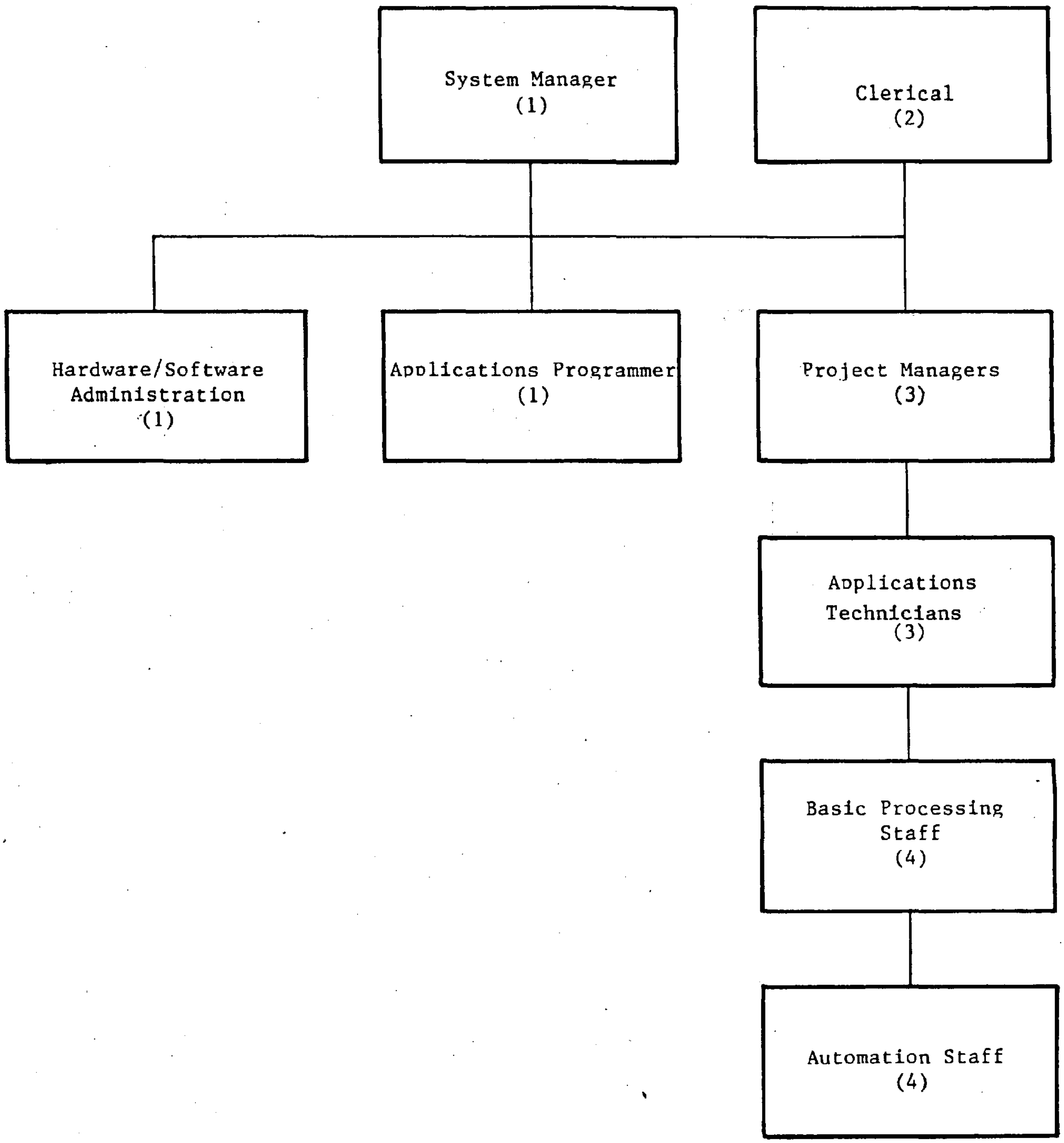


Figure 1

Service Bureau Organizational Chart

hardware/software administration and maintenance. Experience should include an extensive background in electronic data processing, administration or related fields, a working knowledge of one or more computer hardware concepts and maintenance. A background in GIS system administration, maintenance and application would also be especially desirable.

Project Managers - Project managers would be responsible for the day-to-day administration of all application and ongoing data maintenance projects. This generally would include contract administration, overseeing of data automation and ongoing data base maintenance, and application consulting for special projects. Under the direction of the system manager, project managers would also be responsible for the ongoing design and development of the data base, identification of additional hardware/software and special programming needs, and system resource allocations. They would be expected to prepare funding and project proposals, conduct dealings with client organizations or individuals, and prepare written reports. These persons should have an extensive background in natural resource planning, regional planning, geography, or related fields. They should also have a strong working knowledge of GIS application and operational data base maintenance concepts. Experience in needs assessment, data base design, job costing, and a wide variety of application projects would be especially helpful, as would some background in contract administration and project management, and the ability to communicate well, both orally and in witten form.

Applications Technicians - Applications technicians are responsible for technical administration and actual implementation of all data maintenance and application projects. In collaboration with project managers, these staff would be responsible for the development and implementation of data base automation and maintenance procedures and schedule, implementation of all project applications, and technical documentation of the data base and applications. They would also be responsible for overseeing and directing automation staff and would work directly with the hardware/software administrator to solve any technical difficulties which might arise. These technicians would be expected to work with applications programmers and project managers to develop procedures for special projects and ongoing standard applications. Applications technicians require a strong technical background in GIS applications and electronic data processing concepts and procedures. Some background in natural resource or planning fields is helpful. The technician must know operating system and GIS data base concepts and must possess an intimate working knowledge of the capabilities and installations of the GIS software to be applied. Some background in computer programming and programming concepts and practices is useful but not critical.

Applications Programmer - As the system matures, it will become evident that many repetitive and standard GIS applications can be more efficiently handled through the development of applications programs or "macros". Macros are strings of generic GIS tasks linked together to allow the user to perform repetitive or standard GIS tasks by the issuance of a single or series of simple prompted commands. The applications programmer, in collaboration with project managers and applications technicians, would be responsible for the conceptualization of special programming needs, including the translation of standard application or functional needs to a series of specific GIS tasks. This person is also responsible for implementation, testing and documentation of all developed macros. An applications programmer should have an extensive background in GIS applications, automation, management and data base design. He/she should also possess a good working knowledge of computer programming principles and practices and should be conversant in one or more programming languages. Experience with the specific operating system environment and GIS software to be applied is also helpful, although these can be learned fairly quickly by someone with previous GIS application programming experience. Previous experience in programming documentation, application needs assessment, and operational data base design and maintenance principles is also desirable.

Automation Staff - The primary responsibility of automation staff is the preparation, digitizing and keypunching of all map data and associated tabular information. Automation staff require training in various map preparation and automation procedures. Previous experience is desirable but not critical, as the necessary skills are relatively easy to learn. These persons should, however, possess an exceptional eye for detail and be able to carry out detailed procedures in an organized and systematic way.

Basic Processors - Basic processors typically consist of automation staff who have acquired enough system and procedural experience to carry out GIS data processing tasks beyond automation. Specific experience with basic GIS data processing techniques and procedures is helpful, as is exposure to general data processing and programming issues.

Clerical - Clerical staff are responsible for all secretarial and accounting functions pertaining to the operation and administration of the Service Bureau.

Hardware Configuration

The hardware configuration described here is designed to meet the operational needs of a Service Bureau based on assumptions stated earlier. The hardware listed is based primarily on application needs as presently known. No attempt has been made to quantify the ultimate size of the data base, as it was not possible to address the number and complexity of maps necessary to adequately represent complete statewide coverage for each data variable within the scope of the present study. It is, however, based on an assessment of stated GIS needs as they are currently known and extensive experience with the development of similar systems in other parts of the country. Again, the primary purpose of this design is to provide DPED with a framework to evaluate operational alternatives and a model to guide future GIS system planning and implementation efforts.

As illustrated in Figure 2, the basic equipment configuration consists of a mini-computer with a host of associated peripherals for GIS data entry, communications, storage, processing and output. The following is a brief description of each component:

PRIME Mini-Computer - The PRIME 9650 mini-computer is covered in this description. Other PRIME 50 series computers have identical functions but may have more or less capacity. The PRIME 9650 is a multi-user, multi-language, multi-application computer system that supports up to 96 interactive users simultaneously and up to 255 simultaneous active processes. The 9650 can handle anything from number-crunching scientific analyses to input/output oriented business data processing tasks and complex data communications applications. While it offers the ease of use and flexibility usually associated with small computer systems, the 9650 is equipped with features that place it in the performance class of mainframe computers.

It is designed around a 32-bit central processor architecture and comes with up to 8 million bytes of error-correcting main memory. Disk storage of as much as 2.4 billion bytes is available. Also, the 9650 is a virtual memory computer that gives each of its users as much as 32 million bytes of virtual storage.

The PRIME 9650 is a fully compatible member of the PRIME family of computers. The 9650 may run the same peripheral equipment and hardware interfaces as other PRIME computers. The same software programs which operate on other PRIME systems are guaranteed to run on the 9650 with no re-programming under PRIMOS, the operating system. PRIMOS was designed before the computers which it operates.

PRIMOS supports, on a concurrent basis, the following features and support tools:

- Multi-Lingual - FORTRAN, FORTRAN '77, COBOL, BASIC, PL/1 and RPG II, PASCAL and MACRO assembler
- Interactive Users
- Data Entry
- Batch
- RJE - IBM 2780 and HAPS, CDC UT200, UNIVAC 2004, and HONEYWELL CRTs
- DPTX (Distributed Processing Terminal Executive) - IBM 3271/3277 interactive compatibility
- Networking - Communication between processors and/or communication with computer networks
- DBMS - CODASYL complaint
- File Management System
- MIDAS - Multiple Index Data Access System
- FORMS - Forms Management System
- PRIME/POWER+ - Data Query and Reporting
- Source - Level Debugger
- Command Procedure Language (CPL)

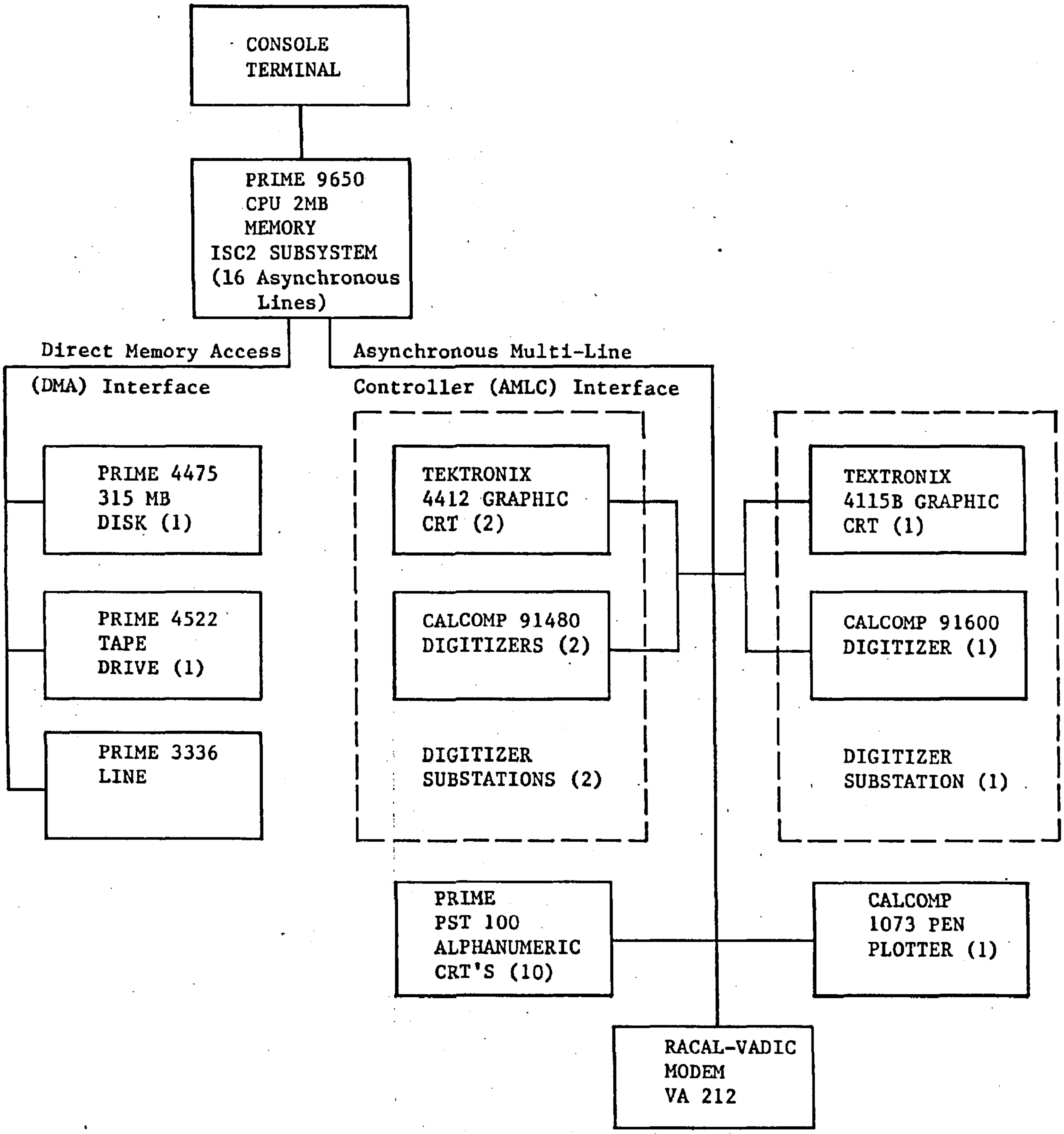


Figure 2

Basic Hardware Configuration
Service Bureau

The PRIME 2250 is sufficiently powerful to handle the current anticipated scope of GIS usage in the state. This model is designed to operate in a normal office environment with regard to its temperature and humidity requirements and quiet operation. An easy-to-use operator interface, start-up and diagnostics make it ideal for smaller office site installation. Experience has shown, however, that demand for GIS system services typically outpaces the capabilities of this smaller model in a short time. For this reason, the PRIME 9650 is recommended for initial hardware acquisition. Both are represented in the cost summary in a following section. Space and operating environment specifications for both models are illustrated in Appendix B.

Data Storage Devices. - For on-line retrieval of data, a PRIME 4475 single 315 (300 MB if removable disk packs are used) megabyte (MB) disk drive has been included. This disk drive supplied by PRIME is made by Control Data Corporation and has a data transfer rate of 1.2 MB per second with an average access time of 30 milliseconds. Additional disk drives up to a total of four 315 MB drives on one controller may also be added. Again, a single 315 MB disk will accommodate all initial applications, but will probably prove inadequate in the near future. As described, however, this on-line storage medium is easily expanded by installation of additional drives.

For off-line and archival data storage, a PRIME tape drive is indicated. The Model 4522 high performance drive features 800/1600 bits per inch (BPI) 9-track recording at 75 inches per second. Vacuum column tape transport mechanisms make this drive very reliable. By means of the tape drive, data can be stored off-line on magnetic tape and loaded to the system only when needed. This cuts down expense related to maintenance of all data on-line and provides relatively inexpensive and quality storage medium for large amounts of data.

Line Printer - A line printer is used to produce fast hard copy of alphanumeric information for tabular reporting, programming code copy, text drafts and a host of other applications. The PRIME Model 3336 serial data matrix printer supplied with the PRIME system offers 300 lines per minute (LPM), 132 characters per line performance, the standard 96 character ASCII set with both 6 LPI and 8 LPI are supported. All FORTRAN carriage controls, including over-printing, are supported.

Alphanumeric Computer Terminals - Alphanumeric computer terminals will be asked by GIS staff to enter and edit tabular data, conduct processing tasks and word processing.

The PRIME PST 100 System Terminal CRT is an alphanumeric terminal which allows several user options, including:

- Half or full duplex
- Baud from 110 to 9600
- Standard or reverse video
- Upper-lower case
- Parity set to odd or even
- Automatic repeat on keyboard characters
- Numeric pad

Tektronix 4115B Color Graphic Display Terminal (CRT) - The Tektronix 4115B is a raster scan CRT with an 8.6 x 11 inch display area. It is typically used both for interactive digitizing/editing as well as color graphic display of various data files or output runs. Features of the 4115B include:

- 4 billion by 4 billion addressable points (1280 x 1020 viewable)
- Full 94-character ASCII characters displayable
- Graphic crosshair cursor, zoom, pan, scrolling
- Hard copy compatibility
- 8 user definable programmable function keys
- Firmware options for expansion of graphics memory for local symbols, gray scale, overlays or background graphics

The Tektronix Plot 10 software Terminal Control System, Interactive Graphics Library and Easy Graph package allow full use of this unit's versatility. The high resolution speed and graphic features of this terminal make it an excellent choice for display of high quality graphics. It is proposed that this terminal be linked to a digitizing table as part of a digitizing work station. This will allow the terminal to be fully utilized when not being used for graphic display.

Tektronix 4112 Monochrome Graphic Display Terminal - The Tektronix 4112 is a raster scan CRT with an 8.6 and 11.5 inch display area. This terminal will be linked to a digitizing table as part of an interactive digitizing work station. Its monochromatic display is adequate for interactive digitizing/editing and can be used for black and white display of data files and output runs. Features of the 4112 include:

- 4096 x 4096 addressable points (640 horizontal by 480 vertical points)
- Full 94-character ASCII characters displayable
- Graphic crosshair cursor, zoom, pan, scrolling
- Hard copy compatibility
- 8 user definable programmable function keys

The Tektronix Plot 10 Software Terminal Control System, Interactive Graphics Library and Easy Graph package can be used with 4112.

Digitizing Table - Spatial geographic data are entered into the computer through the use of a digitizer, a backlit light table to which is attached a movable cursor. As the cursor is moved horizontally and vertically over a map mounted to the digitizing table, electronic devices translate these movements into digital measurements in units of one one-thousandth of an inch. Digitizing is described in some detail in part C of Chapter IV. The digitizing tables proposed here are the CALCOMP 91600 and 91480 models. The CALCOMP 9100 series digitizing tables are reliable, stable and versatile in design. Design techniques eliminate drift due to power and temperature fluctuation and component ageing. No periodic maintenance or alignment is required due to the all-electronic design of the tables. Mode select and clear switches as well as proximity, margin and pen-down indicators are conveniently located on the digitizer table. The active surface area of the CALCOMP 91600 and 91480 tables are 44" x 60" and 36" x 48" respectively.

