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Local Water Resource Information Management System

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ABSTRACT

LOCAL WATER RESOURCE INFORMATION MANAGEMENT SYSTEM

A Beaver Lake water quality database has been designed as a relational database. It has been implemented using software called R:base 5000, a system available for microcomputors using MS- or PC-DOS operating systems.

The data in the database include that concerned with the author(s), title, date of publication, agency doing the study, agency funding the study and complete reference for the document. Other aspects of the database are designed to allow retrievals based on any author, study dates, parameters measured and keywords.

David G. Parker and Sandra C. Parker

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INTRODUCTION

Beaver Lake in Northwest Arkansas is a valuable water resource for which a wealth of water resource information exists. Water resource information about Beaver Lake has been collected by many different people and organizations, including federal, state and local agencies, regional planning commissions, water districts, university researchers, private consulting firms and individual citizens. Because there are so many sources of water resource information, it is very difficult to find out what information exists and even more difficult to gain access to such information. The result of the difficulty of collecting and using information is that much of the existing water resource information about Beaver Lake is not used effectively or even used at all.

Current national database systems like STORET contain water resource information. Other mainframe computer systems, such as the system being developed to coordinate data from the National Reservoir Research Program, also will contain substantial information. Although these national database systems are very powerful, they do have some limitations regarding convenient access to all of the pertinent information about a particular water resource system. One serious limitation is that some information, such as university results and locally funded water quality survey results, may not be contained in a national database.

A. Purpose and Objectives

The present research has utilized current microcomputer tech-

nology and relational database management techniques in the design of a water resource information management system for Beaver Lake. This system supplements and supports the national databases by containing the local information that exists but is not contained in the national databases.

The resulting Beaver Lake database management system is a model system for local and regional water resource information management. Beaver Lake and its tributaries are used to demonstrate the value of the system as an information management tool. This system can be a very valuable tool in the effort to manage intelligently the water resources of Beaver Lake. The results of this project also can be used as a basis for setting up water resource information management systems for other areas of the state or nation.

B. Related Research or Activities

A thorough review of database management system literature has been conducted as a preliminary step in the design of the Beaver Lake database. A summary of the results of this review follows.

Success with database management efforts in any setting will depend on the proper execution of two primary requirements. These requirements are:

1. sound and skillful database analysis and design, and

2. sound and skillful installation and operation of a database/data communications system product.

This report will address both of these requirements, that for database analysis and design considerations. Installation will be

accomplished with a particular database management system and particular computer; however, the system could be installed to operate with other database management systems and other computers in addition to that described in this report.

Database analysis and design considerations in this report are based on two sources of information and experience. Most importantly, the nature of the data concerning Beaver Lake and the needs for the application of these data to the operation of the various agencies and researchers have been of primary concern in the design considerations. A second source of information and experience concerning such database management needs is that of the extensive experience of the authors with the design, installation and operation of such databases.

Database Management Definitions

Since the various terms which are used regarding databases and their operation and management are often defined differently by different users, it is necessary to define database terms as they will be used herein.

Database

A term as basic as 'database' means different things to different people. There are several components, some or all of which may be considered by some to be included in a database. These are: 1) a complex collection or set of data fundamental to an enterprise, 2) the mechanisms to store data in and retrieve data from that collection and 3) various computer programs to manipulate the data and

to display it in the form of useful information to those individuals needing it. These are essential components of a database application, but for the purposes of this report, the term 'database' will be used to refer only to the collection or set of computerized data. This set of data will vary in complexity depending on the complexity of the applications which the data serve. A more extensive definition of a database will be given below.

Database Management System

The second component, the mechanisms to store data in and retrieve data from that collection, is the essence of a database management system. Commercial database management systems have become increasingly sophisticated in recent years. Besides performing simple data in/data out routines, they include procedures for defining a complex database, maintaining an on-line data dictionary, screen generation of data forms and interactive queries by use of a query language.

Applications Programs

The third component of a database application, the programs which manipulate the data and display it in the form of useful information, constitute the applications programs of a database management system. A single application may have many users who have multiple and different uses for various subsets of the data, therefore, many output programs may be required to produce the necessary varied user views of the data. An applications program organizes and formats retrieved data according to specifications for a particular purpose. Such programs are based on either the programming capabilities built into the

database management system, or on a procedural language such as Pascal or Fortran, or on a separate program package which manipulates data such as SAS (Statistical Analysis System).

Data and Information

It is probably clear from the above discussion that the term 'data' is being used in a different way from 'information'. The distinction is subtle, but useful. The version that is encoded and resides in computer storage is data, or unformatted information, while information is formatted data as it appears in some form external to computer storage, such as on a printed report or on a CRT screen. Keeping these terms distinct will allow for more clarity in the discussions.

Entities, Attributes and Values

A more detailed definition of a database is stating that a database is a collection of values that characterize a group of entities. This definition, however, requires the definition of some other concepts, that of entities, attributes and values. These terms particularly are used differently by different people, and a clear understanding of their meaning as used in this report is necessary for precise communication of the database designs presented.

An entity is a person, a thing, an event, a place or a concept. An example is a report concerning water quality in Beaver Lake. An attribute is that which characterizes an entity. Some characteristics of a report are its date of publication, its author, its title or the content of the report. Values, sometimes called data values or

attribute values, are the actual data that identify a specific entity. It is the attribute values for entities that are stored in a database. Possible data values for the report attribute called date, for example, are the dates of publication. Data values for the report attribute called author are the names of the person or persons who wrote the report.

Files, Records, Fields and Keys

A closer examination of the internal data storage characteristics of a database requires the definition of several terms which describe storage concepts. The terms of file, record, field and key are general terms which can be used to apply to data in a database. The term file refers to a collection of data concerning a particular entity type. Each entry in a file, called a record, constitutes data concerning a particular entity of the entity type. The data in each record is separated into fields, each field representing an attribute for which a data value is recorded. A key, if unique, is a field for which the data value of each record is unique, therefore serving to identify particular records. A field may not be unique but still serve as an identifying key field if the data values of the field are used to organize the records in the file, as the basis for retrieving data from some or all of the records in the file, or for matching records with records in other files to produce a report of information from more than one file.

It should be pointed out that with certain kinds of database management systems, some of these concepts are referred to by different terms. This is the case with relational database management

systems, to be defined below. Since the database designs presented herein are intended for use with a relational system, the terms applying to such a system will be clarified. In a relational system, a collection of data concerning an entity type is referred to as a 'table' instead of a file. Entries, or rows, in a table are called 'tuples' instead of records. The term 'attribute' or 'column' is used instead of field. Although these terms are defined in terms of the particular characteristics of relational database management systems, in practice, they tend to be used interchangeably. For example, in the documentation for INFORMIX, a relational database management system, the terms table and tuple are defined (Relational Database Systems, Inc. 1983:8), but the terms file and record are used thereafter in the documentation. The relational database management system called R:base 5000, used by the present authors for implementing the Beaver Lake database, uses the terms table, row and column.

