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DATA-BASE MANAGEMENT SYSTEM FOR RESERVOIR FIELD STUDIES

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Water quality monitoring programs often result in the collection of data of such magnitude and diversity that the use of manual methods of storage and analysis is impractical. Therefore, a critical phase in the planning of monitoring programs is the establishment of a comprehensive Data-Base Management System (DBMS).

A DBMS is a combination of personnel, materials, and methods that provides a structured mechanism for processing raw data into useful information upon which sound management decisions can be based and for the subsequent control, storage, and retrieval of data and processed information. While many DBMSs have been developed and are available through major computer vendors, it is often desirable to modify or develop a system tailored for particular needs.

A DBMS should have the following attributes:

- Central location with easy access by all users.
- Sufficient written documentation.
- Data files capable of easy periodic updating.
- Statistical analysis and data display capabilities.

APPLICATION

Intensive sampling programs were conducted at four CE reservoirs (Lake Red Rock, Iowa; DeGray Lake, Arkansas; Eau Galle Lake, Wisconsin; and West Point Lake, Georgia-Alabama) as part of EWQOS Task VIIA—Reservoir Field Studies (RFS). Data consisted of numerous descriptive, morphometric, hydrologic, meteorologic, and limnologic variables collected during routine or special intensive samplings. The DBMS designed for this project used available computer facilities and Statistical Analysis System (SAS) software and provided a meaningful framework for study planning, data storage, and data analysis (Figure 1).

The initial step in developing the DBMS was the design of all RFS sampling efforts. The experimental design ensured that the sampling strategy, including station locations and variable selection, satisfied the objectives of the study. Before collection of any data, field and laboratory elements were provided with data-code forms. All code forms were designed to group variables by analysis type or collection times. Field workers simply recorded the data in the format specified for each code form. These forms permitted direct keypunching of data from the original field and laboratory forms, thus avoiding transcription errors.

Once the sampling program was designed, guidance was provided for field data collection to ensure proper labeling methods for all samples sent for laboratory analysis. When field sampling and laboratory analyses were completed, the code forms were reviewed for completeness, photocopied, keypunched, and filed for future reference. Temporary raw data files, established directly from keypunch, were transformed into SAS data files and entered into the edit program phase. Editing programs examined variables for presence/absence

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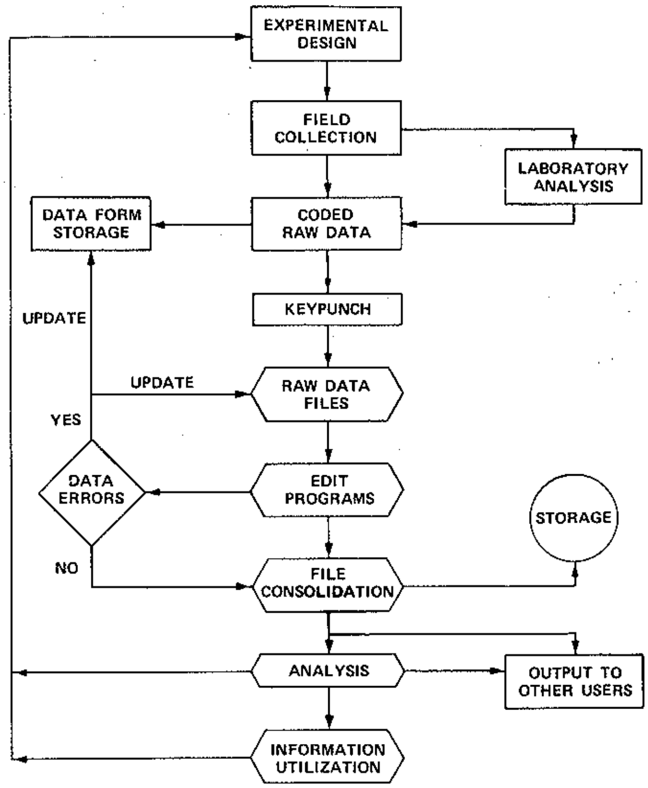

Figure 1. Design of Reservoir Field Studies Data-Base Management System

I. GENERAL INFORMATION
- Library of data
- Study documentation
- Data availability

II. MORPHOMETRY
- Area/capacity
- Station locations
- Volume
- Elevations

III. HYDROLOGY
- Inflow/outflow
- Water quality

IV. METEOROLOGY
- Weather Service
- WES stations

V. LIMNOLOGY
- Water quality
  - in situ
  - chemical
  - physical
  - biological

VI. SEDIMENT QUALITY
- Chemical
- Physical

VII. SPECIAL STUDIES

Figure 2. Listing of consolidated data files for each RFS study site

and proper numeric or character value structure, as well as satisfaction of various conditional constraints. Theoretical constraints (e.g., pH $\leq$ 14 or dissolved phosphorus concentrations $\leq$ total phosphorus) as well as relative constraints (e.g., values far in excess of those previously observed) were employed. Data identified in this matter were checked for accuracy against the original data.