Pen Plotter - A pen plotter is used to produce high quality map and graphic output from the system. The CALCOMP 1073 Pen Plotter chosen for this application is a highly versatile drum plotter with 34 inch wide plot area. It has servomotor pen position devices and 0.001 inch pens, felt tip markers, or liquid ink pens. The controller allows on-line connection to the PRIME CPU with automatic detection and correction of transmission errors with data rates up to 9600 BAUD. The unit has a 2K memory buffer that allows interruptions of data transmission without loss of data. Vector character circle, arc and dashed line generation functions are internal to the controller. Paper is supplied to the drum by a continuous roll up to 150' in length. The completed plots are fed through the front of the plotter so as to be accessible while the unit is generating the next plot.

Modems - Modems are devices which allow data communication via phone lines. There are a number of modems which provide the 300/1200 baud capability required. Recent communication technology advances and price competition have provided a number of technically adequate cost-effective units. Information on Racal-Vadic Model VA 212 Modem is provided in Appendix B along with brochures on the equipment described above.

Service Bureau Cost Summary

The following cost summaries for personnel, software, and hardware to operate and maintain the GIS Service Bureau in the State of Hawaii are based on assumptions stated earlier. All personnel and hardware requirement estimates are based on need as expressed in the course of the current user needs assessment. These estimates are intended to provide an evaluation model to guide DPED in any future GIS development efforts.

Table 3

Personnel Cost Schedule

Service Bureau

Number	Personnel Type	*Md/Yr	Total Md	Approximate Average Salary/Yr	Salary Commitment
1	System Manager	250	250	$40,000	$40,000
1	Hardware/Software Administrator	250	250	35,000	35,000
3	Project Managers	250	750	28,000	84,000
1	Applications Programmer	250	250	26,000	26,000
3	Applications Technicians/ Processors	250	750	25,000	75,000
4	Basic Processing Staff	250	1,000	14,000	56,000
2	Clerical Staff	250	500	12,000	24,000
4	Automation Staff	250	1,000	11,000	44,000
		Total:	4,750		$384,000

*Md = Man-Days

Table 3 is a summary of projected personnel costs, given the staffing level described earlier. Salary amounts are based on averages for similar positions throughout the country. No attempt has been made to adjust these amounts to reflect relative cost of living in Hawaii or other organizational salary or overhead cost parameters which might pertain.

The GIS software modules listed here have been developed or are distributed by ESRI. These systems were used to carry out all automation and manipulation tasks for the pilot study data base and demonstrations described later. Costs listed below reflect current prices of the basic ESRI software modules. The modules are described in some detail in Appendix C of this report.

Table 4 is a summary of projected software costs. Optional software components are included where appropriate, consisting of capabilities which, although not currently needed, may become desired additions as the GIS user community in Hawaii grows.

Estimated hardware costs for a Service Bureau facility are represented in Table 5. Hardware components have been chosen for both quality of product and service.

In summary, personnel, software and hardware costs for this Service Bureau alternative along with the User Network approach are illustrated in Table 14.

User Network Alternative

Description and Issues

The second operational alternative described here for consideration by DPED is conceptually labeled a "User Network" approach. In this scenario each organization contributing data to the system is responsible for entry and maintenance of its own information. A Central GIS Group (CGG) would be responsible for overseeing the archive data base and primary hardware and software components which would remain centralized. Organizations contributing data to the system and requiring substantial use of applications capabilities would maintain equipment, staff and data communications peripherals to do so. Organizations requiring only sporadic or one-time use of the system could contract services from one of the participating agencies or from the Central GIS Group. Financially the User Network might be supported through a system subscription arrangement and various application and data maintenance contracts.

As with a Service Bureau a User Network also has its advantages and disadvantages. The network approach generally may require less inter-agency cooperation. With decentralization of many functions, it would be necessary to replicate various hardware and staff at each primary location, thus losing the economies inherent in a centralized facility. By maintaining these staff and hardware, each participating agency reserves the ability to allocate its own GIS resources in-house according to its own priorities, although both staff and hardware will probably not be fully utilized for GIS

Table 4

Software Cost Schedule

	Basic Software ($)	Optional Software ($)
ARC/INFO[1]	$75,000	
Annual Update Fee[2]	8,200	
NETWORK	10,000	
GRID and GRID/TOPO	30,000	
COGO[3]		$10,000
ELAS[3]		5,000
MINITAB[3]		1,100[4]
ERDAS[3]		35,000
Total:	$123,200	$174,300

[1] ARC/INFO, GRID and GRID/TOPO purchased together subtract $10,000

[2] First year of updates included in base price.

[3] Optional Software Module

[4] Annual License Fee

Table 5

Hardware Cost Schedule

Service Bureau

Unit	Number	Cost/ Unit	T o t a l
PRIME 9650 CPU	1	$148,900	$148,900
PRIME ICS2 Subsystem (16) asynchronous lines)	1	Included	-0-
PRIME 4475 315 MB Disk Drive	1	Included	-0-
PRIME 4522 800/1600 BPI 75 IPS Tape Drive	1	18,500	18,500
PRIME 3336 Line Printer	1	11,000	11,000
TEKTRONIX 4115B Graphic CRT	1	22,950	22,950
TEKTRONIX 4112 Graphic CRT	2	6,500	13,000
CALCOMP 91600 Digitizer (44" x 60")	1	10,412	10,412
CALCOMP 91480 Digitizer (36" x 48")	2	9,092	18,184
PRIME PST 100 Alphanumeric CRT	10	1,250	12,500
CALCOMP 1073 Pen Plotter	1	17,000	17,000
RACAL-VADIC PA212 300/1200 Autodial Modem	1	695	695
		Total:	$273,141

tasks by any single agency. Since more than one agency organization will be responsible for the creation and maintenance of the archive data base, it will be important to establish standardized procedures for data compilation and integration, automation, structuring of final files and data maintenance. The CGG would be required to exercise a certain level of quality control, although the primary responsibility for this function would be maintained by each contributing agency.

Selected staff from each primary user agency would require training in the maintenance and application of GIS technology. Since these staff will probably not be fully occupied with GIS responsibilities, it will be necessary for them to maintain other functions within the organizations as well. The possible lack of focus and divided responsibilities of this arrangement can make it difficult for staff to establish and cultivate a high degree of proficiency with the system, necessitating periodic assistance from the central group, especially for advanced applications. This issue and other factors, such as employee turnover, will make it necessary to establish a regular program of refresher courses and training sessions to maintain proficiency among the various individuals accessing the system.

Again, it must be pointed out that the ultimate efficiency of a GIS is how well it works for the user. A system which allows the user to work directly with the data base will ultimately be more efficient than a system which does not. This fact must be taken strongly into consideration when weighing the choices.

Personnel Requirements

The User Network system, like the Service Bureau, would initially be used by the same core group of state agencies mentioned earlier. This study, which concentrated on ocean data users, was not comprehensive enough to be used as a design for a state multi-agency network system.

Despite the limitations of the study, two approaches to the User Network system design have been developed. The first is a Hypothetical Intergovernmental Agencies System using the information gathered in the interviews conducted during the course of the study. While the system described might not be practical, it does show a method for arriving at personnel and equipment requirements using the interview results. The second approach was to draw up a more likely State Agencies System based in part on information gathered during the interviews and in part on informal discussions with others in the state government, both during the interview process and during the demonstration phase of the study.

Table 6 gives a breakdown of the estimated manpower requirements for each agency by task based on the data needs, uses and desires determined during the interview phase. The result is manpower requirements both by agency and by task for the Hypothetical Intergovernmental Agencies System. Table 7 gives an estimation of these same requrements for a State Agencies System. From this information, hardware requirements and actual departmental

Theoretical GIS Personnel Demand Projections by Task
(values expressed in man-days/year)

	Tabular Data	Cartographic Data							Display	Bibliographic Data		
		Generation/Storage	Manipulation/Analysis									
			Geometric Analysis	Network Analysis	Digital Surface Modelling	Query	Composition	Presentation				
	1	2	3	4	5	6	7	8		9		
	Field Measurement/Observation Retrieve Existing Tabular Data Compilation on Forms Data Entry/Edit Update Storage/Management Data Manipulation Statistical Analysis On-Line Query Report Generation	Air Photo Interpretation Gather Existing Map Data Field Survey (Sampling) Drafting/Compilation on Maps Digitize/Edit Traverse Entry/Cogo Cartographic Data Update Map Join/Edge Match Storage/Management	Polygon Overlay Line in Polygon Vector/Cell Conversion Polygon Dissolve Point in Polygon Polygon to Point Analysis Transformations Buffer/Corridoring Windowing Coordinate Filtering Proximal Analysis Line Length Calculation Area/Perimeter Calculation Aggregation/Districting Contiguity Analysis	Distance Accumulation Area to Network Accumulation Optimal Path Selection Flow Simulation Time/Distance Computation	Spatial Interpolation Contouring Slope/Aspect Sun Intensity Viewshed Road Engineering Design Volume Calculation Cross Sectioning 3-D Viewing	Spatial Query Attribute Query	Generalization Scale Change Modify Features/Text Graphic Superimposition	Symbolize Points Symbolize Lines Symbolize Polygons Text/Annotation Display Legends Modify/Update Features/Text		Indexing Storage Retrieval	GIS Personnel Requirement Summary by Agency	Percent of Total
USGS	15	120	10	5	5	10	10	15		5	195	5%
Army Corps	15	75	10		5	20	5	5		45	180	5%
DPED Ocean Resources	55	40	90		20	40	20	20		95	380	10%
Coastal Zone Management	35	115	110	30	35	230	35	30		120	740	20
DPED Land Use Commission	10	20	20	10		45	25	30		20	180	5%
DPED Land Use Division	5	5	90			120	25	20		35	300	8%
Division of Land Management	15	20	10			65	5	5		30	150	4%
DLNR Division of Aquatic Resources	40	10	5			80	5	5		35	180	5%
DOT Harbor Division Planning	10	25				20	5	10		5	75	2%
Department of Health OEQC			5			50	5	5		10	75	2%
U.H. Oceanography			15		5	15	5	5		30	75	2%
U.H. Look Laboratory	3	2	6			5	2	2		15	35	<1%
C & C Public Works	80	230	200	80	10	80	40	40		20	780	21%
C & C Civil Defense	2	2	10	10		1	2	3			30	<1%
HECO	5	4	10		1	5	2	3		5	35	<1%
Sierra Club	1	2			7	24	4	7		30	75	2%
Private Developers and other Special Applications	25	40	80	15	15	15	15	20		40	265	7%
GIS Functional Requirement Summary	316	710	671	150	103	825	210	225		540	3,750 MD	
Percent of Total	8%	19%	18%	4%	3%	22%	6%	6%		14%	1,000 MD	
											4,750 MD	

Table 6

Theoretical GIS Personnel Demand Projections by Task (values expressed in man-days/year)

	Tabular Data	Cartographic Data	Cartographic Data Manipulcation Analysis					Display Presentation	Bibliographic Data	Summary	%
		Generation Storage	Geometric Analysis	Network Analysis	Digital Surface Model	Query	Composition				
DPED	105	180	310	40	55	435	105	100	270	1600	39.5
DOT	100	200	150	50	75	350	50	100	75	1150	28.3
DLNR	50	75	50	25	50	75	25	100	75	525	13.0
DAGS Survey	50	100	50		50	50	100	50		450	11.1
Hawaiian Homes			10	5	10	70	15	25	15	150	3.7
Dept. of Agriculture			5	5	5	60	5	5	15	100	2.5
Dept. of Health/OEQC			5			50	5	5	10	75	1.9
	305	555	580	125	245	1090	305	385	460	4050	100
	7.5	13.7	14.3	3.1	6.1	26.9	7.5	9.5	11.4	100	

Table 7
State Agencies GIS Personnel Demand Projections by Task by Agency
(Values expressed in man-days/year)
(Does not include central system or management time)

personnel requirements have been drawn. Since the Central GIS Group does not perform task analysis, its personnel and managment time requirements are not included on Tables 6 and 7. However, the personnel and hardware requirements for the CGG are included on Tables 8,9,10,11 as there does need to be provision for that facility and its management within the User Network System. Users have been broken down into three groups: 1) primary users, those agencies requiring substantial use of the GIS and therefore able to maintain most staff and hardware resources in-house; 2) secondary users making more limited use of the system who will maintain certain resources in-house while contracting others to the central GIS group; and 3) tertiary users, typically sporadic or one-time users who may contract most or all of their GIS needs to others.

Hardware Requirements

The hardware configurations described are for both the Hypothetical Intergovernmental Agencies System and State Agencies System and are designed to meet the operational needs of the GIS user network, given all the assumptions stated earlier. Table 8 lists the basic functional capabilities and necessary hardware for each agency or organization in the Hypothetical Intergovernmental Agencies System. Table 9 does the same for the State Agencies System.

The limited scope of the current user needs assessment has confined the analysis of potential system usage to a small segment of probable GIS users within the State of Hawaii. This in turn has limited the exploration of alternative hardware configurations for a GIS network to those which are economically and functionally feasible within these narrow limits. Another option to consider as system usage grows is the establishment of small, separate systems in the offices of each of the primary users. As basic data would be automated or updated at each secondary system, they could be transferred via magnetic tape to the primary GIS, which would still maintain a central archive data base. A physical library of magnetic tapes could be established to allow system users access to a variety of data which could be installed on their own system for use as needed. This would reduce the time factor and uncertainty of transferring data over phone lines as would be the case for facilities not physically connected, and would enable each secondary system to operate autonomously.

User Network Cost Summary

The cost summaries for personnel, software and hardware to operate and maintain a GIS User Network in the State of Hawaii are based on assumptions stated earlier and are intended to serve as a model to guide the state in any future GIS development efforts.

Table 10 summarizes projected personnel cost for the Hypothetical Intergovernmental Agencies System, while Table 11 does the same for the State Agencies System. Salary amounts are based on averages for similar positions throughout the country and have been further averaged to account for existing staff carrying out various levels of GIS tasks in-house. No

		PRIME 9650 CPU	PRIME 675 MB DISK DRIVE 4490	PRIME TAPE DRIVE 4522	PRIME LINE PRINTER 3336	TEKTRONIX 4115B GRAPHIC CRT	TEKTRONIX 4112 GRAPHIC CRT	CALCOMP DIGITIZER 44" x 60" 91602	CALCOMP DIGITIZER 36" x 40" 91482	PRIME PST 100 ALPHANUMERIC CRT	CALCOMP PEN PLOTTER 1073	RACAL-VADIC MODEM PA212			
PRIMARY USERS	DPED Central GIS Group	1		2	1	1	1	2		4	2	4			
	DPED Ocean Resources						1		1	3					
	Coastal Zone Management						1		1	4					
	City and County Public Works						1	1	1	5	1	2			
SECONDARY USERS	USGS								1	2		1			
	Army Corps								1	2		1			
	DPED Land Use Commission									2		1			
	DPED Land Use Division									2		1			
	DLNR Division of Aquatic Resources									2		1			
	Private Developers														
TERTIARY USERS	Division of Land Management									2		1			
	DOT Harbor Division Planning														
	Department of Health OEOC									1		1			
	U.H. Oceanography									1		1			
	U.H. Look Laboratory														
	C & C Civil Defense														
	HECO														
	Sierra Club									1		1			
		1		2	1	1	4	3	5	31	3	15			

Table 8
Hypothetical Intergovernmental Agencies System
Hardware Schedule

		PRIME 9650 CPU	PRIME 675 MB DISK DRIVE 4490	PRIME TAPE DRIVE 4522	PRIME LINE PRINTER 3336	TEKTRONIX 4115B GRAPHIC CRT	TEKTRONIX 4112 GRAPHIC CRT	CALCOMP DIGITIZER 44" x 60" 91602	CALCOMP DIGITIZER 36" x 40" 91482	PRIME PST 100 ALPHANUMERIC CRT	CALCOMP PEN PLOTTER 1073	RACAL-VADIC MODEM PA212			
PRIMARY USERS	Central GIS Group	1		2	1	1		1		3	1	4			
	DPED					1			1	7	1	4			
	DOT					1	1	1	1	6	1	3			
	DLNR						1		1	5	1	5			
SECONDARY USERS	DAGS Survey						1		1	1	1				
	Hawaiian Homes						1			1		1			
	Dept. of Agriculture						1			1		1			
TERTIARY USERS	Dept. of Health/OEQC									2		2			
		1	2	1	4	4	2	4	26	5	20				

Table 9
State Agencies System Hardware Schedule

User Group	Agency	PERSONNEL TYPE	# STAFF	PERCENT COMMITMENT	TOTAL MAN-DAYS/YEAR	AVERAGE SALARY COST PER MAN-DAY	SALARY COMMITMENT
PRIMARY USERS	DPED Central GIS Group	Management	2	100%	500	130	65,000
		Applications	2	100%	500	100	50,000
		Automation	3	50%	375	56	21,000
			subtotal 7		1,375		136,000
	DPED Ocean Resources	Management	1	10%	25	130	3,250
		Applications	3	25%	188	100	18,800
		Automation	3	30%	225	56	12,600
			subtotal 7		438		34,650
	Coastal Zone Management	Management	1	25%	62	130	8,060
		Applications	5	30%	375	100	37,500
		Automation	5	30%	375	56	21,000
			subtotal 11		812		66,560
	City and County Public Works	Management	1	25%	62	130	8,060
		Applications	5	30%	375	100	37,500
		Automation	5	40%	500	56	28,000
			subtotal 11		937		73,560
SECONDARY USERS	USGS	Management	1	10%	25	130	3,250
		Applications	3	10%	75	100	7,500
		Automation	2	30%	150	56	8,400
			subtotal 6		250		19,150
	Army Corps	Management	1	5%	12	130	1,560
		Applications	2	20%	100	199	10,000
		Automation	2	20%	100	56	5,600
			subtotal 5		212		17,160
	DPED Land Use Commission	Management	1	5%	12	130	1,560
		Applications	2	35%	175	100	17,500
		Automation	0	0	0	56	0
			subtotal 3		187		19,060
	DPED Land Use Division	Management	1	5%	12	130	1,560
		Applications	2	60%	300	100	30,000
		Automation	0	0	0	56	0
			subtotal 2		312		31,560
	DLNR Division of Aquatic Resources	Management	1	5%	12	130	1,560
		Applications	2	25%	125	100	12,500
		Automation	0	0	0	56	0
			subtotal 2		137		14,060
	Private Developers	Management	0	0	0		0
		Applications	0	0	0		0
		Automation	0	0	0		0
			subtotal 0		0		0
TERTIARY USERS	Division of Land Management	Management	0	0	0	130	0
		Applications	2	30%	150	100	15,000
		Automation	0	0	0	56	0
			subtotal 2		150		15,000
	DOT Harbor Division Planning	Management	0	0	0	130	0
		Applications	0	0	0	100	0
		Automation	0	0	0	56	0
			subtotal 0		0		0
	Department of Health OEQC	Management	0	0	0	130	0
		Applications	2	20%	100	100	10,000
		Automation	0	0	0	56	0
			subtotal 2		100		10,000
	U.H.Oceanography	Management	0	0	0	130	0
		Applications	2	20%	100	100	10,000
		Automation	0	0	0	56	0
			subtotal 2		100		10,000
	U.H. Look Laboratory	Management	0	0	0	130	0
		Applications	0	0	0	100	0
		Automation	0	0	0	56	0
			subtotal 0		0		0
	C&C Civil Defense	Management	0	0	0	130	0
		Applications	0	0	0	100	0
		Automation	0	0	0	56	0
			subtotal 0		0		0
	HECO	Management	0	0	0	130	0
		Applications	0	0	0	100	0
		Automation	0	0	0	56	0
			subtotal 0		0		0
	Sierra Club	Management	0	0	0	130	0
		Applications	2	15%	75	100	7,500
		Automation	0	0	0	56	0
			subtotal 2		75		7,500
		TOTAL	62		5,085		454,260