Types of Database Management Systems

The selection of a database management system should be done with care. If the database management system is not carefully selected with regard to the application needs, the chance for a successful application is severely reduced. This statement applies equally well to environmental applications, business applications or any application with database needs. This discussion will therefore be concerned with the basic differences in database management systems insofar as these differences have a potential impact for an environmental management application.

Database Management Systems--Logical Data Models

Database management systems differ with respect to the logical organization of the database, or the data model of the system. The nature of the rules that define the relationships between records in the database define a system's data model. Records in an environmental database might be those concerning bibliographic references to environmental studies of interest, parameters measured in the studies, the years in which sampling was conducted, and so on.

There are three major data models: the network model, the hierarchical model and the relational model. Both the network and the hierarchical data models create databases that are rigidly structured by internally defined record relationships. They differ in that hierarchical organizations allow a record type to be owned by only one other record type, while the network data model allows multiple owners of the same record type. For both of these data models, the relationships that bind records together are "pointer-based." The stored data include the storage location of the member records in the structure, often in the form of up and down pointers, and such database management systems create a static environment. Such databases are extremely difficult to change since any redefinition of record relationships requires restructuring the entire database.

The third data model, relational, has a "value-based" mechanism of interrecord relationships. The value-based relationship database management systems create databases that allow the specification of relationships at retrieval time. The system determines at retrieval

time whether records exist that participate in a user-specified relationship, and this determination is made on the basis of matching attribute values between different sets of records. Such systems create a dynamic environment as the locations of the related records are discovered during retrieval.

Network and hierarchical data models allow records to be retrieved and updated only in terms of their predefined relationships. Relational systems, on the other hand, allow relationships to be defined at the time of retrieval, thereby allowing many different user views of the same set of data. For example, one environmental relational database user may retrieve report titles along with information about parameters observed, and this could be accomplished by a matching of document numbers stored as an attribute value in both the bibliographic table and the parameter table. A second user could retrieve bibliographic information along with information about keywords in the report by matching document numbers stored both in the bibliographic table and the keyword table.

In choosing the most desirable database management system for any application, one must carefully assess the nature of the environment in which the system is to operate. A relational system offers the definite advantage of change and growth in a database that is not possible in either a network or hierarchical system. A disadvantage to relational systems which has been frequently cited in the past is that they process data more slowly than pointer-based systems, but relational database technology has developed in recent years such that

this criticism is largely no longer valid. True relational systems with B-tree access methods retrieve data much more rapidly than earlier relational systems. The bottom line in selection of a system may be that if you know exactly what your database should include and how the various record types relate to one another and you will always desire to retrieve data according to this predefined structure, then perhaps a network or hierarchical system would be the best choice. If, however, data need to be combined differently for different purposes and new record types may be added to the database through time, then the best choice would be a relational system. An attempt to apply a static data model to a dynamic environment is doomed to fail.

Database Management Systems--Features

Besides the differences in data models supported by various database management systems, they also may differ with regard to a number of features. The efficient use of these features can make the design and implementation of a database a reasonably expedient process. Before the availability of the modern systems, programming for a database management system required months and often even years of design work, encoding and debugging, still with the risk of being completed only to be found lacking in terms of current needs.

Today's fully featured database management systems allow the prototyping of a database design in a very short period of time, possibly even a week or two. The construction of a prototype means that the database design is communicated to the system and implemented with the input of a small number of records. The adequacy of the design

can be tested, changed if desired, and retested before large numbers of records are input. This entire process can take place in a period of a few weeks, thus allowing for the refinement of the database design without a large investment of time.

The features of modern database management systems which have simplified the implementation of a database, allowing prototyping of the database, include the following:

1. Data definition language--the data definition language allows one to communicate to the system the various entity types, i.e., files or tables, to be included in the database, as well as the attributes or fields for each type and the characteristics of attribute values.

2. Non-procedural query language--often called a 4th generation query language. The query language allows one to retrieve data from the database by virtue of simple statements defining the data to be retrieved. Such languages are called non-procedural and 4th generation because they are used to tell the system what is wanted, not how to get what is wanted as one would have to do with 3rd generation languages such as COBOL, Pascal or FORTRAN.

3. Input by forms--systems which provide for forms generation allow for designing forms on the screen which correspond to manual data collection forms. Data input into the system may be accomplished with the use of these screen forms.

4. Integrated, interactive data dictionary--this facility provides for data definition operations to be automatically recorded in a data dictionary, thereby insuring that discrepancies do not develop

between the database and the data dictionary. Such discrepancies are a real hazard with any external data dictionary, either computerized or manual. The internal dictionary can be queried, manipulated and modified with any such modifications updating both the database and dictionary.

5. Access control--such a facility maintains details of access privileges. Users are identified with passwords which function to control access to different kinds of data as well as to the various functions of the system. For example, it will probably be desirable in a management application to limit the privilege of modifying or updating data to one or a few particular users, while other users may be able only to query and output information. This facility aids the protection of the integrity of the database.

6. Data validation facility--several methods for data validation may be provided. These include enforcing formats for each field, i.e., alphabetic, character, integer, data and so forth, checking field lengths, range checking to limit input values between a minimum and maximum, requiring certain fields to have data input, checking other portions of the database to insure that certain data values are already present in the database, checking for uniqueness of a record, and table lookup for allowable values for a field. These functions cannot eliminate all erroneous data in a database, but they do eliminate most of the sources of error in data input.

7. Report generator--this facility provides a mechanism for generating customized and complex types of reports. Normally pro-

vided are certain built-in functions, such as sum, average, count, maximum, minimum and string manipulation. The more general and flexible the report generator, the less likely an application will require special applications programs written in a procedural language such as Pascal.

It seems clear that the availability of database management systems, such as those being described here, makes it easier to implement a computerized system than it was just a few years ago. However, the availability of inexpensive, sophisticated software certainly does not solve the entire problem. Each application should be accompanied by an application needs assessment to determine the information needs for which a database is to be designed. Decisions must be made concerning what entities, or record types, need to be computerized, what attributes need to be included in the database, and how the data need to be encoded to serve desired purposes.

METHODS AND PROCEDURES

Database Analysis and Design

Successful database analysis and design is based on two processes which go hand in hand. Either one without the other will result in an inferior database design for an application. These two processes are the functional analysis of the agencies, organizations or individuals for whom a database is to be developed, identifying the desirable information products for the application; and a data analysis, identifying the data necessary for producing the desired information products. Information products, as defined above, are intended to mean the physical

output of an application. These products are in the form of documents, lists and other report formats external to the computer, or in the case of on-line systems, such products are in the form of screen report formats.