Table 10
Hypothetical User Network Personnel Cost Schedule

	PERSONNEL TYPE	STAFF	TOTAL	PERCENT COMMITMENT	TOTAL MAN-DAYS/YEAR	AVERAGE SALARY COST PER MAN-DAY	SALARY COMMITMENT
Central GIS Group	Management	2		100%	500	130	65,000
	Applications	2		100%	500	100	50,000
	Automation	3		50%	375	56	21,000
	Total		7		1,375		136,000
DPED	Management	4		10%	100	130	13,000
	Applications	12		30%	900	100	90,000
	Automation	8		30%	600	56	33,600
	Total		24		1,749		136,600
DOT	Management	3		20%	150	130	19,500
	Applications	6		40%	600	100	60,000
	Automation	6		35%	525	56	29,400
	Total		15		1,275		108,900
DLNR	Management	4		10%	100	130	13,000
	Applications	5		20%	250	100	25,000
	Automation	5		20%	250	56	14,000
	Total		14		600		52,000
DAGS Survey	Management	1		20%	50	130	6,500
	Applications	1		50%	125	100	12,500
	Automation	1		50%	125	56	7,000
	Total		3		500		26,000
Hawaiian Homes	Management	1		4%	10	130	1,300
	Applications	2		30%	150	100	15,000
	Automation						
	Total		3		160		16,300
Dept. of Agriculture	Management	1		4%	10	130	1,300
	Applications	2		20%	100	100	10,000
	Automation						
	Total		3		110		11,300
Department of Health/OEQC	Management	1		4%	10	130	1,300
	Applications	2		15%	75	100	7,500
	Automation						
	Total		3		85		8,800
	TOTAL		72	32.5%	5,854	84	495,900

Table 11
State Agencies System
Personnel Cost Schedule

Table 12

Hardware Cost Schedule

Hypothetical Intergovernmental Agencies System

Unit	Number	Cost/ Unit	Total
PRIME 9650 CPU	1	$136,500	$136,500
PRIME ICS2 Subsystem (48 asynchronous lines)	1	20,300	20,300
PRIME 4490 675 MB Disk Drive	Included	-0-	-0-
PRIME 4522 800/1600 BPI 75 IPS Tape Drive	2	18,500	18,500
PRIME 3336 Line Printer	1	11,000	11,000
TEKTRONIX 4115B Graphic CRT	1	22,950	22,950
TEKTRONIX 4112 Graphic CRT	4	6,500	6,500
CALCOMP 91600 Digitizer (44" x 60")	3	10,412	31,236
CALCOMP 91480 Digitizer (36" x 48")	5	9,092	45,460
PRIME PST 100 Alphanumeric CRT	31	1,250	38,750
CALCOMP 1073 Pen Plotter	3	17,000	51,000
RACAL-VADIC PA212 300/1200 Autodial Modem	15	695	10,425
		Total:	$430,621

Table 13

Hardware Cost Schedule

State Agencies System

Unit	Number	Cost/ Unit	Total
PRIME 9650 CPU	1	$136,500	$136,500
PRIME ICS2 Subsystem (48 asynchronous lines)	1	20,300	20,300
PRIME 4490 675 MB Disk Drive	Included	-0-	-0-
PRIME 4522 800/1600 BPI 75 IPS Tape Drive	2	18,500	37,000
PRIME 3336 Line Printer	1	11,000	11,000
TEKTRONIX 4115B Graphic CRT	4	22,950	91,800
TEKTRONIX 4112 Graphic CRT	4	6,500	26,000
CALCOMP 91600 Digitizer (44" x 60")	2	10,412	20,824
CALCOMP 91480 Digitizer (36" x 48")	4	9,092	36,368
PRIME PST 100 Alphanumeric CRT	26	1,250	32,500
CALCOMP 1073 Pen Plotter	5	17,000	85,000
RACAL-VADIC PA212 300/1200 Autodial Modem	20	695	13,900
		Total:	$511,192

attempt has been made to adjust these amounts to other organizational or overhead cost parameters which might pertain. Initial software costs for the User Network would be identical to those identified in the Service Bureau alternative. For reference see Table 4.

Estimated hardware costs are summarized in Tables 12 and 13. Several assumptions have been made in choosing particular manufacturers and models represented in this configuration. The PRIME 9650 CPU is substantially more powerful than will be needed by the system initially. Experience has shown, however, that system demand typically grows quickly and it is anticipated that the 9650 will be able to meet most demands for two to four years. The ICS2 subsystem is easily expanded to handle additional user terminals and peripherals. The ICS2 subsystem components have been configured here to handle up to 48 lines. A single PRIME 4490 675 MB disk drive is specified to accommodate the greater need for on-line data access and retrieval by remote users. The purchase of a single 675 MB disk is more cost-effective than purchasing two 315 MB disks.

In summary, personnel, software, and hardware costs for the Service Bureau, the User Network System including the Hypothetical Intergovernmental Agencies and State Agencies System are illustrated in Table 14.

Additional Information

A ESRI Geographic Information System Software User and Equipment List is provided in Appendix D. In addition, brochures covering the following vendors of Geographic Information software, are provided in Appendix E. The vendors are: Autometric Incorporated (MOSS), Comarc Systems, Erdas, Inc., Intergraph Corporation and Synercom.

B. CONCEPTUAL DATA BASE STRUCTURE

During the course of the user needs assessment, various data sets were identified by interviewees for possible inclusion in a statewide data base. The total list of these is included in the needs assessment summary document. Those which were available for the area of land and ocean lying roughly between Kahe Point and Barbers Point in southwest Oahu were collected for inclusion in the pilot study data base which was automated for demonstration purposes. An assessment of these data provided a basis for the development of a conceptual data base structure to provide a framework and model for future data base development in the state. The conceptual structure represented here encompasses two important components; a data and application component and a spatial indexing component.

Application Levels

Data collected for the pilot study came from over 53 data bases and existed in 22 different scales (Table 15). This fact alone underscores the

Table 14

Summary

Cost Schedule

	Service Bureau	Hypothetical Intergovernmental Agencies System	State Agencies System
Initial Investment			
Software	$123,200	$123,200	$123,200
Hardware	273,141	430,621	511,192
Outside Technical Assistance (Range $90,000 to $300,000)	150,000	150,000	150,000
Total:	$546,341	$703,821	$784,392
Annual Cost			
Salaries	$384,000	$454,260	$495,900
Software Maintenance	9,300	9,300	9,300
Hardware Maintenance	32,777	51,675	61,343
Total:	$426,077	$515,235	$566,543

	Data Source	Variable	Data Form	1"=100' 1:1200	1"=200' 1:2400	1"=300' 1:3600	1"=400' 1:4800	1"=492' 1:5904	1"=500' 1:6000	1"=533' 1:6396	1"=600' 1:7200	1"=700' 1:8400	1"=800' 1:9600	1"=1000' 1:12000	1"=1146' 1:13,752	1"=2000' 1:24000	1"=5208' 1:62,500	1"=8333' 1:100K	1"=10K' 1:120K	1"=10,417' 1:125K	1"=2.8 mi 1:144,230	1"=5 mi 1:316.8K	1"=10 mi 1:633.6K	1"=12 mi 1:760.32K	1"=27 mi 1:1,710.7K
Federal	Army Corps of Engineers - Oahu Coral Reef Inventory (OCRI)	Shore Type	Poly						•			•													
		Detailed Coastline	Poly						•			•													
		Offshore Bottom Type	Poly						•			•													
		Use	Point						•			•													
		Bibliography of Surveys/Studies	Tab.						•			•													
	- Sandy Shoreline Inventory	Shoreline Inventory	Ll/Po			•																			
	U.S. Department of Energy	Water Sampling Points	Point																•						
		Zooplankton Sampling Points	Point																•						
		XBT Sampling Points	Point																•						
	USGS - 7½' and 15' Topographic Quadrangles	Streams	Line													•	•								
		Topography	Ll/Po													•	•								
		Transportation	Line													•	•								
		Nearshore Bathymetry	Ll/Po													•	•								
		Generalized Coastline	Poly														•								
	- Water Resources Data Report	Gauging Stations	Point																			•		•	
		Observation Wells and Water Quality Sampling Sites	Point																			•		•	
	- Oahu Geology Map	Geology	Poly														•								
	- OTEC Geology Report	Bathymetry	Ll/Po			•																			
	SCS Soils Maps	Soils	Poly													•									
	NOAA National Ocean Survey	State Map	Poly																				•		
City and County	Tax Maps Branch	Tax Map Index Sheet First Division (Oahu)	Poly																•						
	Public Works	Development Plan Public Facilities	Ll/Po Point											•											
		Development Plan Land Use	Poly											•											
		Zoning	Poly				•																		
		Existing Land Use	Poly				•																		
		Special Management Areas	Poly													•									
	Parks and Recreation	Beach Parks and Rights of Way	Line																						
	Land Utilization	Floodways	Poly											•											
		Flood Insurance Rate Maps (Firm)	Ll/Po											•											
		Flood Map Index	Poly																	•					
	Civil Defense	Tsunami Inundation	Poly															•							
State		Parcel Maps	Poly	•	•				•					•											
	DPED	Solar Regimes	Po/Ll															•							
		Beach Change Transects	Line			•	•							•	•	•									
	DLNR-Division of Aquatics	Fisheries Chart	Poly																						•
	DLNR-Division of Water and Land Development	Median Annual Rainfall	Po/Ll																		•				
		DLNR Observation Wells	Point	(Latitude/Longitude Coordinates)																					
Institutional	University of Hawaii - Meteorology Department	Meteorology Station Locations	Point																				•		
		Land Surface Form	Poly																				•		
		Annual Average Wind Power	Ll/Po																				•		
		Seasonal Wind Power	Ll/Po																				•		
	Institute of Geophysics	Tsunami Wave Runup Heights	Poly														•								
	Columbia University Lamont-Doherty Geological Observatory	DSV Turtle Dive Tracks	Line			•	•		•						•	•									
Private	HECO	Sediment Test Rod Location	Point		•																				
		Benthic Recording Locations	Point					•																	
		Coral Reef Changes	Poly					•																	
		Algal Abundance	Poly					•																	
		Coral and Algae Test Stations	Point					•																	
		Temperature Plumes	Poly							•															
		Sediment Profile Locations	Line								•														
		Nearshore Surface Temperatures	Point												•										
	E.K. Noda and Associates	Nearshore Bathymetry	Ll/Po			•																			
	Air Photo Tech., Inc.	Natural Color Aerial Photographs														•									

Table 15

Data Collected for Pilot Study

diversity of data compilation and application that occur at every level of government and private industry in the state and the lack of integration of this information that currently occurs. As a result many interviewees complained of difficulties in trying to compare or simultaneously use information in these multitudes of scales.

Generally data had been collected and drafted at a scale and in a form most useful to the organization that had compiled it. Such factors as standard sheet sizes, data resolution and geographic coverage were found to determine the scales and sizes of maps.

Several important considerations were used to guide the development of the conceptual data base structure presented here:

- The application of a multiple-user data base of geographic information requires that data exist in a form and resolution to accommodate the majority of these users.

- Although data in an automated form can be manipulated and output at any scale, it is very important that automated map information be structured in the data base logically by application level. For example, parcel data should be structured to be applied at the same level as other information related by resolution or boundaries, such as "Beach Parks" or "Development Plan Land Use." Conversely, parcel data should not be structured or applied, for instance, with "Rainfall Regimes" data for the Island of Oahu; any application using the two would provide relatively meaningless results unless, for example, parcels were aggregated to some level of generalization that would be compatible with the generalized rainfall regimes.

- Where possible, boundaries of map data which are spatially related should be integrated. For instance, the boundary of a beach park should coincide with the boundaries of the tax map parcel it corresponds to.

Often these interrelationships are not reflected when geographic features are mapped independently. Differences in interpretation, mapping scale, purpose and methods can result in variations in the mapped delineation of data elements which functionally and logically should be wholly or partially coincidental. Where data elements to be automated and integrated to a data base have been mapped independently, it is often necessary to establish an intermediate integration process prior to automation.

An integrated mapping process resolves some major obstacles to the computerized handling of spatially defined environmental information: the cost of automating multiple parametric data planes; the cost of doing polygon overlays in the computer; the problem of polygon "splinters" created through the overlay process; and perhaps most important, the problem of mismatched data sets which are supposed to be related and consistent. In many respects the latter point represents the ultimate argument for the integration process. When analysis involving overlay is done in a data base, the mismatches among the data planes can cause major errors to surface across the mapped output. Differentiating between the valid and invalid values which are thus registered is difficult and often impossible. Using computer logic to resolve the discrepancies once the data are automated represents a coarser and less sensitive means than careful decision-making on a case-by-case basis by an experienced resource specialist with photos, basemaps and related maps at hand.

Cost considerations relate to the considerable amount of staff-time and machine-time required to effectively automate and then overlay a number of maps in the computer. The cost of data base automation is a function of the number of maps to be automated and the complexity of the features on those maps. If a number of features are common to every map to be automated, a great saving can be realized by automating these common features only once, rather than for each map. The solution to this problem offered by the integrated approach is that any line which is common to any two or more data maps is represented only once on the manuscript map for automation. In addition the integrated manuscripting process represents a pre-automation polygon overlay, wherein the polygons represented on the final manuscript represent the units created through the overlay of each of the separate data planes.

The computer overlay process is both time-consuming and expensive. It also results in the creation of splinter polygons. Numerous small splinter polygons are typically created when computer software is used to overlay individually automated data variable maps. The splinters are often due to the failure of what should be identically placed lines on the individual map, to coincide precisely with one another. For example, the boundary of a marsh may be shown in different locations on the vegetation map, the soils maps, and the landform map; or, even if shown in the same place, the boundary may be digitized somewhat differently each time. Even slight variations in the X, Y coordinates of the points which define such lines, occurring from one map to the next, will cause splintering. The splinters will be visible in plotted overlay maps and will also evidence themselves in automated analyses of polygon characteristics. The splinters are confusing both to the cartographic display of the data and to their analysis and interpretation as well.

There are constraints and limitations to integrated mapping. Maps of related data types may not be available at the same time and therefore cannot be initially compared. Creation of extensive integrated manuscript maps can become time consuming and expensive. Also, the nature of integrated mapping is such that it changes one or more data sets in the process. These changes must be verified by the original mapping entity or carefully interpreted to ensure the continued integrity of the data.

The realities of an operational data base require a careful balance of the concerns mentioned. This is especially true where much information within the data base is dynamic and changing over time. As elements within the data base change, it is important to know how all other elements will be affected. These considerations and an assessment of various levels of applications described by interviewees were used both for the identification of four basic application levels and the structuring of information for inclusion in the demonstration data base. The four application levels are the following:

Detailed Resource Inventory and Planning Level. Much map data used by interviewees are, for planning and inventory purposes, highly detailed. Tax maps used in one form or another by most planning organizations in the state include spatial units down to the parcel level. Parcel maps do exist which depict metes and bounds, lot dimensions, and locations of structures, although these are not generally used for planning applications. Maps, such as those of the Oahu Coral Reef Inventory, nearshore bathymetry, USGS 1:24,000 topography and others contain relatively detailed information which is used in day-to-day operations by many organizations. The Detailed Resource Inventory and Planning Level is intended to meet these detailed planning needs. A scale of 1:12,000 (1"=1000') was chosen as the optimum scale for integration of data at this level. It represents a compromise between the most detailed data interviewees listed for use in planning applications at scales around 1:6,000 (1"=500') to data compiled by USGS and others at scales of 1:24,000 (1"=2000') and above. At 1:12,000 a 1/4 acre parcel is about .10" on a side, approaching the minimum mapping resolution possible for discerning individual units. Another consideration for this choice of scale was the spatial indexing system that would be used. USGS 1:24,000 topographic quandrangles represent the most consistent and extensive geographic coverage for the islands. The USGS quadrangles make excellent basemaps, and each 1:12,000 map can comprise one-quarter of a typical 1:24,000 map at a size which is easily handled. This is explained in more detail in the section describing the statewide spatial indexing system. Pilot study data variables identified for integration at this level are indicated in Table 16.

Generalized Planning Level. For regional data inventory and applications, a more generalized data base should be established. Map information containing extensive coverage of land or ocean areas within certain limits should be compiled at a resolution commensurate with its density and application level. A scale of 1:62,500 (1"=1 mile) was chosen for this level. Again, USGS 1:62,500 topographic quadrangles provide the most consistent mapping base for land areas. These boundaries can also be conveniently extended seaward using latitude/longitude 15' intervals to define map boundaries at sea. This is also explained in more detail in the spatial indexing system section. Data falling within this level are such things as rainfall and solar regimes, regional hydrology, annual wind power, and others as indicated in Table 16.

Special Projects and Applications. Most data and applications not falling within the first two levels would be included here. These can range from site-specific drafting projects to analyses of ocean currents for the southern Pacific Ocean. These data would not become part of the statewide archive data base but would rather consist of one time or infrequent special projects undertaken by organizations who desire the technical capabilities of a GIS system, but whose particular application

	Variable	Data Type	Map Integration Level: 1:12,000	1:62,500	Special Projects/ Applications	Geobibliography
State	Zoning	Poly	•			
	Solar Regimes	Poly		•		
	Beach Change Transects	Point				•
	Fisheries Chart	Poly			•	
	Median Annual Rainfall	Li/Po		•		
	DLNR Observation Wells	Point		•		
Federal	Shore Type	Poly	•			
	Detailed Coastline	Poly	•			
	Offshore Bottom Type	Poly	•			
	Existing Use	Point	•			
	Bibliography of Surveys/Studies	Point				•
	Shoreline Inventory	Point				•
	Water Sampling Points	Point				•
	Zooplankton Sampling Points	Point				•
	XBT Sampling Points	Point				•
	Streams (Major)	Line		•		
	Streams (Detailed)	Line	•			
	Topography	Li/Po	•			
	Transportation	Line	•			
	Nearshore Bathymetry	Li/Po	•			
	Generalized Coastline	Poly		•		
	Gauging Stations	Point	•			
	Observation Wells and Water QualSampl	Point	•			
	Geology	Poly	•			
	Bathymetry	Li/Po	•			
	Soils	Poly	•			
	NOAA (State Map)	Poly			•	
City and County	Development Plan Public Facilities	Po/Li	•			
	Development Plan Land Use Zoning	Poly	•			
	Tax Map Index First Division (Oahu)	Poly				•
	Existing Land Use	Poly	•			
	Special Management Areas	Poly	•			
	Beach Parks and Right of Ways	Poly	•			
	Floodways	Poly	•			
	Flood Insurance Rate Maps	Poly	•			
	Flood Map Index	Poly				•
	Tsunami Inundation	Poly	•			
	Parcel Maps	Poly	•		•	
Institutional	Meteorology Station Locations	Point				•
	Land Surface Form	Poly		•		
	Annual Average Wind Power	Li/Po		•		
	Seasonal Wind Power	Li/Po		•		
	Tsunami Wave Runup Heights	Poly	•			
	DSV Turtle Dive Tracks	Line				•
Private	Sediment Test Rod Locations	Point				•
	Benthic Recording Locations	Point				•
	Coral Reef Changes	Poly				•
	Algal Abundance	Poly				•
	Coral and Algae Test Stations	Point				•
	Temperature Plumes	Poly				•
	Sediment Profile Locations	Point				•
	Nearshore Surface Temperatures	Point				•
	Nearshore Bathymetry	Li/Po	•			
	Natural Color Aerial Photographs	Image				•

Table 16

Map Integration Levels

is so site-specific or macro-regional as to be of little utility to the majority of other system users. Pilot study variables considered to fall within this level are indicated in Table 16.

Georeferenced Bibliography. One of the most commonly requested capabilities of GIS system stated by interviewees was access to bibliographic data by geographic area. The possible applications of this capability would range from scientific research to permit review. Georeferencing of bibliographic information can be accomplished by delineating the area referenced by any particular document as a spatial unit, that is, a point, line or shape (polygon). For example, a research paper about a certain area would use the boundaries of that area for georeferencing. Likewise, DSV Turtle dive documentation might be referenced by the track of the DSV Turtle as a line and a paper about a site-specific historical dig as a point. These units can be assigned unique number identifiers that can be used as a link to textual bibliographic data, which could then be retrieved by user-defined geographic area.

The georeferenced bibliography has been singled out as an application level all of its own because as a rule, the capture and application of the data will be sufficiently generalized as to be independent of scale factors. Bibliographic georeferencing could be implemented at any scale commensurate with the geographic specificity of any particular document and then combined to an index map containing all spatial reference units from which retrievals could be made. This concept is further described in the following section. Pilot study data candidates for inclusion at this level are again listed in Table 16.

Statewide Spatial Indexing System

The establishment of a statewide automated data base of geographic information will require the development of a standardized spatial indexing system into which map information can be structured. There currently exists no such standards in Hawaii covering both land and ocean areas. USGS 1:24,000 and 1:62,500 maps have long been used as a base for various mapping efforts, but these typically do not include coverage of ocean areas and these scales and formats do not always accommodate all mapping needs. With a GIS many format and scale requirements can be tailored to the needs of the user. Scale can be increased or decreased as desired, and formats, boundaries and geographic coverage can all be manipulated to the user's satisfaction. The handling of a large, complex geographic data base serving a multiple-user community, however, must be structured in a standardized way to facilitate a systematic approach to data base creation, retrieval and management. Also, the archive data base must be structured to accommodate application levels described previously. The concept of an indexing system to handle very large data bases of geographic information actually goes beyond simple spatial indexing to include indexing by data type as well. This stucture and the software to manage it are called a map library. A map library serves as the organizational structure for collections of maps or "coverages". In a typical map library, coverages can be organized in two dimensions - by subject/feature into layers and by location into tiles. This organizational structure is discussed below.

Tiles - The geographic area contained in a map library is divided into a set of non-overlapping tiles. Although tiles are generally rectangular (e.g., 7.5' x 18'), they may be any shape. All geographic information in the map library is partitioned spatially by this tile framework.

Layers - A layer is a coverage type within a library. All data in the same layer have the same coverage feature types and thematic variables. Examples of layers are terrain units, hydrography, and archeological sites. Layers may be thought of as coverages which cross several tiles.

Map Sections - A specific tile and map layer define a map section. A map section is therefore a coverage whose boundaries are defined by the tile limits. In the map library context, a geographic data base can be defined as a set of tiles and layers. The tiles are defined by a special coverage called the INDEX coverage. It is an ordinary polygon coverage where each tile equals a polygon. The attribute file for the INDEX coverage contains such information as tile name, presence and location. The INDEX coverage is essentially a map of the tile system of a library.

An additional auxiliary file is the layer file. It contains a table of all layers present in the data base. Recorded in the table are the layer name, coverage name (all the individual coverages that compose a layer have the same name, which may be different from the layer's name), presence and type (point, line or polygon).

The spatial and subject/feature aspects of a map library are illustrated in Figure 3. The concept of a map library is fundamental to the operational management of a large geographic data base such as might be implemented in the State of Hawaii. A three-level indexing system is described here which defines the spatial structuring of tiles for the three archival data bases.

1:12,000 Scale Spatial Indexing System. The creation of a detailed data base for planning at a scale of 1:12,000 should be structured to provide an index model and geographic coverage of land, nearshore and offshore areas requiring this level of detailed information. As derived through the current user needs assessment, geographic coverage at this level should include all major and minor islands and selected shoals, reefs, and ocean areas falling within the limits of the state's jurisdiction. Most detailed map data assessed in the course of this study would be covered under this definition, and coverage could be extended to accommodate exceptional data as required. The organizational structure of the 1:12,000 scale index was based primarily on existing boundaries and coverage of USGS 1:24,000 topographic quadrangles.

As stated previously, these maps provide an excellent basemap for rectifying other data sets to the same scale and include some of the most consistent and extensive map coverages of land areas in the islands. Also, their boundaries are based in large part on 7 1/2' latitude/longitude increments which provide a convenient convention for extension of standard map tiles seaward. A standard USGS 1:24,000 quadrangle can be quartered and each section photo-mechanically enlarged to 1:12,000 scale to produce basemaps approximately 22 1/2" high by 21" wide - a size which is generally convenient to handle. All other data to be automated and applied at this level can then be rescaled and rectified to the basemap prior to automation, thus ensuring matching of related geographic features. The 1:12,000 indexing scheme is illustrated in Figure 4, which shows both the quartering of existing USGS 1:24,000 quadragles and how these boundaries can be extrapolated to sea to extend the 1:12,000 tiling scheme out to the extent of the state's jurisdiction.

1:62,500 Scale Spatial Indexing System. The indexing of maps for generalized planning applications at a scale of 1:62,500 is conceptually similar to the previous scheme. Again USGS topographic quadrangles were used as the foundation of the tiling structure, but in this case the USGS scale is the same as the integration scale, and thus no further photo-mechanical manipulation is required. Data to be automated and applied at this level are generally of an island-wide nature or include substantial expanses of ocean areas. The boundaries of USGS 1:62,500 quadrangles are essentially based on 15' latitude/longitude increments, although this rule is frequently broken in Hawaii to include the totality of one or more islands on a single sheet. The same concept can be used, however, to extend the tiling scheme seaward to the U.S. 200-mile boundary or beyond to accommodate special data as required. Figure 5 illustrates a sample of current coverage by USGS 1:62,500 scale maps and how these can be extended to the 200-mile limit to provide map tiling of ocean areas.

Geobibliography Indexing System. The tiling system to be created for the structuring of geobibliographic data is fundamentally different from the other two examples in that scale or precision of spatial features are used only for retrieval of tabular bibliography data and have no other spatial value. Spatial data maintained in an automated form are in effect independent of scale, but they do have precision. Geobibliography features are only as precise as they were delineated and automated initially; thus detailed study areas may be defined very precisely and generalized study areas very coarsely. In application, areas of interest might also be defined precisely by a user with a particular focus and again generally for broad-scope research. Taking into account these characteristics, the tiling structure of the 1:62,500 data base was designated to provide also the structure for the geobibliography. The 1:62,500 tiles would include complete geographic coverage out to the 200-mile economic limits and enough resolution at full scale to allow delineation of most geobibliography units requiring detail. In a certain sense the geobibliographic data base could be perceived as another data layer of the 1:62,500 data base, although in practice it would be maintained as a single coverage equivalent to the index coverage of the latter. This would directly accommodate generalized delineations of areas for retrieval of

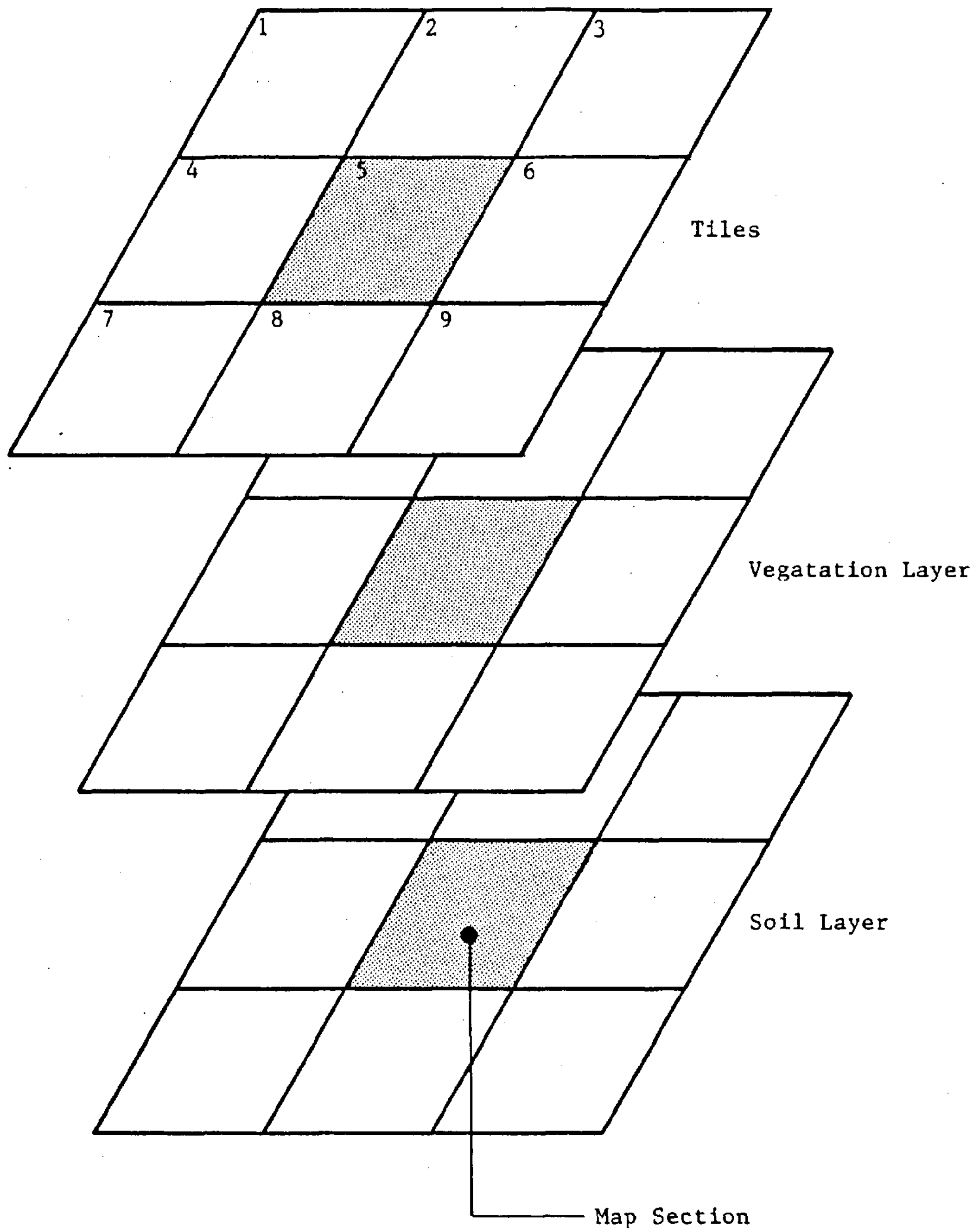


Figure 3

Map Library Spatial and Feature
Indexing Concept

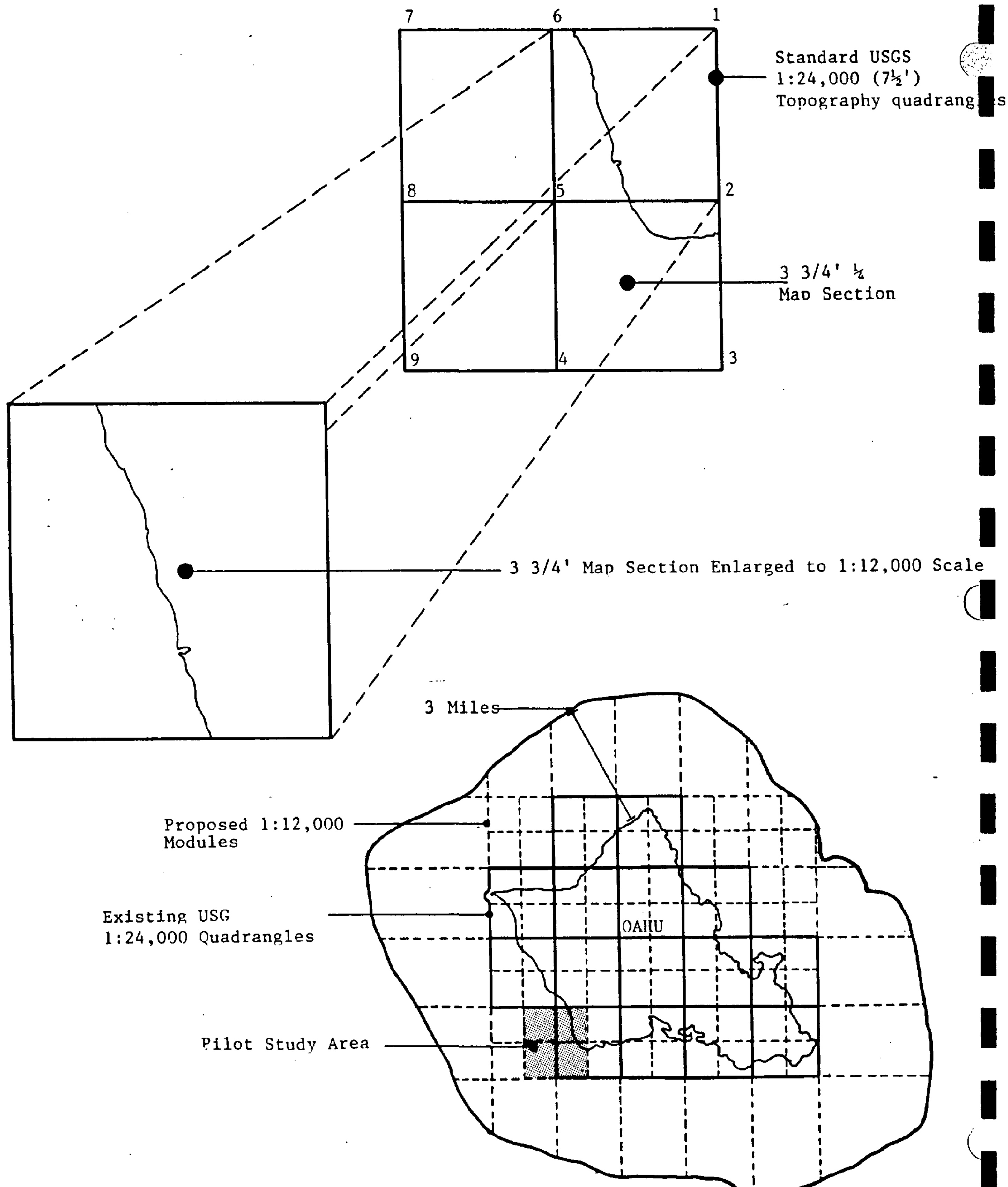


Figure 4

1:12,000 Scale Spatial Indexing System

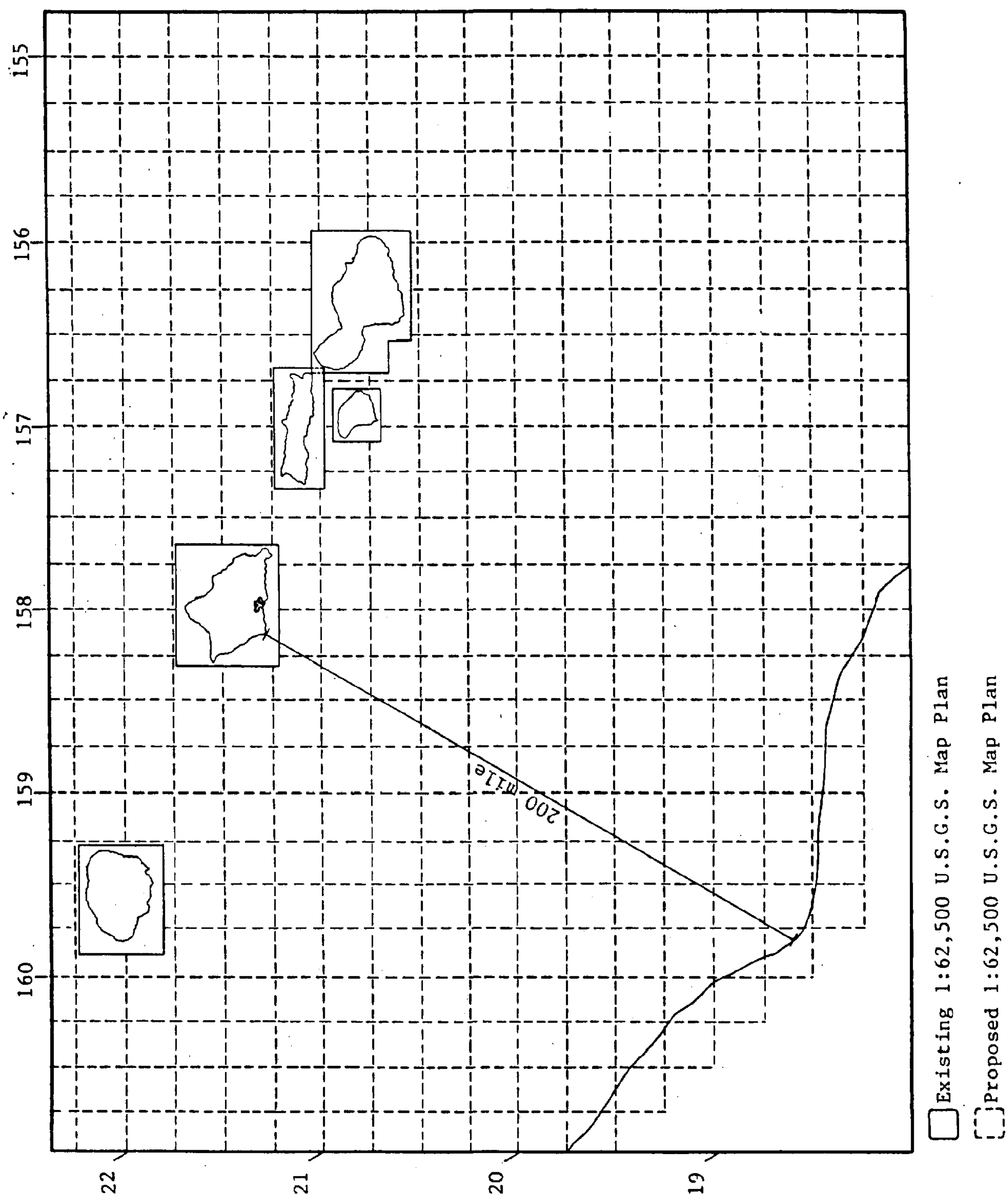


Figure 5
1:62,500 Scale Spatial Indexing System

bibliogrphic information. Retrievals requiring more focused delineation would specify geographic coordinates or "zoom" into the coverage by means of software or hardware mechanisms.