The current research has included a functional analysis and a data analysis for the Beaver Lake database. The functional analysis is a 'top-down' approach and by necessity must precede the data analysis. In designing a database for an application, it is necessary to first analyze the information needs for which the application is to be implemented. In order to do this, the objectives of the application are defined. Only by defining these objectives is it possible to insure that the database design will satisfy the information needs of the application.

The data analysis approach, on the other hand, is a 'bottom-up' process that works with and analyzes the information products of the application for which the database is being designed. It is the opposite of the functional analysis but operates on the results of the functional analysis, the defined information products necessary for the application. It is the goal of data analysis to examine these products and, through a step-by-step process, convert the data into a detailed model of how the data in the system interact. The stages of data analysis as applied in this study (adapted after process defined by Perkinson 1984) are based on a relational data model and are as follows:

Stage 1. Data Collection and Normalization

Gather and break data up into small logical groups (entities), using normalization, thus making each relation as independent as possible.

Stage 2. Entity-relationship Mapping

Associate entities that are identified with each other (i.e., related) using entity-relationship mapping techniques.

Stage 3. Data Modeling

Draw a logical structure (schema) using logical synthesis.

Stage 1 will result in the definition of the entity types to be included in the database. In relational terminology, these entities represent the relations or tables that constitute the database. The process of normalization reduces data to small stable structures. It is a technique for decomposing data into smaller structures in which each attribute is totally dependent upon the primary key of the entity in which it resides. Normalization depends upon a knowledge and understanding of data in the functional setting being examined and the way it relates together. A result of normalization, for example, is to remove repeating groups of attributes of an entity into a separate relation. This requires a redundancy in order to relate the two relations properly, and this is what is referred to in relational terminology as 'controlled redundancy'. The necessary redundancy is the inclusion of an attribute in the newly defined relation which identifies the particular entity in the original relation to which the new entity is related. This identification is necessary to allow appropriate merging of the data in the two relations. It is these relation-

ships which are used in the mapping of Stage 2.

The schema, produced in Stage 3, is an overall logical database description (Martin 1977:61). This description is in the form of a chart of the names of the entity types (relations) in a database, the names of the attributes of each relation, and the characteristics of the attribute values.

Functional Analysis for a Beaver Lake Database

Beaver Lake is of considerable economic importance to Northwest Arkansas. This man-made lake is approximately 73 miles long and has about 480 miles of shoreline. It covers approximately 32,000 acres and is located in the counties of Washington, Benton, Carroll and Madison. It is a multipurpose reservoir, serving to provide hydroelectric power, flood control on the lower White River, a recreational facility, and a source of drinking water to the cities of Springdale and Fayetteville.

There is a need for long-term management policies regarding Beaver Lake which will guarantee the continuation of appropriate water quality to support the functions served by the reservoir. Any such policies need to be based on the most complete and accurate information available. The goals and objectives regarding resource management are:

A. To provide for the protection of water quality for a source of drinking water.

B. To provide for flood control for the lower White River.

C. To maintain the appropriate water quality to allow the lake

to serve as a recreational facility for boating, swimming and fishing.

D. To guide further interpretation through scientific study of the reservoir.

E. To serve for generating hydroelectric power.

These goals and objectives are broad, complex and far reaching, and they obviously require many and varied information products if they are to be executed satisfactorily. An important part of these information products will be concerned with the documents and publications pertinent to the interpretation of the reservoir and a list of these information products follows; access to such information products may be through off-line lists or on-line ad hoc queries:

A. List of documents concerned with Beaver Lake water quality.

B. List of documents concerned with one or more particular water quality parameters.

C. List of documents concerned with one or more particular authors.

D. List of documents concerned with one or more keywords used for classifying such documents.

E. List of documents concerned with studies done between particular dates.

Beaver Lake Data Analysis

As stated previously, the first stage of a data analysis involves the data definition process, as seen from the bottom-up. This was accomplished by a careful examination of a number of publications

reporting studies regarding water quality and other environmental features of Beaver Lake, both preimpoundment and postimpoundment. This process identified the entities and their attributes that are found in these pertinent reports. The results of this process are then examined for assurance that the identified data are sufficient for serving as a basis for the generation of the information products identified in the functional analysis.

The first step of data analysis is to identify the types of environmental data pertinent to the defined functions and to group these data into relations. These relations are then normalized to eliminate repeating groups of attributes within a relation.

The basic environmental entity type, the publication and the attributes associated with each publication, identified by the data analysis follows:

1) Entity type - publication regarding Beaver Lake

   Publication attributes -

   a. Name of publication or report
   b. Author or Authors
   c. Title of publication
   d. Date of publication
   e. Agency producing the report
   f. Agency to whom the report was submitted
   g. Complete bibliographic citation
   h. Keywords for indexing publications
   i. Years in which sampling was done

Some of the references for Beaver Lake include sampling procedures and the measurement of various parameters related to water quality while others do not. A publication may indicate measurement of the following parameters:

Parameter attributes -

a. alkalinity, bicarbonate
b. alkalinity, total
c. bacteria, total coliform
d. bacteria, fecal coliform
e. bacteria, fecal streptococcus
f. calcium
g. carbon dioxide
h. chloride
i. conductivity
j. dissolved oxygen
k. hardness
l. hydrogen sulfide
m. iron
n. magnesium
o. nitrogen, nitrate
p. nitrogen, nitrite
q. nitrogen, ammonia
r. nitrogen, total
s. pH
t. phosphorous, total

u. phosphorous, orthophosphate

v. phosphorous, polyphosphate

w. potassium

x. silica

y. sodium

z. sulfate

aa. temperature

ab. total organic carbon

PRINCIPAL FINDINGS AND SIGNIFICANCE

Relational Mapping and Schemas

The previous step identified the entity and its associated attributes required to produce the information products indicated by the functional analysis. The present step will identify the relations to be defined and the relationships defined by the structure of records and lay out the physical database structures or schema.

The document entity type is normalized into five relations (or tables), one for the main document relation and four subsidiary relations. The main document table is called "bib", and the four subsidiary tables are called "authors", "keywords", "param" and "study". The schema and its explanation will be presented below.

Beaver Lake Database Schema

The main document table contains the following attributes:

Table: bib

Attributes:

Name	Type	Length	Content
doc	integer		Unique document number.
f_author	text	25 chars	Name of first or only author, last name first.
date	text	4 chars	Date of publication.
title_1	text	66 chars	First 66 characters of title.
title_2	text	66 chars	Second 66 characters.
title_3	text	66 chars	Third 66 characters.
title_4	text	66 chars	Fourth 66 characters.
r_by	text	70 chars	Name of agency producing report.
r_for	text	70 chars	Name of funding agency.
refer_1	text	66 chars	First 66 characters of reference.
refer_2	text	66 chars	Second 66 characters.
refer_3	text	66 chars	Third 66 characters.
refer_4	text	66 chars	Fourth 66 characters.
refer_5	text	66 chars	Fifth 66 characters.
refer_6	text	66 chars	Sixth 66 characters.