III. SYSTEM IMPLEMENTATION RECOMMENDATIONS

The conceptual system design and creation of the Kahe Point pilot study data base represent a first-step effort by DPED towards the establishment of a statewide coastal and ocean resources geographic information system for Hawaii. Response from potential users of the system during interviews and subsequent demonstrations of the system in Honolulu was overwhelmingly in support of this effort. The development of the system offers the opportunity to implement a statewide resource information base to support planning and economic development. It may provide a vehicle for dialogue and cooperation between various levels of local, state and federal governments, private industry and educational and research institutions.

It is evident that the need and the desire for a GIS system exists. Before such a system can be realized however, there are many economic, logistical and political hurdles which must be negotiated. The scope of the current study did not allow for a full evaluation of these factors but did provide some insights and impressions which have been used to develop the system implementation recommendations described in this section. These recommendations are intended for use by the state as an initial roadmap for continuing effort in the development of the system. In fact, system implementation is an evolving process that does not stop with the acquisition of hardware and software but rather changes and grows as the scope, focus and functional elements of the system grow. The same is true of initial system planning.

The steps outlined in the following sections must be constantly evaluated and reevaluated as the implementation process progresses, so that once the system is operational it will have been established on a firm and well-directed foundation. Several issues having potential impact on system implementation became evident during the user needs assesment.

- Few government agencies or private organizations within Hawaii have either the resources or the need to singly maintain a full GIS. Some level of cooperation will have to be built initially between participating agencies if such a system is to be economically and fully utilized. This is true of those organizations and applications dealing primarily with offshore resources and ocean planning. It became evident as the needs assessment progressed that although there are many applications and users for offshore data, the greater current need is for land-based and near-shore data. Organizations involved in ocean resources and planning applications would be best served if they could share the support and use of a GIS system with other users, even though those users are concerned primarily with land-based applications. For a shared system to be fully and economically used, some level of cooperation will first have to be built between the participating agencies.

- No evidence was available to suggest there has been any public dialogue between potential major system users to begin the development of an institutional framework of support for the system. This is a critical issue which should be addressed early in the process of system implementation.

- Generally there exists little firsthand knowledge regarding the capabilities and limitations of an automated GIS. This has led in some cases to confusion about what a GIS is and in others to inflated expectations about what it can do.

- Suspicion of centralized information systems is generally high. Whatever organizational form the system eventually takes, it must be structured to ensure that it receives utmost confidence and support from its intended users from the start.

- The initial group of potential system users interviewed in the course of this study represented a wide spectrum of interests and applications. This served well to identify the ultimate scope and application of such a system but did not allow a focused or comprehensive assessment of the system needs of all departments within key organizations who will probably comprise the majority of system usage.

The following is an outline and description of tasks necessary to continue the current course in the development of a statewide ocean and coastal resources GIS in Hawaii. The current study has provided a valuable first step in synthesizing a direction for system development. The tasks described here are intended to capitalize and expand on what has been learned.

The implementation of each of the general tasks listed will require one or more specific tasks, some of which may be simple (requiring a few days of effort), while others will require months to implement and large expenditures of funds. Some tasks may be performed by state staff; others will require support from outside consultants.

The initial and ongoing implementation tasks for a full, statewide GIS will require several years and commitment of substantial resources. Successful implementation will depend on a carefully prepared plan for the organizational units and personnel involved. The tasks which are most necessary, cost effective, technically feasible and logically appropriate are recommended for early implementation. Additional tasks will evolve as the implementation plan evolves.

A. Develop Institutional Framework.

A critical first step in the implementation of the system is the development of the institutional framework and linkages that will provide the foundation of the system. The group of organizations comprising this initial framework should be those with the greatest need for, interest in, and commitment to the development of the system. Although the assessment did not address the individual needs of every division of the various state departments interviewed, a general impression was gleaned which identified probable major users of the system within the state who would comprise the initial GIS group. Potentially these would include the Department of Planning and Economic Development (DPED), the Department of Land and Natural Resources

(DLNR), the State Department and Transportation (DOT), the Department of Accounting and General Services (DAGS) Survey Division, the Department of Agriculture, Hawaiian Homes Commission, and the Department of Health/OEQC. Certain departments at the University of Hawaii, including the Department of Tropical Agriculture, the Hawaii Institute of Geophysics and the Department of Oceanography might also participate. Another potential major user would be the City and County of Honolulu. Federal agencies, namely the U.S. Fish and Wildlife and the U.S. Army Corps of Engineers, also expressed interest.

It should be realized, however, that the establishment of institutional linkages between levels of government would probably be more complicated than if the users were confined to the state government alone. Once the central GIS paricipants have been identified it will be necessary for the heads of the various departments to come to some consensus regarding the general organizational form to be pursued - whether the Service Bureau approach, the User Network approach or some combination of the characterstics of each. A GIS steering committee should then be established, consisting of representatives from each of the participating divisions. Care should be taken to ensure that these representatives can speak and make commitments for their agency and not be intent on protecting their turf at the expense of the system. The purpose of this committee will be to first define the particulars of the institutional framework and secondly to direct subsequent steps in the implementation plan.

The operation of the GIS will require numerous institutional arrangements to facilitate the acquisition and flow of data, access to GIS processing capabilities, financial support for the GIS components and control of data and equipment. With the sharing of data as a design concept, certain mapping and update procedures will require definition. Institutional arrangements will also be required for facilitating and controlling access to GIS resources. These arrangements must specify the authority and assignment of responsibilities of the various organizations; the rights and procedures for access by user organizations; the criteria, method and procedures for establishing priorities and schedules; and the responsibilities and procedures for financing the GIS and its operation.

The long-term success of a Geographic Information System is directly proportional to success in keeping current the information stored. Establishing procedures for adding, editing and updating data is one of the most important tasks that must be accomplished before, during and after implementation. While the staffs of the various participating departments would be involved in establishing and maintaining these procedures, consideration should be given to hiring a consultant to provide initial guidance in setting up the required procedures.

A person from among the representatives should be appointed as the GIS steering committee manager. It will be this person's responsibility to ensure that all specific implementation plan tasks are assigned evenly and appropriately and that these are carried out in a timely and efficient manner. The manager will also be responsible for the majority of administrative functions, including preparation of progress reports for distribution to department heads. Because it is likely that the committee itself will act mostly in an advisory role, it is suggested that the steering committee manager be given a small staff to assist in devloping a detailed implementation plan. In addition the manager should have a budget for hiring outside expertise as needed.

B. Assess Existing Hardware/Software Capabilities Within Pertinent Institutions.

A comprehensive survey of hardware/software capabilities within the participating departments should be undertaken to identify possible linkages to the GIS. The survey should include a technical description of any and all central processing units, terminals, plotters, printers and other peripherals which might be compatible with GIS usage.

In addition a descriptive survey of all current software systems should be conducted to determine the possibility of any linkages by function or by data base. Detailed data base descriptions should be compiled for H-PASS, all geographic related data maintained by the State Electronic Data Processing Division and any other automated data bases which might exist.

All hardware, software and data descriptions should be compiled in a file for later synthesis. Where complete descriptions are not available, the managing agency of the component or a technical consultant should produce this documentation to be included in the file. A complete and comprehensive survey will be critical to other tasks in the implementation plan; therefore, a member of the manager's staff should be assigned the responsibility of ensuring it is carried out adequately.

C. Conduct Detailed User Needs Assessment.

The findings of the current general user needs assessment should be expanded to include other divisions in the various participating departments who were not interviewed in the current study. This assessment might be carried out by state staff, or it could be contracted out to a private consultant. Besides conducting a basic inventory of generic GIS functions and data types needed by the various participants, the detailed user needs assessment should seek to quantify the needs of each and identify the precise GIS functions required to carry out each specific task. These steps will provide the framework for later development of applications "macros," strings of generic GIS functions which allow a system user to carry out complicated standard tasks with the issuance of a single command. The form and content of specific standard geographic analyses carried out by each entity will also provide information useful for structuring final archive files on the computer. This aspect is described in more detail in the section following.

D. Define Requirements of the System.

Based on information acquired through the detailed user needs assessment, it will be possible for state staff or an outside consultant to define exactly the data base and hardware/software requirements of the system. The models implemented in the current study will serve as a valuable guide for this effort.

Detailed data requirements should be based on a comprehensive assessment of the various data requested by users and applications to which they will be put. Some data and applications may be more efficiently maintained in a manual form and should be identified as such. Others may already exist in an automated form and will require assessment for possible inclusion or interfacing to the GIS system.

Specific application requirements of the users should be used to structure final automated archive data files as they will reside on the computer. The files should be structured to accommodate the majority of uses and users. For example, if five divisions consistently applied overlaid data combining tax map parcels and slope, then that combination might be maintained on the computer as a combined file so that each user would not have to perform that operation redundantly. Likewise, if that combination were used only sporadically and the majority of users required the separate files, then they might be maintained both as separate and combined files.

The definition of data base needs should also address the issue of data integration described earlier. A list of data sets commonly compared or overlaid for various applications should be organized into groupings of logically or spatially related map information. Mapping and manual integration procedures should be established to integrate this information prior to automation. Procedures for the integration of the Kahe Point pilot study were developed as part of this study, and these are described at some length in the "Data Mapping" section of this document.

The comprehensive assessment of user needs will most certainly reveal needs not accounted for in the current study. This will require a reassessment of the preliminary hardware configuration described previously and the development and iterative evaluation of alternative configurations. The GIS steering committee should solicit input of the steering committee manager's staff and consultants to help develop conceptual alternatives and design of the final configuration.

E. Develop Design and Comprehensive Work Plan for System Implementation.

The most intensive effort to be carried out by the steering committee will be the development of specific hardware and data base designs and the final operational procedures and work plan for system implementation. All information compiled from the previous tasks must be analyzed in this task to synthesize the final form, content and operating procedures of the GIS. A comprehensive work plan for actual system implementation addressing both short-term and long-term objectives should be developed to provide an initial and ongoing guide to system implementation and development. The work plan should identify and assign responsibility for implementation of key tasks and programs, including the following:

- Formalization of Institutional Arrangements. This will involve the formalization of all agreements and understandings regarding system operating conventions, funding arrangements, staffing commitments, time schedule, cost schedules and all other matters relating to the implementation and operation of the GIS system.

- Identification and Assignment of GIS staff. Depending on the final operational form chosen, it will be necessary to assign or hire staff to fill the various GIS positions. The system manager and hardware/software administrator should be hired during final planning stages to ensure some consistency between planning and actual implementation. In-house staff to be assigned GIS duties on a part or full-time basis should be identified prior to commencement of training where possible.

- Documentation of All System and Organizational Operating Conventions. A "State of Hawaii Ocean and Coastal Resources Geographic Information System Reference Guide" should be authored to provide a comprehensive reference manual for all matters pertaining to system operating procedures. This would include detailed information on data capture and automation procedures, and data maintenance schedules. A comprehensive catalog of other system documentation, including software user manuals, hardware operating and maintenance guides and other pertinent reference materials, must also be developed. This document would function as a general system reference and index to all other system documentation.

- Funding Appropriations. A team of persons from the steering committee or staff should be assigned the task of identifying and implementing funding alternatives for the financial support of the GIS. This task must be carried out prior to finalization of institutional arrangements because funding will be a critical component of those agreements. The team should develop a detailed resource requirement schedule based on the comprehensive implementation plan and prepare a cash flow analysis by which to project short-term and long-term budget requirements of the system. The appropriations team would work with various division representatives and department heads to develop a resource commitment schedule and operating budgets for each entity.

- Hardware/Software Acquisition. A team within the steering committee or staff should be assigned the responsibility of evaluating the various hardware and software GIS systems available. This can take one of two forms. Extensive testing of available systems can be conducted by devising a series of specific GIS tasks similar to those that will be typically carried out on the system in Hawaii. This series of tasks is then used as a "benchmark" for testing the various systems and their ability to meet the needs of the Hawaii system. Two to three state staff knowledgeable in GIS applications or an independent consultant would be sent to the site of each of the potential system vendors to conduct the testing and evaluation. This process can be very time-consuming and expensive. Alternatively the team could develop a comprehensive request for proposal (RFP) which would detail very specifically the data application, and general hardware configuration needs of the system. This RFP would be sent to qualified vendors and the team would decide on a system based on proposal responses.

- Software Training Programs. The system manager will maintain the responsibility of organizing and scheduling the software training program. Prior to commencement of the program, this person must ensure that all pertinent staff have been assigned or hired and are available to attend training. Typical software training may run anywhere from one to three weeks, depending on the complexity of the subject matter to be covered and the type of software acquired. The manager should take advantage of this initiation period to also familiarize staff with system operating procedures and general institutional considerations by conducting orientation sessions prior to commencement of formal software training.

- Data Base Development Programs. A team from the manager's staff should be assigned the task of developing and documenting a data base development and maintenance program. This effort will probably require substantial input from an outside consultant. The team should concentrate on developing a comprehensive request for proposal, detailing the need for the development of data automation and maintenance procedures and initial data base development services.

F. Hardware/Software Implementation.

Once a GIS system has been chosen, the system manager will be responsible for making all necessary arrangements prior to actual acquisition and installation of the equipment. The manager must ensure that all equipment environments can be accommodated, including where appropriate, temperature and humidity control, space requirements, electrical connections, and electrical protection devices, phone lines for remote terminals, hardware linkages to location of terminals and various peripherals, sound control, and a variety of other preparations which must be made prior to equipment installation. The scope of this task can vary considerably with the size and complexity of the final system design. Software is normally installed by the vendor after equipment installation and prior to software training. The manager should arrange adequate storage facilities or software backup and data storage of magnetic tapes prior to software installation to ensure these are not damaged by heat or humidity or other elements which can damage magnetic tape.

G. Data Base Implementation. Initial development of the system data base will probably comprise the single most time and resource consuming component of system implementation. A choice must be made by the state whether to develop the data base slowly over time, using available in-house resources, or to hire outside consulting and automation services for initial data base development. The primary disadvantage of the former alternative is that the system would not be fully operational for several years following hardware/software acquisition. It would not be practical for the state to acquire the equipment and staff to conduct an intensive automation effort only to possess idle resources when the primary work was completed. Alternatively, the state could elect to contract initial data base creation to an outside contractor prepared to undertake this level of production.

In reality, the final data base creation effort could consist of elements of both the previous alternatives. For example, the state could elect to hire a consultant to develop specific data capture procedures and implement these in the automation of key priority areas of the islands for immediate application. The state could then adapt these procedures and over time expand the data base to include lesser priority areas. Also, individual departments or divisions might elect to acquire data base automation services to develop particular data sets or areas of interest, although care must be taken to ensure that the final products of these efforts conform with the design and intent of the overall system.

A very practical first step in developing a statewide data base would be to order from the United States Geological Survey (USGS) the 1:24,000 Digital Elevation Models (DEM) and the Digital Line Graphs (DLG) for the entire state. A combination of the DEM and DLG data bases would provide the state with the following digitized information:

- Topography
- Hydrography: steams, rivers, irrigation channels or canals, ditches, lakes, ponds, reservoirs, springs and wells
- Combined Hydrography
- Boundaries
- Transportation Systems: roads and trails.

The average cost per quad to have USGS digitize these data bases is:

- DEM: $1,300 per quad
- DLG: $1,650 per quad.

In addition, there is a charge of $100 per quad data set for transcribing and a $25 charge per tape required. All fifteen DEM have already been completed for Oahu and eight for the island of Hawaii (Kilauea Crater, Volcano, Kalalua, Pahoa South, Kau Desert, Makaopuhi Crater, Kalapana and Naliikakani Point). In addition, four of the DLG coverages of Oahu will be finished by mid-1985 (Honolulu, Puuloa, Waipahu and Schofield). USGS has no plans to do any additional digitizing of quads in Hawaii without local government participation. Moreover, demand for USGS digitizing services is building and the price is a bargain. It is recommended that the state prioritize the list of the quads which require digitizing and issue a purchase order to USGS. Actual payment is required only when a quad is completed. USGS will provide the price per quad for digitizing, a delivery time-table (within 60 days) which could be used for timing other aspects of the statewide data base development. A summary of anticipated costs associated with this effort is illustrated in Table 17.

Digitized ocean bathymetry data is available from the National Ocean and Atmospheric Administration (NOAA). All the data collected since 1930 have been digitized; however, not all of the data are presently available from NOAA. Appendix F contains 16 dot plots of the data presently available. Cost of this data is very reasonable. The cost for the first file is $125, plus $20 per additional file. Thus all 16 files (each file covers an area approximatly 60 miles x 60 miles) in a one-second grid would cost $425. The balance of the data collected since 1930 is expected to be available within the next six to 12 months.

The proposed implementation schedule is represented in Figure 6.