The table "authors" includes an entry for each author of the document, therefore, one document may be related to one or more authors:

Table: authors

Attributes:

Name	Type	Length	Content
doc	integer		Unique document identification.
author	text	25 chars	Author's name, last name first.

The table "keywords" includes an entry for each keyword by which

a document may be retrieved:

Table: keywords

Attributes:

Name	Type	Length	Content
doc	integer	1 value	Unique document identification.
keyword	text	60 chars	Word or phrase describing content of report.

The table "study" is used for the dates that study samples were taken in the lake. Each sample year is one entry, therefore, one document may be related to one or more study years:

Table: study

Attributes:

Name	Type	Length	Content
doc	integer	1 value	Unique document identification.
year	text	4 chars	Year in which sampling was done.

The table "param" includes the parameters measured by the study. One document will not relate to more than one row of parameters, and some of the documents do not reference parameters at all:

Table: param

Attributes:

Name	Type	Length	Content
doc	integer	1 value	Unique document identification.
ph	text	1 char	"y" indicates pH.
alkal	text	1 char	"y" indicates alkalinity, total.
hardness	text	1 char	"y" indicates hardness.

Name	Type	Length	Content
calcium	text	1 char	"y" indicates calcium.
magnes	text	1 char	"y" indicates magnesium.
bicarb	text	1 char	"y" indicates alkalinity, bicarbonate.
sulfate	text	1 char	"y" indicates sulfate.
chloride	text	1 char	"y" indicates chloride.
sodium	text	1 char	"y" indicates sodium.
potas	text	1 char	"y" indicates potassium.
silica	text	1 char	"y" indicates silica.
hyd_sul	text	1 char	"y" indicates hydrogen sulfide.
toc	text	1 char	"y" indicates total organic carbon.
conduct	text	1 char	"y" indicates conductivity.
c_diox	text	1 char	"y" indicates carbon dioxide.
nitrate	text	1 char	"y" indicates nitrogen, nitrate.
nitrite	text	1 char	"y" indicates nitrogen, nitrite.
phos	text	1 char	"y" indicates total phosphorous.
o_phos	text	1 char	"y" indicates orthophosphate.
p_phos	text	1 char	"y" indicates polyphosphate.
ammonia	text	1 char	"y" indicates ammonia.
iron	text	1 char	"y" indicates iron.
do	text	1 char	"y" indicates dissolved oxygen.
temp	text	1 char	"y" indicates temperature.
nitrogen	text	1 char	"y" indicates total nitrogen.
t_colif	text	1 char	"y" indicates total coliform.

Name	Type	Length	Content
f_colif	text	1 char	"y" indicates fecal coliform.
f-strep	text	1 char	"y" indicates fecal streptococcus.

Beaver Lake Database Implementation

The database schema defined above has been implemented with a relational database management system called R:base 5000 (Microrim 1985). This software is available for microcomputers using MS- or PC-DOS operating software.

The data entered into the system is from a library search of studies which have been concerned with water quality in Beaver Lake (Ashworth and Mitchell 1982). These references are listed in Appendix A. Appendix B contains an example page from a listing of the documents with measured parameters indicated. Appendix C contains a listing of the documents with their keywords listed. This keyword list is not meant to be exhaustive of the possible keywords that can be used in the system. New keywords can be added to the system at any time. Appendix D contains examples of five specific retrievals from the system, illustrating the kind of queries that can be answered by the system. These examples are not exhaustive, but merely indicate some possible retrievals.

CONCLUSIONS

A Beaver Lake water quality database design has been completed, designed as a relational database. It has been implemented using software called R:base 5000, a system available for microcomputers using MS- or PC-DOS operating systems.

The data in the database includes that concerned with the author(s), title, date of publication, agency doing the study, agency funding the study and complete reference for the document. Other aspects of the database are designed to allow retrievals based on any author, study dates, parameters measured and keywords.

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APPENDIX A.

Listing of Documents in Beaver Lake Database

Beaver Lake References

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"Beaver Reservoir Study. Benton and Washington Counties, Arkansas". Public Health Service, Dallas, Texas, June, 1959.

Becker, David A. and Robert G. Heard. "A Preimpoundment Survey of the Helminth and Copepod Parasites of Micropterus Spp. of Beaver Reservoir in Northwest Arkansas". Transactions of the American Fisheries Society, Vol. 95, No. 1, January, 1966.

Becker, David A., et al. "Pre- and Postimpoundment Ichthyoparasite Succession in a New Arkansas Reservoir". Department of Zoology, Univ. of Arkansas, 1970.

Bennett, Wayne D. "The Effect of Impoundment of the Water Quality and Microbial Ecology in Beaver Reservoir from June, 1968 to June, 1969". Master's thesis, Univ. of Arkansas, 1970.

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Dale, Edward E. "The Composition and Abundance of Vegetation Inhabiting the Water Fluctuation Zones of Beaver and Bull Shoals Lakes". Submitted to Fish and Wildlife Service by the Department of Botany and Bacteriology, Univ. of Arkansas, July, 1978.

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Dendy, John S. "Bottom Fauna Development in Beaver Reservoir, Northwest Arkansas, During the Period of Filling, 1964 to 1966, Final Report". Submitted to Fish and Wildlife Service by the Departments of Zoology and Entomology, Univ. of Arkansas, May 1, 1968.

Drach, Robert F. "Pre- and Postimpoundment Trends and Possible Effects of Helminth and Crustacean Parasites of Black Basses in Beaver Reservoir, Arkansas". Master's thesis, Univ. of Ark., 1970.

Drury, Douglas D. "The Bacterial and Algal Activity in the Metalimnion of Beaver Reservoir". Master's thesis, Univ. of Arkansas, 1973.

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Meinecke, James I. "Effects of Rotenone on Zooplankton in an Ozark Reservoir Cove". Master's thesis, Univ. of Arkansas, 1978.

Meyer, Richard L. "Biochrome Analysis as a Method for Assessing Phytoplankton Dynamics, Phase I". Water Resources Research Center, Univ. of Arkansas, December, 1974.

Meyer, Richard L. "Biochrome Analysis as a Method for Assessing Phytoplankton Dynamics, Phase II". Water Resources Research Center, Univ. of Arkansas, June, 1975.

Miner, F.D. and L.O. Warren. "Bottom Fauna of Beaver Reservoir". Submitted to Fish and Wildlife Service by the University of Arkansas, March 1, 1967.