Table 17

Quad Digitizing

Cost Schedule (effective 2/85)

Set	Quads by County Kauai, Oahu, Maui, Hawaii				Quads Total	Digitize DEM $1,300 each DLG $1,650 each	Transcribe at $100 each	Totals
DEM Total	K	O	M	H				
	12	15	24	74	125		$12,500	
Completed	0	15	0	8	23			
Contract for	12	0	24	66	102	$132,600		
DLG Total	12	15	24	74	125		$12,500	
Completed	0	4	0	0	4			
Contract for	12	11	24	74	121	$199,650		
Sub-Total (estimated)						$332,250	$25,000	$357,250
Plus Cost of Tapes (estimated 2 data sets per tape)								$3,125
							Estimated Total:	$360,375

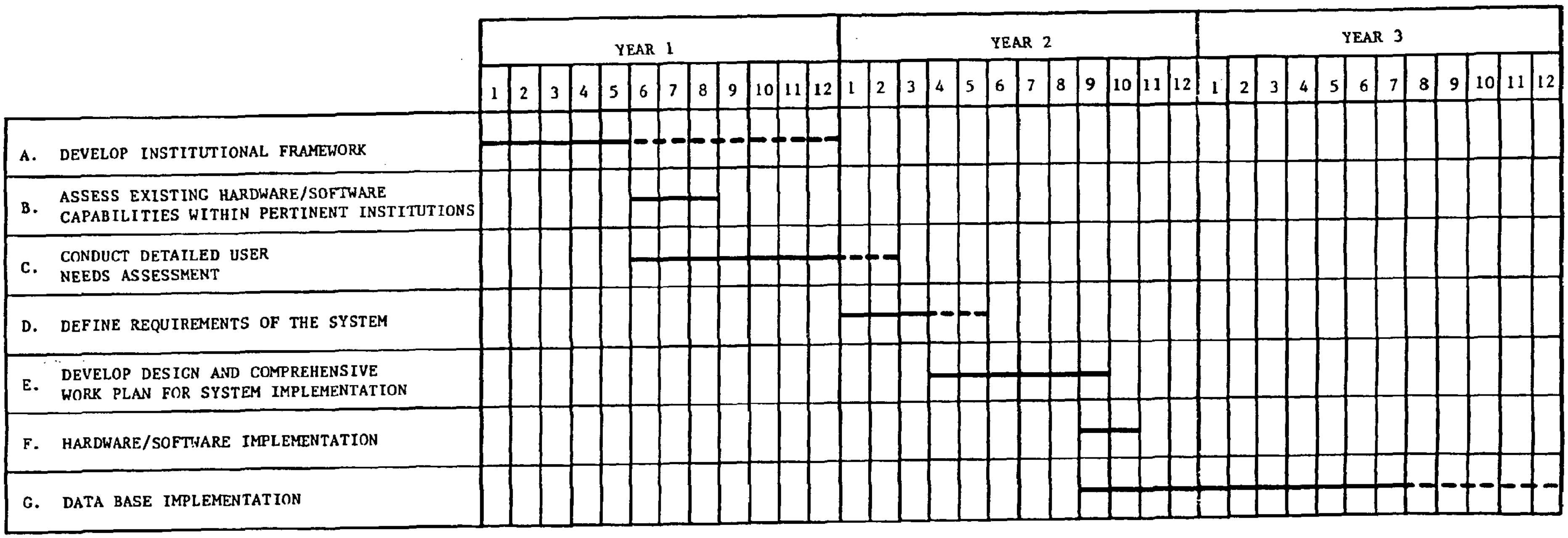


Figure 6

GIS System Implementation Schedule

________ Major Activities

-------- Minor Activities

IV. DEVELOPMENT OF THE DEMONSTRATION DATA BASE

A pilot study area of some 70 square miles of ocean and land area lying roughly between Kahe Point and Barbers Point in southwest Oahu was chosen to demonstrate the form and capabilities of an ocean and coastal resources geographic information system. This area was selected by DPED because of its proximity to the proposed Ocean Thermal Energy Conversion (OTEC) plant. Research conducted in support of this project resulted in there being more ocean-related data available in this area than in any other areas (except perhaps the area of Keahole Point, Kona, Hawaii) of the state's waters. Pertinent available data identified during the user needs assessment were collected from over a dozen sources for inclusion in the data base. These data were carefully evaluated for usefulness and ease of application in an automated form. Collected data existed in 22 different scales. Each data element was assigned to one of the application levels described previously under "Conceptual Data Base Structure" and grouped together for integration and mapping. Most data were photomechanically or manually rescaled, rectified to a common basemap and manually redrafted to create integrated manuscript maps in preparation for automation.

Spatial boundary data were digitized and data describing the characteristics of those features keypunched. Continuous surface topographic data were hand encoded and keypunched to an automated file. A series of processing steps was executed on each of the automated files to identify or remove errors, create topology, link attribute files with spatial files, and a variety of other operations. Several special products and analyses were produced from the final files for demonstration purposes.

Just prior to the completion of the demonstration data base, three staff members of DPED traveled to Redlands, California, to review the data base being developed and to learn the steps involved in developing a digitized geographic data base.

Final map files were converted to DLG/ASCII common format and written to magnetic tape for transportation and installation on the Digital Equipment Corp. (DEC) VAX 11/780 super minicomputer of Sam O. Hirota, Inc. of Hawaii. This computer has 2 megabytes of main memory and 700 megabytes of disc storage capacity. Peripherals used included a Summagraphics 3' x 4' digitizing tablet, a Tektronix 4113 color workstation with 512 kbytes of memory and a Calcomp 9060 plotter. Demonstrations of the system were conducted in Honolulu for a period of two weeks, during which time over 200 persons representing the various participants of the user needs assessment and other interested parties attended.

The development of the pilot study data base had two basic objectives. First the demonstration of the data base and system in Honolulu served as an excellent vehicle for introducing persons in the state to the basic concept of what a GIS is and what it can do. Secondly, it allowed the consultant team an opportunity to carefully evaluate a representative cross-section of data which might be incorporated in a statewide system and to develop the mapping and automation procedures to accommodate it.

The following sections describe in detail the steps taken to develop the pilot study data base. Also included are resource summaries outlining staff time and commitment of hardware resources necessary to implement each task. The additional information may be useful in estimating resources necessary to carry out further data base development in the future.

A. Data Collection, Evaluation and Classification

DPED initially designated an area of approximately 50 square miles surrounding Kahe Point to be established as the study area for the demonstration data base. Contractor staff were to define the exact boundaries of the site. As described previously, the spatial indexing system for data integration at the detailed planning level was based on the boundaries of USGS 1:24,000 scale topographic quadrangles. The Ewa quadrangle, covering the Kahe Point area, extends northward to a point near Nanakuli, south below Barbers Point, east beyond Makakilo, and west approximately one mile to sea. The western half of the quadrangle was photographically enlarged to produce two - 3.75' x 3.75' (1:12,000 scale) basemaps. The boundaries for an additional two 1:12,000 scale basemaps were created by extending existing boundaries another 3.75' longitude to sea. The extent of the pilot study data base (and the location and boundaries of the 4 modules) is represented in Figure 7. The boundaries of an existing 1:62,500 scale topographic quadrangle were used to delineate the generalized planning level module boundary. Other special project boundaries were delineated separately according to the extent of existing maps.

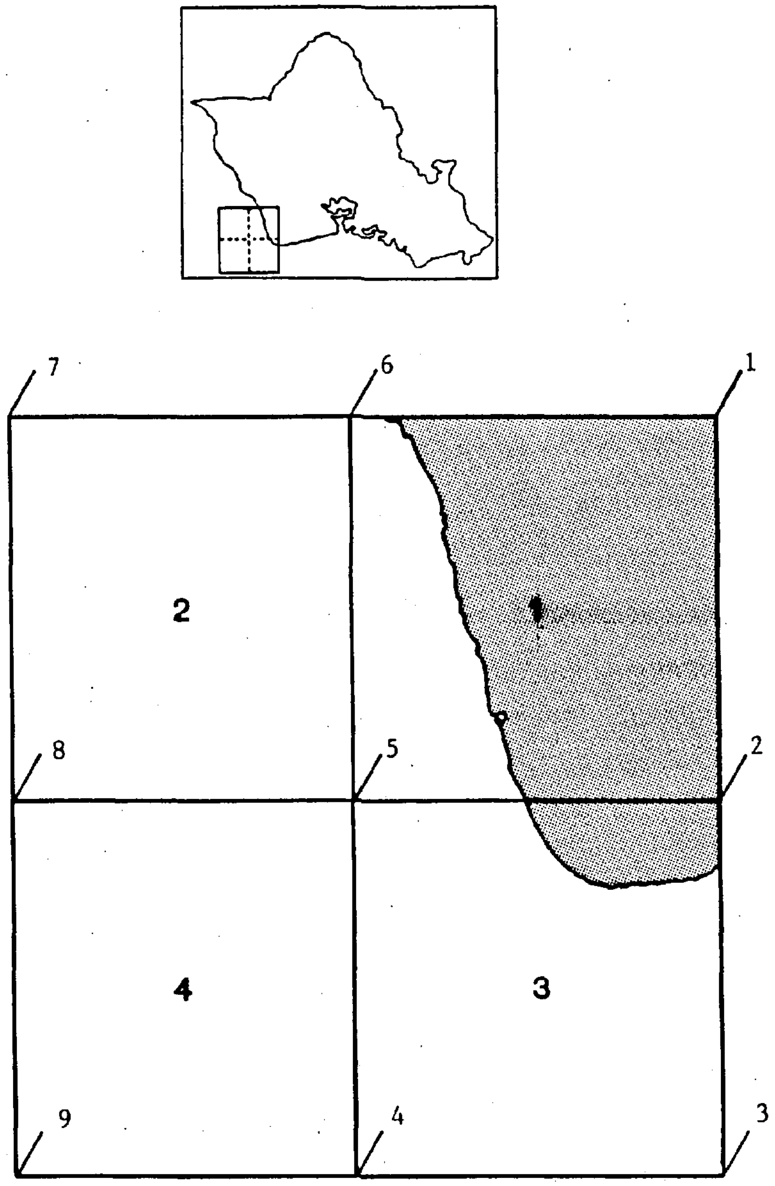
Data collected for the pilot study and their original map scales are represented in Table 18. Each individual data element was assessed against known applications to determine which application level it would fall within. Within each application level grouping, data elements were further grouped according to spatial or logical groupings in preparation for map integration. The outline of these groupings listed in Table 14 illustrates the essential nature of the data structure and classifications employed in the creation of the Kahe Point pilot study data base. Basic data classifications were based entirely on original source materials with the exception of slope, which was interpreted from topographic data and based on arbitrarily assigned slope classes. Every classification element was assigned a code which would later be used to efficiently enter this information on the computer. A complete enumeration of the classification and codes is provided in Appendix G of this report.

Table 19 is a summary of staff time spent in collecting and assessing data for the Kahe Point pilot study area.

B. Data Mapping

The mapping phase of the pilot study involved the formatting and integration of data collected from a variety of federal, state, and private sources.

Data were rescaled, reformatted and drafted to create 13 separate manuscript maps. Each of these manuscripts represented a class or format of data that



	LATITUDE	LONGITUDE
1.	21° 22' 30"	158° 05' 15"
2.	21° 18' 45"	158° 05' 15"
3.	21° 15'	158° 05' 45"
4.	21° 15'	158° 09'
5.	21° 18' 45"	158° 09'
6.	21° 22' 30"	158° 09'
7.	21° 22' 30"	158° 12' 15"
8.	21° 18' 45"	158° 12' 45"
9.	21° 15'	158° 42' 45"

Figure 7

Kahe Point Pilot Study Area

TABLE 18
PILOT STUDY

Manuscript Organization 1:12,000
Detailed Planning Data Base

Manuscript No.	Manuscript Name	Variable	Data Form
I	Political/ Administrative Units	Tax Map Parcels	Polygon
		Development Plan Public Facilities	Polygon
		Development Plan Land Use Zoning	Polygon
		Beach Parks and Rights-of-Way	Polygon
II	Transporation/ Administrative Features	Development Plan Public Facilities	Line
		Development Plan Land Use	Line
		Transportation Network	Line
		Highway Access	Point
		Development Plan Public Facilities	Point
		Tax Map Easements	Line
III	Topography/ Bathymetry	Topography/Bathymetry Contours	Line
IV	Integrated Terrain Unit	Geology	Polygon
		Soils	Polygon
		Shore Type	Polygon
		Slope	Polygon
		Existing Land Use	Polygon
		Landform	Polygon
V	Tsunami/Flood Hazards	Floodways	Polygon
		Flood Insurance Rate Zones	Polygon
		Tsunami Inundation Areas	Polygon
		Base Flood Zones	Line
VI	Hydrology/Water Quality	Streams	Line
		Gauging Stations	Point
		Observation Wells	Point

Manuscript No.	Manuscript Name	Variable	Data Form
VII	Nearshore Ocean Resources/Use	Offshore Bottom Type	Polygon
		Use	Point
		OCRI Bibliographic Survey	Point
VIII	Coast/Waterbody Template	Land/Water Interface	Polygon
IX	Cultural Sites	Site #	Point
		Site Type	Point

1:62,500
General Planning Data Base

Manuscript No.	Manuscript Name	Variables	Data Form
I	Partial Integrated Terrain Unit	Rainfall Regimes	Polygon
		Generalized Surface Form	Polygon
		Annual Average Wind Power Regimes	Polygon
		Seasonal Wind Power Regimes	Polygon
		Solar Regimes	Polygon
		Rainfall Contours	Lines
		Solar Contours	Lines
		Rain Gauges	Point
II	Hydrology	Major Streams	Line
		Hydrologic Stations	Point
III	Coastline/ Waterbody Template	Coast/Waterbodies	Polygon

Special Projects and Applications Data Base

Manuscript No.	Manuscript Name	Variables	Data Form
I	Fisheries Chart No. 2	Fish Catch Reporting Units	Polygon
		Partial Fish Catch Record	Tabular
II	OTEC Benchmark	Site/Test Locations	Point
III	State Map	Type	Polygon
		Zone	Polygon
		Name	Polygon
IV	DSV Turtle Dive Tracks	Data	Line
		Dive #	Line

	Tabular Data	Cartographic Data: Generation/Storage	Cartographic Data: Manipulation/Analysis: Geometric Analysis	Cartographic Data: Manipulation/Analysis: Network Analysis	Cartographic Data: Manipulation/Analysis: Digital Surface Modelling	Cartographic Data: Manipulation/Analysis: Query	Cartographic Data: Display: Composition	Cartographic Data: Display: Presentation	Bibliographic Data		
	Field Measurement/Observation Retrieve Existing Tabular Data Compilation on Forms Data Entry/Edit Update Storage/Management Data Manipulation Statistical Analysis On-Line Query Report Generation	Air Photo Interpretation Gather Existing Map Data Field Survey (Sampling) Drafting/Compilation on Maps Digitize/Edit Traverse Entry/Cogo Cartographic Data Update Map Join/Edge Match Storage/Management	Polygon Overlay Line in Polygon Vector/Cell Conversion Polygon Dissolve Point in Polygon Polygon to Point Analysis Transformations Buffer/Corridoring Windowing Coordinate Filtering Proximal Analysis Line Length Calculation Area/Perimeter Calculation Aggregation/Districting Contiguity Analysis	Distance Accumulation Area to Network Accumulation Optimal Path Selection Flow Simulation Time/Distance Computation	Spatial Interpolation Contouring Slope/Aspect Sun Intensity Viewshed Road Engineering Design Volume Calculation Cross Sectioning 3-D Viewing/Surface Mapping	Spatial Query Attribute Query	Generalization Scale Change Modify Features/Text Graphic Superimposition	Symbolize Points Symbolize Lines Symbolize Polygons Text/Annotation Display Legends Modify/Update Features/Text	Indexing Storage Retrieval (including biographic reporting)	Administration/Coordination	
PROJECT MANAGER	5	20									25
SENIOR TECHNICAL STAFF											
JUNIOR TECHNICAL STAFF											
AUTOMATION STAFF											
SENIOR MAPPING STAFF	2	10									12
JUNIOR MAPPING STAFF		5									5
	7	35									42

Table 19

Data Collection, Evaluation and Classification
Resource Summary
(Values expressed in man-days)

could conveniently and meaningfully be combined to one map. Three variables were automated indirectly from source materials and so required special handling during the automation stage. Some of the information was areal, such as offshore bottom type or geology, and was shown as spatial units called polygons. Other information was in the form of points or lines, such as observation wells or DSV Turtle dive tracks respectively. All three formats of data, categorized according to the types of information conveyed, were mapped for the study.

The 1:12,000 integrated terrain unit map utilized a mapping concept which resolved related environmental data to a single manuscript map. Its creation involved the rescaling, manual overlay and integration of inividually mapped single-variable overlays onto a single map. Each overlay contributed lines which were drafted onto the manuscript. However, given that many boundaries between natural phenomena were often coincident, the process often involved the delineation of a single line on the manuscript in place of several different but generally consistent lines which existed on individual overlay maps.

This principle also was applied to the integration of political/ administrative boundaries. For instance, the boundary of an existing land use unit in most cases is intended to coincide with tax map parcel boundaries. When simply rescaled, the maps often would not match, so where the intention to match the parcel boundary was obvious, the land use was changed slightly by delineating the boundaries of both with a single line. Very small mapping units on the overlays, generally those smaller in size than appropriately 1/4 acre, were typically merged into larger surrounding or adjacent units. Thus the data on this manuscript are generally considered to have a minimum polygon resolution of 1/4 acre. The primary exception to this rule was tax map parcels and shore types, which were mapped regardless of size.

Method

The basic concept underlying the preparation of integrated polygon maps like Manuscripts Numbers I and IV was the Integrated Terrain Unit Mapping (ITUM) approach, used to integrate several kinds of variables into a single polygon map. The following are general principles dealing with the distribution of natural geographic attributes that relate to the ITUM approach:

1. The Principle of Graded Likenesses and Infinite Differences in Natural Areas - No two geographic locations or areas are ever exactly alike, although similarities can be perceived between areas which permit classification of areas into like kinds. The degree of perceived dissimilarity increases directly as the closeness of scrutiny increases. Conversely, similarities become more obvious as observation is less detailed.

2. The Principle of Areal Transitions - Changes in natural geographic characteristics from one area to another are usually gradational. The rate of change along such gradations may vary. Thus the placement of a line drawn to show the separation of any two features

is in part a subjective decision. This means that for two or more data variables, different lines can be resolved into a single line representing the best fit for both features. This can then be drafted onto the final ITUM manuscript.

3. The Principle of Continuous Alteration of Areal Characteristics with Time - All the characteristics of any geographic area are changing continuously, although each feature changes at a rate which differs from the rate of change for other features. Since some features change more rapidly than others, the map has some data dealing with rapidly changing features and other data dealing with features which change quite slowly under most circumstances.

4. The Principle of the Functional Interrelatedness of Environmental Elements - As the pattern of any environmental or cultural attribute changes, it will have recognizable effect on the patterns of other environmental attributes in the same area. This interrelatedness often means that the various features of an area will respond somewhat as a unit - what might be called a "spatial response unit". The rate of environmental changes is determined by those factors mentioned in Principle 3.