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Mullan, James W. and Richard L. Applegate. "The Physical-Chemical Limnology of a New Reservoir (Beaver) and a Fourteen Year Old Reservoir (Bull Shoals) Located on the White River, Arkansas, and Missouri". Bureau of Sport Fisheries and Wildlife, Fayetteville, Arkansas, 1965.

"National Eutrophication Survey, Report on Beaver, Table Rock, and Bull Shoals Reservoirs, Arkansas and Taneycomo Reservoir, Missouri; Benton, Carroll, Boone, Marion and Baxter Counties, Arkansas; and Barry, Stone, Taney, and Ozark Counties, Missouri". Working Paper N. 480, Office of Research and Development, U.S. Environmental Protection Agency, February, 1977.

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Newton, Scott H. "The Fecundity of White Bass, Roccus Chrysops, (Rafinesque), in Beaver Reservoir, Arkansas". Master's thesis, Univ. of Arkansas, 1968.

Olmsted, Larry L. "The Feeding Biology of White Bass, Roccus Chrysops (Rafinesque), in Beaver Reservoir, Arkansas". Master's thesis, Univ. of Arkansas, 1971.

Owen, Wilbur B. "A Continued Pre- and Postimpoundment Survey of the Helminth and Crustacean Parasites of Micropterus Dolomieui Lacepede, M. Punctulatus (Rafinesque) and M. Salmoides (Lacepede) (Perciformes) of Beaver Reservoir in Northwestern Arkansas". Master's thesis, Univ. of Arkansas, 1969.

"Present Municipal Water Use Including Information of Deficiencies in Supply in the Arkansas-White-Red Basins". Public Health Service, Little Rock, Arkansas, October, 1952.

Russell, Harry C. "An Initial Assessment Contamination and Pollution of Beaver Reservoir Property Development". Special problem, Univ. of Arkansas, 1975.

Schmitz, Eugene H. "Limnetic Zooplankton Dynamics in Beaver Reservoir, Including an Inventory of Copepod Species and an Evaluation of Vertical Sampling Methods". Submitted to Bureau of Sport Fisheries and Wildlife by the Department of Zoology, Univ. of Arkansas, October, 1973.

Schmitz, Eugene H. "Selected Aspects of the Limnology of Zooplankton in Beaver and DeGray Reservoirs, Arkansas, with Emphasis on the Development of a Method for the Estimation of Zooplankton Biomass". Submitted to Fish and Wildlife Service by the Univ. of Arkansas, 1975.

Schmitz, Eugene H. "Zooplankton Limnology of Beaver and DeGray Reservoirs in Arkansas, Period of Performance: June 1, 1977 to May 31, 1978". Submitted to Fish and Wildlife Service by the Univ. of Arkansas, 1978.

Short, Edgar D. "Limnetic Zooplankton Dynamics in Beaver Reservoir Including a Preliminary Report on Vertical Distribution Patterns". Submitted to Bureau of Sport Fisheries and Wildlife by the Univ. of Arkansas, June, 1974.

Short, Edgar D. "Seasonal and Diel Vertical Distribution of Zooplankton in Beaver Reservoir, Arkansas, Including an Assessment of Species Composition, Diversity, and Horizontal Distribution". Master's thesis, Univ. of Arkansas, 1977.

Stephens, Allen D. "Seasonal Variation of the Phytoplankton Community and Nutrient Concentration of Beaver Reservoir from July, 1972 to June, 1973". Master's thesis, Univ. of Arkansas, 1973.

Stone, Larry J. "A Study: Effects of Geology and Nutrients on Water Quality Developments". Paper presented at the Annual Conference, AWWR, May 17, 1973.

Stone, Steven J. "Septic Tank Pollution of Beaver Reservoir". Special problem, Univ. of Arkansas, 1972.

"A Water Quality Data Computer Program, Compiled to Present". STORET. Arkansas Department of Pollution Control and Ecology, Little Rock, Arkansas.

Thibodeaux, Louis J. "An Aqueous Environmental Simulation Model for Mid-South Lakes and Reservoirs". Water Resources Research Center, Univ. of Arkansas, June 30, 1976. Note: there is also an additional "Appendix A" which is "Documentation of Computer Program" for the above report.

Warren, L.O. "Preimpoundment Studies of the Aquatic Insect Fauna of the Beaver Reservoir Basin, 1963 to 1964, Final Report". Submitted to Fish and Wildlife Service by the Department of Entomology,Univ. of Arkansas, September 30, 1964.

"Water Resources Data for Arkansas". U.S. Geological Survey Water Data Reports, published reports from 1968 to present.

White River Beaver Dam and Lake Design Memorandum No. 13-4. "Updated Master Plan for Development and Management of Beaver Lake". U.S. Corps of Engineers, 1974.

Yellayi, Rama Rao. "A Contribution to the Dynamics of White Bass Morone Chrysops (Rafinesque) Population in Beaver Reservoir, Arkansas". Dissertation, Univ. of Arkansas, 1972.

APPENDIX B.

Listing of Documents with Measured Parameters

Mullan, James W. and Richard L. Applegate. "The Physical-Chemical Limnology of a New Reservoir (Beaver) and a Fourteen Year Old Reservoir (Bull Shoals) Located on the White River, Arkansas and Missouri". Bureau of Sport Fisheries and Wildlife, Fayetteville, Arkansas, 1965.

	*
Alkalinity, Bicarbonate	:y
Alkalinity, Total	:
Bacteria, Total Coliform	:
Bacteria, Fecal Coliform	:
Bacteria, Fecal Streptococcus	:
Calcium	:y
Carbon Dioxide	:
Chloride	:y
Conductivity	:y
Dissolved Oxygen	:
Hardness	:
Hydrogen Sulfide	:y
Iron	:
Magnesium	:y
Nitrogen, Nitrate	:
Nitrogen, Nitrite	:
Nitrogen, Ammonia	:
Nitrogen, Total	:
pH	:
Phosphorous, Total	:
Phosphorous, Orthophosphate	:
Phosphorous, Polyphosphate	:
Potassium	:y
Silica	:y
Sodium	:y
Sulfate	:y
Temperature	:
Total Organic Carbon	:y

* a "y" indicates that the parameter was measured; a blank indicates that it was not.

APPENDIX C.

Listing of Documents with Keywords

General Design Memorandum, No. 6. "White River Watershed, Beaver Reservoir, White River, Arkansas". U.S. Army Corps of Engineers, 1960.

general design

White River Beaver Dam and Lake Design Memorandum No. 13-4. "Updated Master Plan for Development and Management of Beaver Lake". U.S. Corps of Engineers, 1974.

master plan

"Comprehensive Basin Study Main Report, Volume 1, White River Basin, Arkansas and Missouri". White River Basin Coordinating Committee, June, 1968.

White River basin study

"Final Operation and Maintenance Environmental Statement, Beaver Lake, Arkansas". U.S. Army Engineer District, Little Rock, Ark., 1974.

operation and maintenance

"Present Municipal Water Use Including Information of Deficiencies in Supply in the Arkansas-White-Red Basins". Public Health Service, Little Rock, Arkansas, October, 1952.

water needs

"Beaver Reservoir Study. Benton and Washington Counties, Arkansas". Public Health Service, Dallas, Texas, June, 1959.

water needs

Market, Don. "The Economic Impact of Beaver Lake Reservoir: A Cost Benefit Study". Arkansas Water Resources Research Center, Univ. of Arkansas, September, 1973.

economic impact

"Water Resources Data for Arkansas". U.S. Geological Survey Water Data Reports, publ. reports from 1968 to present.

water quality data source

Horn, M.E. and D.E. Garner. "Soil and Water Chemistry in the Beaver Reservoir Area, White River, Arkansas". Department of Agronomy, Univ. of Arkansas, September, 1964.

preimpoundment water quality

Mullan, James W. and Richard L. Applegate. "The Physical-Chemical Limnology of a New Reservoir (Beaver) and a Fourteen Year Old Reservoir (Bull Shoals) Located on the White River, Arkansas, and Missouri". Bureau of Sport Fisheries and Wildlife, Fayetteville, Arkansas, 1965.

postimpoundment water quality
physical-chemical limnology

Horn, M.E. and J. S. Runsick. "Water Quality in Beaver Reservoir Watershed Postimpoundment Investigations, July, 1964 to July, 1966". Department of Agronomy, Univ. of Arkansas, August, 1966.

postimpoundment water quality

Bennett, Wayne D. "The Effect of Impoundment of the Water Quality and Microbial Ecology in Beaver Reservoir from June, 1968 to June, 1969". Master's thesis, Univ. of Arkansas, 1970.

postimpoundment water quality
microbial ecology

Stephens, Allen D. "Seasonal Variation of the Phytoplankton Community and Nutrient Concentration of Beaver Reservoir from July, 1972 to June, 1973". Master's thesis, Univ. of Arkansas, 1973.

postimpoundment water quality
phytoplankton
nutrient concentration

Stone, Larry J. "A Study: Effects of Geology and Nutrients on Water Quality Developments". Paper presented at the Annual Conference, AWWA, May 17, 1973.

postimpoundment water quality
geology
nutrient concentration

Dale, Edward E. "Final Report on Ecological Investigations of Existing Vegetation in the Preimpoundment and Watershed Area of Beaver Lake". Submitted to Bureau of Sport Fisheries and Wildlife by the Department of Botany and Bacteriology, Univ. of Arkansas, 1962.

biology
preimpoundment vegetation

Dale, Edward E. "The Composition and Abundance of Vegetation Inhabiting the Water Fluctuation Zones of Beaver and Bull Shoals Lakes". Submitted to Fish and Wildlife Service by the Department of Botany and Bacteriology, Univ. of Arkansas, July, 1978.

biology
postimpoundment vegetation

Warren, L.O. "Preimpoundment Studies of the Aquatic Insect Fauna of the Beaver Reservoir Basin, 1963 to 1964, Final Report". Submitted to Fish and Wildlife Service by the Department of Entomology, Univ. of Arkansas, September 30, 1964.

biology
preimpoundment aquatic fauna
Diptera
Plecptera
Ephemeroptera

Dendy, John S. "Bottom Fauna Development in Beaver Reservoir, Northwest Arkansas, During the Period of Filling, 1964 to 1966, Final Report". Submitted to Fish and Wildlife Service by the Departments of Zoology and Entomology, Univ. of Arkansas, May 1, 1968.

biology
freshwater sponges
period of filling aquatic fauna
Chironomidae
Porifera

Duncan, T.O. "Freshwater Sponges in Beaver Reservoir". Southwestern Naturalist, March 1, 1977.

freshwater sponges
period of filling aquatic fauna
biology
Spongillafragilis leidy
Meyenia mulleri
Meyenia crateriformis potts
Trochospongilla leidyi
Asteromeyenia

Aggus, Larry, R. "Summer Benthos in Newly Flooded Areas of Beaver Reservoir During the Second and Third Years of Filling, 1965-1966". Reservoir Fisheries and Limnology, American Fisheries Society, Special Publication No. 8, 1971.

Chironomidae
Crustacea
period of filling aquatic fauna
summer benthos
biology

Miner, F.D. and L.O. Warren. "Bottom Fauna of Beaver Reservoir". Submitted to Fish and Wildlife Service by the Univ. of Arkansas, March 1, 1967.

Chironomidae

Applegate, Richard L. and James W. Mullan. "Zooplankton Standing Crops in a New and an Old Ozark Reservoir". Limnology and Oceanography, Volume 12, No. 4, October, 1967.

Copepod Cyclopoid
Copepod Calanoid
biology
period of filling zooplankton
Cladoceran Bosmina
Cladoceran Daphnia

Damico, Sam. "Limnetic Zooplankton Population Dynamics in Beaver and Bull Shoals Reservoirs: Composition, Seasonal Abundance, Structure, and Vertical Migration". Submitted to Bureau of Sports Fisheries and Wildlife by the Department of Zoology, Univ. of Arkansas, August, 1972.

Crustacea
postimpoundment zooplankton
biology
Cladocera
Colonial Rotifer
Copepoda
Entomostraca
Cyclopoida

Schmitz, Eugene H. "Limnetic Zooplankton Dynamics in Beaver Reservoir, Including an Inventory of Copepod Species and an Evaluation of Vertical Sampling Methods". Submitted to Bureau of Sport Fisheries and Wildlife by the Department of Zoology, Univ. of Arkansas, October 1973.

biology
postimpoundment zooplankton
Copepoda
Rotatoria
Asplanchna priodonta
Chaoborus punctipennis
Cladocera daphnidae

Short, Edgar D. "Limnetic Zooplankton Dynamics in Beaver Reservoir Including a Preliminary Report on Vertical Distribution Patterns". Submitted to Bureau of Sport Fisheries and Wildlife by the Univ. of Arkansas, June, 1974.

Cyclopoida
Cladocera
Calanoida
biology
postimpoundment zooplankton
Asplanchna priodonta
Bosmina longirostris
Ceroidaphnia lacustris
Daphnia parucla

Schmitz, Eugene H. "Selected Aspects of the Limnology of Zooplankton in Beaver and DeGray Reservoirs, Arkansas, with Emphasis on the Development of a Method for the Estimation of Zooplankton Biomass". Submitted to Fish and Wildlife Service by the Univ. of Arkansas, 1975.