As indicated in the earlier section of this report entitled "Conceptual Data Base Structure," the ITUM mapping process resolves some major obstacles to the computerized handling of spatially defined environmental information: the cost of automating multiple parametric data planes; the cost of doing polygon overlays in the computer; the problem of polygon "splinters" created through the overlay process; and perhaps most important, the problem of mismatched data sets which are supposed to be related and consistent.

Much of the data employed in the development of Kahe Point demonstration data base was in a format which required rescaling, adjustment to imagery or both before it was in a form amenable to integration into a manuscript map. In the rescaling process, a combination optical/manual procedure was followed. This method involved the use of an optical pantograph with Kargl reflecting projector with a rated distortion factor of less than 0.01%. Collateral maps were placed on a platform and their images were optically projected upward onto a glass surface. Enlargement or reduction of the original collateral maps occurred as the map-to-lens ratio was changed. Fastening the mylar copy of the topogrphic basemap onto the projection glass allowed the collateral to be reformatted to the basemap scale of 1:12,000 or 1:62,500. In certain cases the enlarging or reducing process was repeated twice to achieve the required scale. After the transformation was adjusted to the basemap scale, it was manually transferred onto the drafting film. Care was taken to ensure that all information was transferred accurately and that no transposition of information codes occurred. An edit check of the hand-drawn map compared it to the original data.

The physical characteristics and interpretive values of the phenomena mapped for this project were derived largely from the collateral maps and documents which were provided. Aerial imagery and basemaps were used to verify, rectify and clarify the distribution and areal extent of the phenomena mapped from the collateral. Patterns were adjusted to match the imagery and the basemaps. The imagery and basemaps thus act as geographic "contols" for reformatting of cartographic inconsistencies between the various data variables. Next the polygons or line segments delineated on the data maps were assigned code numbers. These code numbers referred to the different values or characteristics which each such delineation represented. The code numbers were then either applied directly to the manuscript map itself or were referenced, in turn, to sequential numbers applied to the map. In either case the numbers used were related to the polygons or line segments shown on the map by placement within the polygons or immediatly adjacent to the lines. Each module was then edgematched to its adjoining module. Where lines of any kind crossed from one module into the other, their location and match were carefully checked. A check was also made to be sure that the code assignments along each side of the shared border were correct and consistent with those across the border in other modules.

As noted earlier, mapped phenomena can be represented by polygons, points, or lines. To create polygon maps, the study area was divided into smaller discrete areas, each bounded by a closed line, called a polygon. Each polygon is homogenous with respect to the variable or variables to which the particular polygon delineation refers. For purposes of identification and description, the individual polygons on a manuscript map were given sequential identification numbers. Each polygon's sequential identifier was then used to associate the polygon with an identically numbered set of attribute codes. An example of a polygon map is illustrated in Figure 8. This map is the Oahu Coral Reef Inventory (OCRI) Offshore Bottom Type comprised of some 300 individually numbered polygons. As in this example, polygon numbering typically commenced with the number 1 in the upper left corner of the manuscript map and progressed sequentially toward the lower right corner.

On the point and line manuscript maps, points were shown as two short line segments crossed at the location of each point feature, and linear features were drawn as line segments. Coded values for lines and points were either applied directly to the manuscript map or they were referenced to the map by the use of sequential identification numbers, as with polygons. Locators for the labels associated with points or lines were similar to the centroids associated with polygons, in that they designated the lower left corner location of the first symbol of the label for a point or line.

The maps created for the Kahe Point pilot study area are outlined below. A description of each is followed with a discussion of special procedures developed to handle the unique features of each variable.

1:12,000 Scale Detailed Resource Inventory and Planning Level

Manuscript I - Political/Administrative Units

The Political/Administrative manuscript is comprised of cultural polygon units, including tax map parcels, development plan public facilities, development plan land use zoning and beach parks and rights-of-way. These variables were spatially related in that their boundaries generally

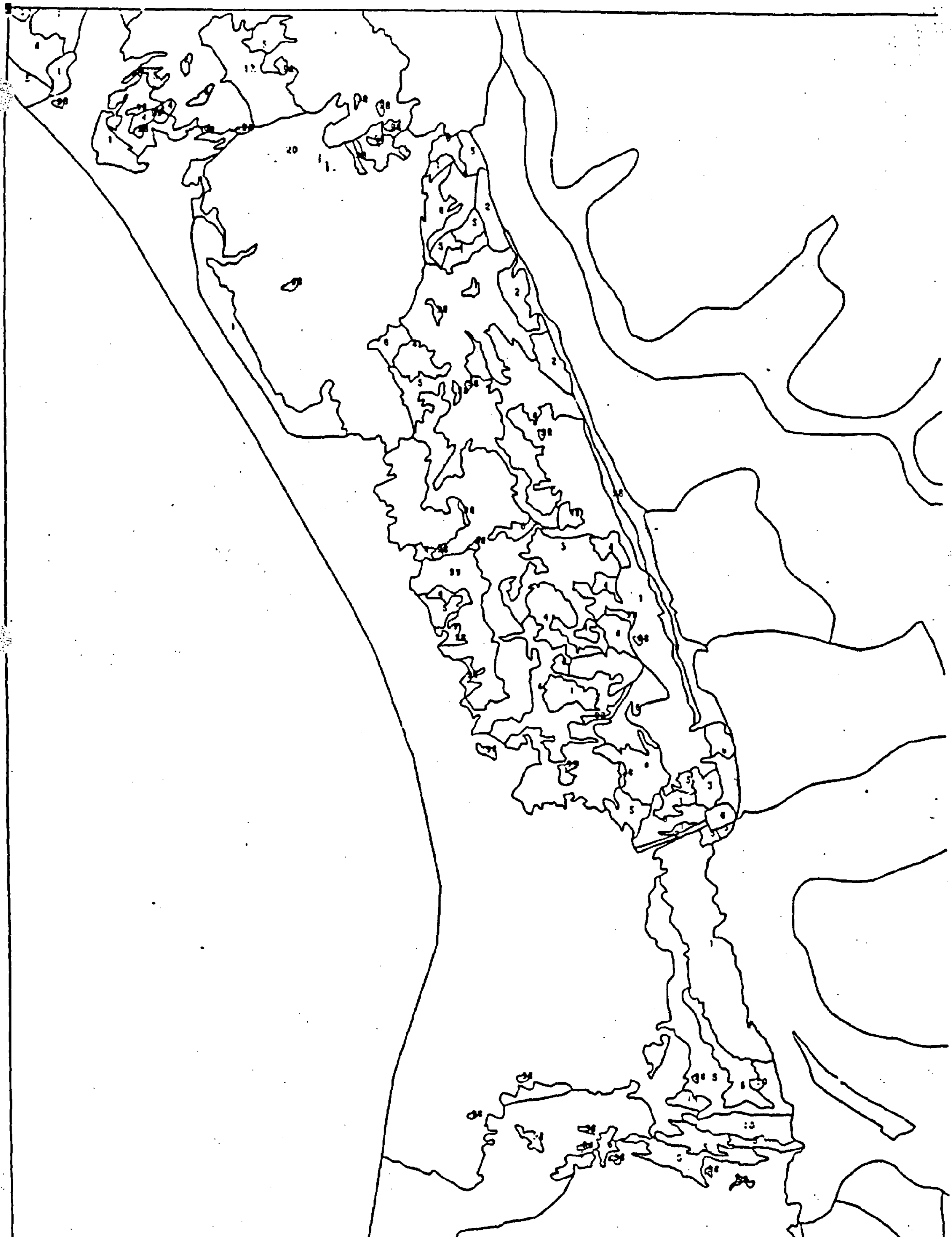


FIGURE 8
Polygon Map

coincided with tax parcel boundaries.

Since they provided a framework for the mapping of all other variables within this manuscript, the tax map parcels were addressed first. The original parcel maps were acquired from the City and County of Honolulu, Tax Maps Branch. The maps were highly variable in scale and composed of many panels, each portraying parcels within a certain plot, or plots within a certain section in the case of undeveloped or rural locations. Each panel was manually rescaled with an optical pantograph device to a scale of 1:12,000.

Several problems were encountered in creating the composite parcel map which bear mentioning. Handling numerous maps at as many different scales was time-consuming because inconsistencies between the various maps had to be rectified. Not all maps could be rescaled on the optical pantograph due to this device's limitations. In these cases the panels were either rescaled photographiclly or delineated by matching aerial photo and basemap features to determine gross boundaries.

Generally plat maps were difficult to register because of insufficient reference features. Also, plat map features were often distorted and inconsistent from panel to panel. Where possible, these discrepancies were rectified through aerial photo interpretation.

Two areas contained too much detail to be accurately mapped and automated at the 1:12,000 scale. These areas were left blank on this manuscript. The areas in queston were then mapped and automated at a scale of 1:6,000 and then automatically overlayed to the parcel coverage to complete that variable. This process is described in more detail in a following section.

Farrington Highway and the Interstate were depicted as polygonal units on the tax maps, although they are not assigned a parcel number. These units appeared as voids on the plat panels as well, so were assigned to one plat or another to make the plat coverage continuous. All parcel boundaries were ultimately rectified to match major transportation network features of the USGS photographically enlarged basemap.

Development Plan Public Facilities data integrated to this manuscript included polygonal units from the collateral. Public facilities features were also mapped as points and lines; these are covered in descriptions of other manuscripts. The data was acquired from the City and County of Honolulu. The public facilities map had been originally drafted at a scale of 1:24,000, so it required only direct transfer and rectification to the transportation network of the original USGS topoquad, rescaled to 1:12,000 and finally rectified to the parcel boundaries. The major difficulty encountered in the mapping of this variable was that the delineations tended to be diagrammatic, requiring a certain amount of interpretation to rectify those generalized boundaries to the more spatially specific parcel boundaries.

Development Plan Land Use Zoning data were also acquired from the City and County of Honolulu. This map also existed at a scale of 1:24,000, so the same basic process of rectification, rescaling and final rectification described in the previous example was followed. The generalization represented in the previous variable was also apparent here. The Barber's Point Harbor was delineated differently for each variable mapped, so these boundaries were all maintained, rather than integrated, since the exact intention of these delineations was not known.

The Zoning Map was acquired from the City and County of Honolulu. This map, at an original scale of 1" - 400' was manually rescaled with the optical pantograph. Features were rectified where possible to match parcel boundaries and major transportation routes on the basemap.

The existing land use map appeared to be out of date and contained many inconsistencies when compared to the basemap and aerial photos. The existing collateral map was updated, using aerial photo interpretation.

The Beach Parks and Rights-Of-Way maps acquired from the City and County of Honolulu Department of Parks and Recreation presented no special problems. Parcels delineating the boundaries of these parks were simply identified and coded by parcel and required no drafting of additional boundaries.

Manuscript II - Transportation/Administrative Features

This manuscript was comprised of transportation and administrative line and point features. It was comprised of development plan public facility lines and points, development plan land use lines, transportation network, highway access points, and tax map easement lines.

Development Plan Public Facilities line and point features at a scale of 1:24,000 were rectified directly to the 1:24,000 basemap and rescaled. Line features following the same path were mapped as a single line and coded to each of the represented features. Point features represented the polygonal circular features present on the original map to indicate possible future public facilities, the point representing the center of that feature. Additional codes were added to describe the radius of the represented circle so these could be reproduced as desired. Again the major difficulty encountered was the generalization with which this map had been drafted, especially in its depiction of lineal features. Multiple lines traveling along the same path represented an apparently exaggerated corridor width.

Only administrative boundaries of the Development Plan Land Use were delineated. These were mapped as lines because the administrative jurisdiction over the areas on either side of the line could not easily be determined. The lines were rectified to parcel boundaries from Manuscript I.

The Transportation Network was transferred directly from the USGS basemap. Aerial photographis were used to update delineations and these were rectified to match the parcel maps.

Highway Access points were extracted from the taxation maps. These points occurring along Farrington Highway and the Interstate were manually rescaled from the collateral source maps. Easement lines were also extracted from taxation maps and manually rescaled on the optical pantograph. Easements were assigned their unique identifiers and width value in feet. If more than one easement corresponded to the same line, then each easement number and width were coded in successive columns on the coding forms.

Tax Map Parcel/Transportation Feature Blow-up

Two areas of the study area contained detailed parcel information. Makakilo and Holokai Hale residential areas were mapped at a larger scale than the rest of the study area.

Since the numerous roads in the area were to match the parcels, the roads were also mapped at the larger scale. Only Manuscript I and II were enlarged for these areas. Since there was a zoning map provided for these areas at a large scale which depicted parcels, it was decided to do the blow-ups to that scale (1" = 400').

When Manuscript I and II were drafted, a polygon was drawn around the area to be blown up. No data was given for these areas at that time. ESRI then provided mapping staff with plots of the blown-up areas at the large scale. Mapping staff proceeded to fill in the missing data, mapping it at the larger scale and making an edgematch to the surrounding unenlarged area. The ESRI plot did provide surrounding polygon and line data useful for the edgematch.

Additional higher value sequence numbers were given to these areas.

Manuscript III - Topography/Bathymetry

Topography contours were automated directly from the 1:12,000 basemaps. Bathymetry contours were photographically rescaled from two sources: a USGS Open File Report, "Bathymetry of the Oahu OTEC Site"; and a report by Edward K. Noda and Associates, "Nearshore Bathymetry, Kahe Point, Oahu, OTEC Common Base Environmental Data Study." Discrepancies between the two studies in an overlay area were omitted since there was no practical means of rectifying the data of one source or the other. USGS nearshore bathymetric contours were transcribed where no more detailed data were available.

Manuscript IV - Integrated Terrain Unit Map

The integrated terrain unit map combined various land based natural resource information to a single composite manuscript map using methods described previously. Variables integrated to this manuscript included geology, soils, shore type, slope, interpreted land use and land form.

The USGS Geology map of Oahu was rescaled photographically from a scale of 1:62,500 to a scale of 1:12,000. In the process the geology lines became quite generalized and these were integrated to other related variables in the manuscript. Soil Conservation Service (SCS) Soil maps were manually rescaled with the optical pantograph. These maps were difficult to resolve manually as they had been delineated atop photo-base maps which were not planimetric and thus did not match the basemap. Overall registration was accomplished by registering and drafting small areas at a time, thus distributing the distortion error over the entire surface of the map.

Shore Type was extracted from the Army Corps of Engineers, Oahu Coral Reef Inventory (OCRI) maps. The inventory maps were manually rescaled. Many of the units were partially or entirely below mapping resolution. However, these were maintained during mapping and automation where possible.

Slope was interpreted from the USGS basemap. A slope scale was constructed based on a pre-designated slope classification scheme, and slope classes were manually delineated at the 1:24,000 scale and manually rescaled to 1:12,000.

Land Use was photo-interpreted from available color and black-and-white aerial photographs. The resulting delineations were manually rescaled to 1:12,000. Landform was likewise interpreted from the topography, slope and aerial phgotography.

Within this manuscript, land use comprised the most certain delineations. Soil and slope were first integrated with each other. Along the coast, shoreline was integrated with soils and geology. Finally all were combined and integrated to land use to create the final composite manuscript.

Manuscript V - Tsunami/Flood Hazards

This manuscript contained all variables related to tsunami inundation and other flood hazards. These included floodways, Flood Insurance Rate Maps (FIRM), tsunami inundation maps, and base flood zones.

Both the Floodways and FIRM maps from the U.S. Federal Insurance Administration had been delineated on USGS 1:24,000 topographic quadrangles, so these were transferred directly and rescaled to 1:12,000. Data on Tsunami Inundation Areas acquired from the City and County of Honolulu Department of Civil Defense, were roughly delineated on a very large scale map accompanied by a textual description of these boundaries. This information was compared against basemap features, and a more precise boundary was transcribed to the manuscript. Base flood zones from the floodways maps depicting potential depth of inundation were transferred directly and rescaled.

Manuscript VI - Hydrology/Water Quality

Stream courses were delineated directly from the USGS basemap. Gauging stations and observation wells were also transferred directly from a DLNR water quality map which had been drafted onto a USGS 1:24,000 basemap.

Manuscript VII - Nearshore Ocean Resources/Use

This manuscript contained polygonal and point-related nearshore features, including offshore bottom type, nearshore use and bibliographic reference points, all extracted from Army Corps Oahu Coral Reef Inventory (OCRI) maps.

Offshore Bottom Type units were rescaled manually. This data had been originally interpreted by Army Corps staff from aerial photographs and other source documents. Several problems were encountered in remapping these data to a form which would be compatible with automation as a polygonal coverage. The boundaries of many offshore bottom type polygonal units had not been closed because of insufficient clarity in the imagery during original photo-interpretation or because of other sources of uncertainty. Also, some units contained multiple codes with no boundary lines delineating separate units. Where possible, the mapping staff used additional photo interpretations of existing aerial imagery to close off polygons. These new boundaries were coded so they could be distinguished from original boundaries if desired. Also, an arbitrary line was drawn at the edge of interpreted data to close off very large polygons and to delineate the area generally defined as nearshore. Special combination codes were devised to define multiple code complexes where these existed.

Various Nearshore Uses were delineated on the OCRI maps as graphic icons. The centers of these were delineated as points and manually rescaled and drafted to the manuscript. Bibliographic survey sites were likewise rescaled and drafted.

Manuscript VIII - Coast/Waterbody Template

The coast/waterbody template was constructed to provide a consistent coastline for all mapped variables. In production this boundary is automated once and then automatically imposed on all other variables at the 1:12,000 scale. This ensures that all mapped variables will match at the coast and that this boundary need only be mapped and automated once, thus saving time and effort. The Oahu Coral Reef Inventory contained the most up-to-date and detailed coastline available. The coast boundary line was extracted from the OCRI maps and manually rescaled to 1:12,000. Miscellaneous waterbodies were likewise derived from aerial photo-interpretation and extracted from the USGS basemap as deemed appropriate.

Manuscript IX - Cultural Sites

Cultural sites of anthropological and/or archaeological interest as identified by the U.S. Army, "Barber's Point Final Environmental Impact Statement." The features were represented as points which were photographically enlarged from the original report figures and then manually registered to known features on the 1:12,000 basemap.

1:62,500 Scale Generalized Planning Level

A series of three manuscripts were compiled and automated to illustrate the possible form and content of a data base at this level. The following descriptions of the individual manuscripts indicate the data variables mapped at the 1:62,500 scale. The USGS 1:62,500 scale topographic quadrangle covering the entire island of Oahu was used as the basemap for these manuscripts.

Manuscript I - Partial Integrated Terrain Unit

Several data variables were compiled into this manuscript. These included rainfall regimes, generalized surface form, annual average wind power regimes, seasonal wind power regimes, solar regimes, rainfall contours, solar contours and rain gauge locations. The manuscript has been adjusted partly because it does not contain all variables typical of an integrated terrain unit map.