Alona rectangula
postimpoundment zooplankton

estimation of zooplankton biomass
Cladocera
biology
Rotatoria
Copedoda
Alona monacantha
Simocephalus expinosos

Short, Edgar D. "Seasonal and Diel Vertical Distribution of Zooplankton in Beaver Reservoir, Arkansas, Including an Assessment of Species Composition, Diversity, and Horizontal Distribution". Master's thesis, Univ. of Arkansas, 1977.

biology
postimpoundment zooplankton
Cyclops bicuspidatus thomasi
Mesocyclops edar
Diaptomus reighardi
Cladocera
Bosmina longirostris
Ceriodaphnia lacustris
Daphnia parvula
Daphnia ambigua
Daphnia rosea
Daphnia brachyurun
Simocephalus expinosos
Rotatoria

Schmitz, Eugene H. "Zooplankton Limnology of Beaver and DeGray Reservoirs in Arkansas, Period of Performance: June 1, 1977 to May 31, 1978". Submitted to Fish and Wildlife Service by the Univ. of Arkansas, 1978.

biology
postimpoundment zooplankton
Cyclopoida
Calanoid
Nauplii
Copepodid
Cladocera
Bosmina longirostris
D. parvula
Asplanchna priodonta
Rotatoria

Meinecke, James I. "Effects of Rotenone on Zooplankton in an Ozark

Reservoir Cove". Master's thesis, Univ. of Arkansas, 1978.

biology
postimpoundment zooplankton
rotenone
Rotatoria
Copepoda
Cladocera
Diaphanosome leuchtenbergianum

Meyer, Richard L. "Biochrome Analysis as a Method for Assessing Phytoplankton Dynamics, Phase I". Water Resources Research Center, Univ. of Arkansas, December, 1974.

biology
postimpoundment phytoplankton
biochrome analysis
Chroomonas
Cryptomonas
Stephanodiscus
Cyclotella
Pandorinamorum

Meyer, Richard L. "Biochrome Analysis as a Method for Assessing Phytoplankton Dynamics, Phase II". Water Resources Research Center, Univ. of Arkansas, June, 1975.

biology
postimpoundment phytoplankton
biochrome analysis

Corey, R. Reece, George W. Mann and Byron Van Dover. "Final Report Microbiological Survey". Department of Botany and Bacteriology, Univ. of Arkansas, 1964.

biology
bacterial and algal activity

Drury, Douglas D. "The Bacterial and Algal Activity in the Metalimnion of Beaver Reservoir". Master's thesis, Univ. of Arkansas, 1973.

biology
bacterial and algal activity
Cryptomonas
Scenedesmus
Tetraedron

Fragillaria
Polycystis

Becker, David A. and Robert G. Heard. "A Preimpoundment Survey of the Helminth and Copepod Parasites of Micropterus Spp. of Beaver Reservoir in Northwest Arkansas". Transactions of the American Fisheries Society, Volumne 95, No. 1, January, 1966.

biology
postimpoundment parasites
Micropterus spp.
Posthodiplostomium minimum
Neoechinorhynchus cylindratus
Protecephalus ambloplitis

Holmes, Perry D. "The Helminth and Copepod Parasites of Roccus Chrysops (Rafinesque), Micropterus Dolomieui Lacepede, M. Punctulatus (Rafinesque), and M. Salmoides (Lacepede) (Perciformes) of the Beaver Lake Watershed in Arkansas". Master's thesis, Univ. of Arkansas, 1964.

biology
postimpoundment parasites
Micropterus spp.
Roccus chrysops

Heard, Robert G. "A Preimpoundment Survey of the Helminth and Copepod Parasites of Micropterus Dolomieui Lacepede, M. Punctulatus (Rafinesque), and M. Salmoides (Lacepede) (Perciformes) of Beaver Reservoir in Northwest Arkansas". Master's thesis, Univ. of Arkansas, 1965.

biology
postimpoundment parasites
Micropterus spp.

Evans, Wallace A. "A Comparative Preimpoundment and Early Postimpoundment Survey of the Helminth and Copepod Parasites of Micropterus Dolomieui Lacepede, M. Punctulatus (Rafinesque), and M. Salmoides (Lacepede) (Perciformes) of Beaver Reservoir in Northwest Arkansas". Master's thesis, Univ. of Arkansas, 1968.

biology
preimpoundment parasites
postimpoundment parasites
Micropterus spp.

Owen, Wilbur B. "A Continued Pre- and Postimpoundment Survey of the Helminth and Crustacean Parasites of Micropterus Dolomieui Lacepede, M. Punctulatus (Rafinesque), and M. Salmoides (Lacepede) (Perciformes) of Beaver Reservoir in Northwestern Arkansas". Master's thesis, Univ. of Arkansas, 1969.

biology
preimpoundment parasites
postimpoundment parasites
Micropterus spp.
Ergasilus caeruleus
Urocleidus principalis
Argulus mississipiensis
Clavunculas bursatus
Urocleidus furcatus
Leptorhynchoides thecatus

Drach, Robert F. "Pre- and Postimpoundment Trends and Possible Effects of Helminth and Crustacean Parasites of Black Basses in Beaver Reservoir, Arkansas". Master's thesis, Univ. of Arkansas, 1970.

biology
preimpoundment parasites
postimpoundment parasites
Urocleidus furcatus
Posthodiplostomum minimum
Spinitectus carolini
Ergasilus caeruleus
Clavunculus bursatus
Neoechinorhynchus cylindratus
Actinocleidus fusiformis
Urocleidus principalis
Ergasilus caeruleus

Becker, David A., et al. "Pre- and Postimpoundment Ichthyoparasite Succession in a New Arkansas Reservoir". Department of Zoology, Univ. of Arkansas, 1970.

biology
preimpoundment parasites
postimpoundment parasites

Carr, William D. "A Comparative Pre- and Postimpoundment Survey of the Helminth and Crustacean Parasites of Micropterus Punctulatus (Rafinesque) and M. Salmoides (Lacepede) (Perciformes) in Beaver Reservoir, Arkansas". Master's thesis, Univ. of Arkansas, 1975.

biology
preimpoundment parasites
postimpoundment parasites
Micropterus spp.

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Micropterus sp.

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Roccus chrysops

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Dorosoma

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Dorosoma cepedianum

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Dorosoma petenense

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Dorosoma cepedianum
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Dorosoma cepedianum
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postimpoundment fish study
Dorosoma cepedianum

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ecosystem modeling

Dunn, James E. and Chester Murphy. "Use of Transfer Function Models to Forecast Sport Fish Harvest in Beaver Reservoir". Submitted to Fish and Wildlife Service by the Univ. of Arkansas, July 15, 1977.

transfer function models
forecast sport fish harvest

Thibodeaux, Louis J. "An Aqueous Environmental Simulation Model for Mid-South Lakes and Reservoirs". Water Resources Research Center, Univ. of Arkansas, June 30, 1976. Note: there is also an additional "Appendix A" which is "Documentation of Computer Program" for the above report.

environmental simulation model

APPENDIX D.

Examples of Retrievals from the System

Example 1. The following represents a retrieval from the database for a particular author, "James W. Mullan":

Applegate, Richard L. and James W. Mullan. "Food of the Black Bullhead (Ictalurus melas) in a New Reservoir". Southeastern Assoc. Game and Fish Commissioners 20th Annual Conference, 1966.

Applegate, Richard L. and James W. Mullan. "Food of Young Largemouth Bass, Micropterus salmoides, in a New and Old Reservoir". Transactions of the American Fisheries Society, Vol. 96, No. 1, January 20, 1967.

Applegate, Richard L. and James W. Mullan. "Standing Crops of Dissolved Organic Matter, Plankton, and Seston in a New and an Old Ozark Reservoir". Reservoir Fishery Resources Symposium held in Athens, Georgia, April 5-7, published November, 1968.

Applegate, Richard L and James W. Mullan. "Zooplankton Standing Crops in a New and an Old Ozark Reservoir". Limnology and Oceanography, Volume 12, No. 4, October, 1967.

Mullan, James W. and Richard L. Applegate. "Centrarchid Food Habits in a New and Old Reservoir During and Following Bass Spawning". Proceedings of the 21st Annual Conference of the Southeastern Association of Game and Fish Commissioners, 1967.

Mullan, James W. and Richard L. Applegate. "Food Habits of Five Centrarchids During Filling of Beaver Reservoir, 1965-66". Technical Papers of the Bureau of Sport Fisheries and Wildlife, No. 50, April, 1970.

Mullan, James W. and Richard L. Applegate. "The Physical-Chemical Limnology of a New Reservoir (Beaver) and a Fourteen Year Old Reservoir (Bull Shoals) Located on the White River, Arkansas, and Missouri". Bureau of Sport Fisheries and Wildlife, Fayetteville, Arkansas, 1965.

Example 2. The following represents a retrieval from the database for a particular parameter, magnesium:

Bennett, Wayne D. "The Effect of Impoundment of the Water Quality and Microbial Ecology in Beaver Reservoir from June, 1968 to June, 1969". Master's thesis, Univ. of Arkansas, 1970.

Horn, M.E. and D.E. Garner. "Soil and Water Chemistry in the Beaver Reservoir Area, White River, Arkansas". Department of Agronomy, Univ. of Arkansas, September, 1964.

Horn, M.E. and J.S. Runsick. "Water Quality in Beaver Reservoir Watershed Postimpoundment Investigations, July, 1964 to July, 1966". Department of Agronomy, Univ. of Arkansas, August, 1966.

Mullan, James W. and Richard L. Applegate. "The Physical-Chemical Limnology of a New Reservoir (Beaver) and a Fourteen Year Old Reservoir (Bull Shoals) Located on the White River, Arkansas, and Missouri". Bureau of Sport Fisheries and Wildlife, Fayetteville, Arkansas, 1965.

Example 3. The following represents a retrieval from the database for a particular keyword, "freshwater sponges":

Dendy, John S. "Bottom Fauna Development in Beaver Reservoir, Northwest Arkansas, During the Period of Filling, 1964 to 1966, Final Report". Submitted to Fish and Wildlife Service by the Departments of Zoology and Entomology, Univ. of Arkansas, May 1, 1968.

Duncan, T.O. "Freshwater Sponges in Beaver Reservoir". Southwestern Naturalist, March 1, 1977.

Example 4. The following represents a retrieval from the database for a particular funding agency, "Fish and Wildlife Service":

Dale, Edward E. "The Composition and Abundance of Vegetation Inhabiting the Water Fluctuation Zones of Beaver and Bull Shoals Lakes". Submitted to Fish and Wildlife Service by the Department of Botany and Bacteriology, Univ. of Arkansas, July, 1978.

Dendy, John S. "Bottom Fauna Development in Beaver Reservoir, Northwest Arkansas, During the Period of Filling, 1964 to 1966, Final Report". Submitted to Fish and Wildlife Service by the Departments of Zoology and Entomology, Univ. of Arkansas, May 1, 1968.

Dunn, James E. and Chester Murphy. "A Study of the Feasibility of Ecosystem Modeling of Beaver Reservoir". Submitted to Fish and Wildlife Service by the Univ. of Arkansas, July 15, 1976.

Dunn, James E. and Chester Murphy. "Use of Transfer Function Models to Forecast Sport Fish Harvest in Beaver Reservoir". Submitted to Fish and Wildlife Service by the Univ. of Arkansas, July 15, 1977.

Kilambi, Raj V. and Lyman E. Barger. "Dynamics of Feeding Ecology of Larval Shad, Dorosoma, in Beaver Reservoir, Arkansas, Final Report". Submitted to Fish and Wildlife Service by the Department of Zoology, Univ. of Arkansas, 1975.

Miner, F.D. and L.O. Warren. "Bottom Fauna of Beaver Reservoir". Submitted to Fish and Wildlife Service by the Univ. of Arkansas, March 1, 1967.

Schmitz, Eugene H. "Selected Aspects of the Limnology of Zooplankton in Beaver and DeGray Reservoirs, Arkansas, with Emphasis on the Development of a Method for the Estimation of Zooplankton Biomass". Submitted to Fish and Wildlife Service by the Univ. of Arkansas, 1975.

Warren, L.O. "Preimpoundment Studies of the Aquatic Insect Fauna of the Beaver Reservoir Basin, 1963 to 1964, Final Report". Submitted to Fish and Wildlife Service by the Department of Entomology, Univ. of Arkansas, September 30, 1964.

Example 5. The following represents a retrieval from the database for a particular date of publication, 1972:

Ball, Robert Lee. "The Feeding Ecology of the Black Crappie, Pomoxis Nigromaculatus, and the White Crappie, Pomoxis annularis, in Beaver Reservoir, Arkansas". Master's thesis, Univ. of Arkansas, 1972.

Carnahan, Gary L. "Eutrophic Potential of Beaver Reservoir Influents". Special problem, Univ. of Arkansas, 1972.

Damico, Sam. "Limnetic Zooplankton Population Dynamics in Beaver and Bull Shoals Reservoirs: Composition, Seasonal Abundance, Structure, and Vertical Migration". Submitted to Bureau of Sports Fisheries and Wildlife by the Department of Zoology, Univ. of Arkansas, August, 1972.

Stone, Steven J. "Septic Tank Pollution of Beaver Reservoir". Special problem, Univ. of Arkansas, 1972.

Yellayi, Rama Rao. "A Contribution to the Dynamics of White Bass Morone Chrysops (Rafinesque) Population in Beaver Reservoir, Arkansas". Dissertation, Univ. of Arkansas, 1972.