Rainfall Regimes, Contours and Rain Gauge locations (mapped as polygons, lines and points respectively) were acquired from the State of Hawaii Department of Land and Natural Resources. The original map was at a scale of 1" = 2 miles. The map was manually rescaled to 1:62,500 with the optical pantograph. Slight adjustments were made where rainfall and solar contours were nearly coincidental.

Generalized Surface Form was extracted from figures in the U.S. Department of Energy, "Pacific Northwest Laboratory Wind Energy Resource Atlas", as were the Seasonal and Annual Wind Power Regimes. These data became highly generalized when enlarged to the 1:62,500 scale and presented integration problems and lack of registration due to distortion at the larger scale and no reference base for integrating lines with confidence.

Solar Regimes and Contours were acquired from the State of Hawaii Department of Planning and Economic Development. A map entitled "A Homeowner's Guide to Solar Water Heating on Oahu with Oahu Sunshine Map" contained solar contours which were rescaled and rectified to the USGS 1:62,500 basemap. These lines were also used to delineate the boundaries of Solar Regime polygonal units which were assigned the median value of the contours bordering each.

Manuscript II - Hydrology

A map of major streams for the island of Oahu was acquired from the USGS Water Resources Division. All streams delineated on this map were rescaled and rectified to the basemap. Some observation wells and gauging stations existed at locations where no streams had been delineated on the USGS map. These were added where interpretation of the topography provided sufficient definition. Latitude/longitude coordinates of observation wells and gauging stations were acquired from the same report. The coordinates were keypunched, and points representing their locations were plotted out at a scale of 1:62,500. These were redrafted and rectified to stream locations on the USGS basemap.

Manuscript III - Coastline/Waterbody Template

As was the case with the 1:12,000 data base, variables at the 1:62,500 level required sharing of a common coastline to facilitate analysis and display. The coastline was drafted directly from the USGS basemap with slight smoothing applied to areas of dense crenulation. Waterbodies above a 2 1/2-acre resolution were also drafted to this manuscript. The USGS coastline was updated with a current photo-interpreted boundary of the Barbers Point Harbor to provide a point of reference between the 1:12,000 and 1:62,500 scale data bases.

Special Projects and Applications

Four manuscripts were created and automated to illustrate other types of data and applications which might be handled within the system but which could probably not reside within the archive data base levels described previously. The following is a brief description of each manuscript.

Manuscript I - Fisheries Chart No. 2

The State Department of Land and Natural Resources, Division of Aquatic Resources fisheries chart is a map depicting statistical reporting units by which commercial catches are recorded. Fish catch records are maintined as an automated file by the State Department of Budget and Finance, Electronic Data Processing Division. The chart covers the main Hawaiian Islands, extending some distance northwest from Niihau and southeast from Hawaii. Batch reporting units cover an area of approximately 20 x 20 miles square and the tabular files go back nearly 40 years. Tabular files are keyed to the spatial units by means of a unique identifying number which is assigned each unit. Since this data set would probably not be physically combined with other data in the archive data bases, it was not necessary to rescale or rectify it prior to automation, so no additional manuscripting was necessary.

OTEC Benchmark Sites

Locations of recent ocean benchmark and accompanying survey sites were extracted from a report prepared by Edward K. Noda and Associates in support of "Environmental Studies for the Proposed Ocean Thermal Energy Conversion (OTEC) Plant, Kahe Point". The locations were illustrated very generally in the report as figures, but were also accompanied by specific latitude/longitude coordinates. These coordinates were keypunched to the computer and used to generate points representing the survey sites. No manuscript was prepared for this variable.

State Map

Four National Oceanic and Atmospheric Administration (NOAA) nautical charts were compiled to prepare a map of the entire State of Hawaii showing major land areas and charted shoals, banks and reefs. Each chart was manuscripted individually and included reference points of known geographic location. Once automated, the maps were appended to create a single map.

DSV Turtle Dive Tracks

Also extracted from the Noda report were recorded maps of DSV Turtle dive tracks at Kahe Point. Again, the tracks had been delineated relative to known geographic latitude/longitude locations, and these were used as reference to overlay the separately mapped and automated tracks to a single map.

Table 20 is a summary of staff time spent in carrying out the mapping stage of the pilot study.

C. Data Automation

The next step in implementing the pilot study data base was the automation of all collected and manuscripted geographic information. The information prepared for automation was in two basic formats: the manuscript maps and the codes for those maps. The maps were automated by a process called digitizing. Lines defining each of the polygons or line segments were stored in the computer as series of x,y coordinates connected by straight line segments. Points were represented by single x,y coordinates. Given that the polygon coordinates were closely spaced and the connecting straight lines were very short, the automated polygons closely approximate the curved lines drawn on the original manuscripts. The codes, which describe the attributes of the environmental variables represented on the manuscipts, were keypunched direcly into the computer. A series of programs was then run on both the map and code data to eliminate errors and inconsistencies and to prepare the information for analysis, modeling and computer mapping. This procedure was followed for each of the manuscripts described previously. In addition to polygon, point and line data automated for the pilot study, a special data base of gridded topographic information was compiled for the generation of 3-D views and selected topographic analyses. This grid data base was created by manually overlaying a grid to the topographic basemap and recording on coding forms the topographic value of the centroid of each cell.

The technical process involved in transferring geographic data from the manuscript maps and associated codes to the automated data files can be divided into four major tasks. These are described as follows:

1. Manuscript Map Preparation for Digitizing - Before any manuscript map was automated, it was carefully checked for errors and prepared for actual digitizing. The checking included examination for missing polygons or codes, extraneous lines, or problems which might cause confusion during digitizing. Next a unique number was assigned to each

	Tabular Data	Cartographic Data							Bibliographic Data		
		Generation/Storage	Manipulation/Analysis				Display				
			Geometric Analysis	Network Analysis	Digital Surface Modelling	Query	Composition	Presentation			
	Field Measurement/Observation Retrieve Existing Tabular Data Compilation on Forms Data Entry/Edit Update Storage/Management Data Manipulation Statistical Analysis On-Line Query Report Generation	Air Photo Interpretation Gather Existing Map Data Field Survey (Sampling) Drafting/Compilation on Maps Digitize/Edit Traverse Entry/Cogo Cartographic Data Update Map Join/Edge Match Storage/Management	Polygon Overlay Line in Polygon Vector/Cell Conversion Polygon Dissolve Point in Polygon Polygon to Point Analysis Transformations Buffer/Corridoring Windowing Coordinate Filtering Proximal Analysis Line Length Calculation Area/Perimeter Calculation Aggregation/Districting Contiguity Analysis	Distance Accumulation Area to Network Accumulation Optimal Path Selection Flow Simulation Time/Distance Computation	Spatial Interpolation Contouring Slope/Aspect Sun Intensity Viewshed Road Engineering Design Volume Calculation Cross Sectioning 3-D Viewing/Surface Mapping	Spatial Query Attribute Query	Generalization Scale Change Modify Features/Text Graphic Superimposition	Symbolize Points Symbolize Lines Symbolize Polygons Text/Annotation Display Legends Modify/Update Features/Text	Indexing Storage Retrieval(including biographic reporting)	Administration/Coordination	
PROJECT MANAGER										2	2
SENIOR TECHNICAL STAFF		3									3
JUNIOR TECHNICAL STAFF	2	5									7
AUTOMATION STAFF										8	13
SENIOR MAPPING STAFF		5									45
JUNIOR MAPPING STAFF	10	35									
	12	48								10	70

Table 20
DATA MAPPING RESOURCE SUMMARY
(values expressed in man-days)

of the four manuscript maps for each of the sixteen modules to distinguish it from all of the other files. Certain of the manuscripts were further subdivided into variable files during processing, reflecting the different types of data included on these maps.

Next each manuscript map was prepared for digitizing by geographic reference tic points on each map in sequence from north to south. Then the origin point and centroid of each polygon were marked.

2. Digitizing - Using a process termed "digitizing," all data recorded on the manuscript map was converted to machine readable form. A digitizer - a backlighted drafting table to which is attached a movable cursor - was used to make this conversion. As the cursor was moved horizontally and vertically over each manuscript map mounted on the digitizer table, electronic devices translated these movements into digital measurements in units of one thousandths of an inch. The numbered tic marks were digitized first. The cursor was moved to each tic mark and, by pressing a key, a record was sent to a mini-computer for storage. After all tic marks were digitized, each polygon, point, and line on the map was similarly recorded and stored. The digitized record indicated the precise location in x,y coordinates, of all mapped information with respect to the tic marks. The tic marks represented known points of latitude and longitude to which all of the mapped information was referenced. Data digitizing and all subsequent data automation processes utilized ARC/INFO and GRID software. These software sets have been developed by ESRI during the past twelve years.

   The digitizing process involved systematically recorded data according to a standard set of procedures. For polygon data, this involved selecting and recording a string of x,y coordinates, termed "vertices," where a change in direction occurred along the border of each polygon. Curves were approximated by short straight line segments. All polygons were automated as closed units. They were digitized in a specific order and sequenced accordingly. Lines were digitized like polygons, except that the strings of x,y coordinates were not required to close. Point features were represented by single x,y coordinates.

   In addition to the coordinate files created through digitizing, topographic files were created in a grid format. First a grid of 1/4" cells was plotted onto a sheet of mylar. At 1:12,000 scale, each cell represented 250' on a side, or a land area of approximately 1.4 acres. The grid sheet was sequentially attached to mylar copies of the 1:12,000 basemaps and run through a blueprint machine to make multiple copies of each. The blueprint sheets were partitioned according to coding connections to allow several people to work on the maps simultaneously. The topographic value of the center of each cell was manually transcribed to a coding sheet. The information from the resulting coding sheet was subsequently keypunched to the computer twice, and the files compared to identify possible keypunching errors. Finally a series of programs was run against the topographic grid data base to produce 3-D views of the pilot study area.

3. Editing of Digitized Files - After the manuscript map was digitized, the

stored record was transferred from the digitizer's mini-computer to a large computer for further processisng. The first step in the editing process was to shift and scale the coordinates of each file relative to tic marks which provided geographic reference. From this step, lists were generated which allowed tic identification numbers, tic coordinates, sequence numbers, donut level identifiers and code numbers to be checked. Because of machine errors during digitizing, it was sometimes necessary to redigitize a polygon or a series of polygons. After these editing steps were completed, changes were made and the revised files were stored. At this stage all information stored in the file was numerically accurate. After these machine edits, a plot of each manuscript map for each module was generated. These computer maps were used to visually check the accuracy of the digitized and machine-edited x,y coordinates against the original manuscript maps.

Following the visual edit of points, lines, and polygons, the numeric attribute codes which had been keypunched into the computer were associated with their appropriate spatial unit. Each of the data variables in the system was plotted out at the manuscript scale and compared against manually prepared overlays of the collateral data. These plots, termed "dropline plots", were used to ensure that each data variable was accurately delineated and coded in the computer data file. Most data errors discovered in this edit process were corrected using ARC/INFO edit software. For cases where entire polygons were missing, the original manuscript map was remounted on the digitizer and the entire polygons were digitzed. This redigitized information was merged into the previous information set.

4. Final File Generation - This process involved the creation of final point, line, and polygon files for the study area. Two preliminary steps were required for completion of the x,y coordinate files. The first step involved the conversion of the digitized tic coordinates, which were referenced in inches, to a geographic coordinate referencing system such as UTM. The next step involved the manipulation of various files created for each map module to structure them to a form compatible with the types of outputs and applications to be implemented. At the completion of this step, the data files were in their final x,y coordinate format.

Table 21 is a summary of staff time spent in carrying out the data automation stage of the pilot study. Values shown represent person days.

D. Computer Mapping

The automated data files for the Kahe Point pilot study area were used to produce a variety of maps illustrating the content of the basic data base and several display and analysis examples. Basic data maps portray information directly from the data entered into the computer in the form of manuscript maps and codes. Selected analyses were conducted to illustrate the cartographic and tabular manipulation capabilities of the system.

	Tabular Data	Cartographic Data								Bibliographic Data		
		Generation/Storage	Manipulation/Analysis				Display					
			Geometric Analysis	Network Analysis	Digital Surface Modelling	Query	Composition	Presentation				
	Field Measurement/Observation Retrieve Existing Tabular Data Compilation on Forms Data Entry/Edit Update Storage/Management Data Manipulation Statistical Analysis On-Line Query Report Generation	Air Photo Interpretation Gather Existing Map Data Field Survey (Sampling) Drafting/Compilation on Maps Digitize/Edit Traverse Entry/Cogo Cartographic Data Update Map Join/Edge Match Storage/Management	Polygon Overlay Line in Polygon Vector/Cell Conversion Polygon Dissolve Point in Polygon Polygon to Point Analysis Transformations Buffer/Corridoring Windowing Coordinate Filtering Proximal Analysis Line Length Calculation Area/Perimeter Calculation Aggregation/Districting Contiguity Analysis	Distance Accumulation Area to Network Accumulation Optimal Path Selection Flow Simulation Time/Distance Computation	Spatial Interpolation Contouring Slope/Aspect Sun Intensity Viewshed Road Engineering Design Volume Calculation Cross Sectioning 3-D Viewing/Surface Mapping	Spatial Query Attribute Query	Generalization Scale Change Modify Features/Text Graphic Superimposition	Symbolize Points Symbolize Lines Symbolize Polygons Text/Annotation Display Legends Modify/Update Features/Text	Indexing Storage Retrieval(including biographic reporting)	Administration/Coordination	
PROJECT MANAGER											8	8
SENIOR TECHNICAL STAFF	5	20										25
JUNIOR TECHNICAL STAFF	8	37										45
AUTOMATION STAFF	16	27										43
SENIOR MAPPING STAFF												
JUNIOR MAPPING STAFF												
	29	84									8	121

Table 21
DATA AUTOMATION RESOURCE SUMMARY

The study area, as described previously, was comprised of four 1:12,000 scale modules. To illustrate the entire breadth of the pilot study data base, most 1:12,000 variables were plotted for module number one. This module contained the most complete representation of all variables in the data base. A total of 49 basic data and demonstration maps on both paper and mylar were produced and are listed in Table 22.

Two basic data maps were produced to represent information at the 1:62,500 scale. These included Solar Regimes and Rainfall Regimes. Both were produced in color on a pen plotter.

Selected applications were conducted to illustrate other data and the cartographic and tabular analysis capabilities of the system. A series of maps was produced from fish-catch data to illustrate geographic distribution of fish catches for three species by number caught and dollar value. To illustrate inventory capabilities, a random point was located near the HECO generating plant and a one-mile buffer generated from the point. The resulting circular polygon was overlayed to several variables within the data base; and several tabular listings were produced summarizing resources falling within the buffer by acre. A variable buffer was generated on all streams falling within module one. Each stream class was assigned a different buffer distance and a map produced illustrating the composite atop the basemap. For all modules, a detailed composite basemap was produced depicting topography, bathymetry, transportation network, tax parcels, and streams. Each variable was composed graphically to create a final composite basemap containing information which typically would be represented on a traditional manually produced basemap. Other graphic depictions of various basic data were produced to illustrate other display capabilities of the system.

Early in the study, SETS, Inc. learned that the U.S. Fish and Wildlife Service was having their Anchorage, Alaska office digitize (using the ARC/INFO software) for its Pacific Islands Area Office, an area near Kilauea National Park as a demonstration of the capabilities of Geographic Information Systems. Their original plan was to have the Alaska office deliver hard copies of the data base to the Pacific Islands Area Office. SETS personnel contacted the Alaska office through the Pacific office, and it was agreed that the former would complete the data base in time for inclusion in the DPED data base. This data base, while not part of this project, proved interesting to those involved in forestry management. In addition, it showed how complicated map-related data can be transferred from one agency's data base to another quickly and efficiently.

In addition to maps delivered to DPED, a magnetic tape containing the archive data base in ARC/INFO format was delivered. The tape contained both coordinate and tabular files for all data variables listed previously. A complete listing of the files is included in Appendix H. The U.S. Fish and Wildlife Service data, per their request, are not included in the data base provided as part of this project.

Table 22

BASIC DATA AND DEMONSTRATION MAPS

Basic Data and Maps (Paper Copy)

#	Variable(s)	Data Form	Module
1:12,000 Scale			
1	Tax Map Parcels	Polygon	1
2	Development Plan Public Facilities	Polygon	1
3	Development Plan Land Use Zoning	Polygon	1
4	Zoning	Polygon	1
5	Beach Parks and Rights of Way	Polygon	1
6	Development Plan Public Facilities	Line	1
7	Development Plan Land Use	Line	1
8	Transportation Network	Line	1
9*	Highway Access	Point	1
10	Development Plan Public Facilities	Point	1
11	Tax Map Easements	Line	1
12	Topography/Bathymetry Contours	Line	1
13	Geology	Polygon	1
14	Soils	Polygon	1
15	Shore Type	Polygon	1
16	Slope	Polygon	1
17	Existing Land Use	Polygon	1
18	Landform	Polygon	1
19	Flood Boundaries	Polygon	1
20	Flood Insurance Rate Zones	Polygon	1
21	Tsunami Inundation Areas	Polygon	1
22	Base Flood Zones	Line	1
23	Streams	Line	1
24*	Gauging Stations	Point	1
25	Observation Wells	Point	1
26	Offshore Bottom Type	Polygon	1
27	Use	Point	1
28	OCRI Bibliographic Survey	Point	1
29*	Land/Water Interface	Polygon	1
30*	Archaeological Site #	Point	1

Demonstration Maps (Paper Copy)

31	(Basemap) Topography/Bathymetry Transportation Network Tax Map Parcels Streams		1,2,3,4
32	(Stream Buffer) Topography/Bathymetry Streams Variable Stream Buffer		1

#	Variable(s)	Data Form	Module
33	(Point Buffer) Topography/Bathymetry		1
	Streams		
	Point Buffer		
34	Shaded Slope Map		1
35	Shaded Coral Reef Inventory Map		1

1:62,500 Scale

36	Rainfall Regimes		
37*	Solar Regimes		

Other

38	Fisheries Chart and Summary Map		

Basic Data Atlas (Mylar Copy)
(Module 1)

1:12,000 Scale

39	Topography/Bathymetry	Line
40	Soils	Polygon
	Offshore Bottom Type	Polygon
41	Tax Map Parcels	Polygon
42	Existing Land Use	Polygon
	Offshore Use	Point
43	OCRI Survey Sites	Point
	Cultural Sites	Point
44	OTEC Sampling Stations	Point
	Turtle Dive Tracks	Line
45	Zoning	Polygon
46	Transportation Network	Line
47	Flood Hazard	Polygon
	Flood Boundaries	Polygon
	Tsunami Inundation	Polygon
48	Streams	Line
	Observation Wells	Point
	Gauging Stations	Point
49	Development Plan Land Use	Polygon

*Indicates maps not delivered in hard copy as part of this report. Copies of all other maps are included.