While many errors can be detected in the editing step, subtle errors occurring within acceptable limits can only be detected through point-by-point verification of the data. Unedited as well as edited versions of the data were sent to the person responsible for the collection of the data for verification. Verified printouts were then returned for updating. Changes made in computer files were also made on stored code forms to ensure consistency of all data records. Data verification was an iterative process in that the data might be checked several times before final acceptance.

Once the data had been verified, the SAS files were consolidated to produce files of logically grouped variables (Figure 2). Computer storage of the consolidated files was accomplished on both magnetic disk and tape. Data to be used immediately or in the near future were maintained on-line for analysis; a complete copy of all data collected during routine sampling was stored off-line on magnetic tape. Retrieval of all data was easily accomplished by DBMS personnel.

The final phases of the DBMS were data analysis and interpretation. Data analysis could vary from simple graphical displays to sophisticated statistical techniques based on the study objectives and questions being asked. The DBMS could also respond to a diversity of analytical requests by providing raw or processed data to other users in almost any format.

The extraction and partitioning of various aspects of RFS data for analysis contributed to the design of sampling strategies at the four CE reservoirs. For example, a statistical analysis and resultant graphic display of epilimnetic chlorophyll a concentrations at DeGray Lake, Arkansas, clearly demonstrated significant longitudinal variation from headwater to dam (Figure 3). Monitoring stations were located (designated by arrows in Figure 4) to investigate the full range of variability in various constituents and thereby permit adequate characterization of water quality conditions found in DeGray Lake. This information was combined with

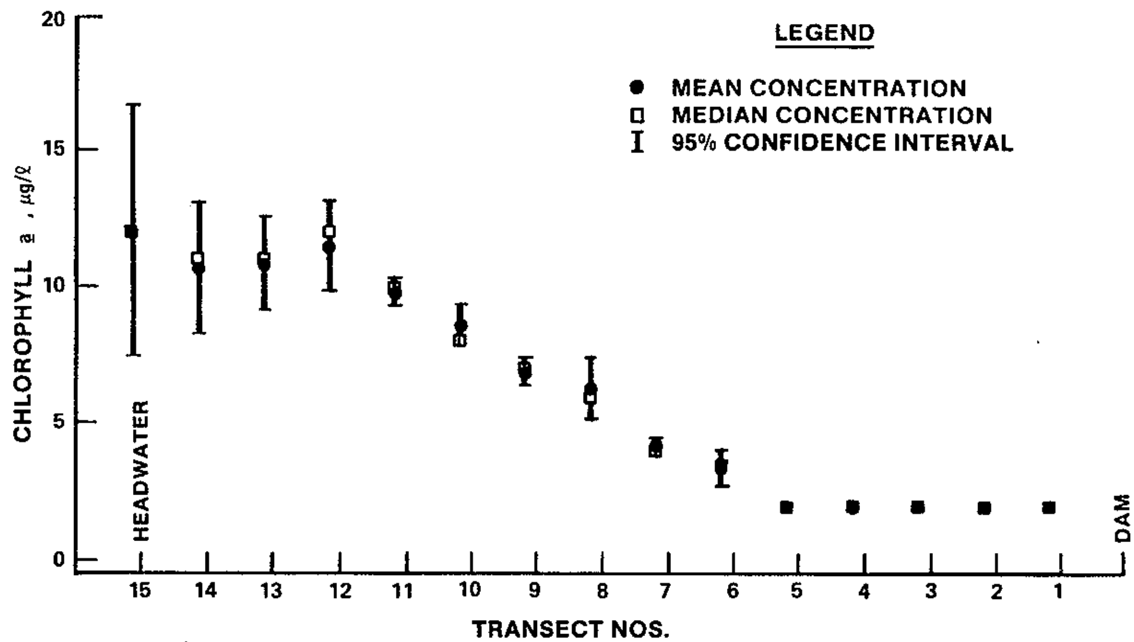

Figure 3. Changes in mean and median chlorophyll a concentration with distance in July 1979

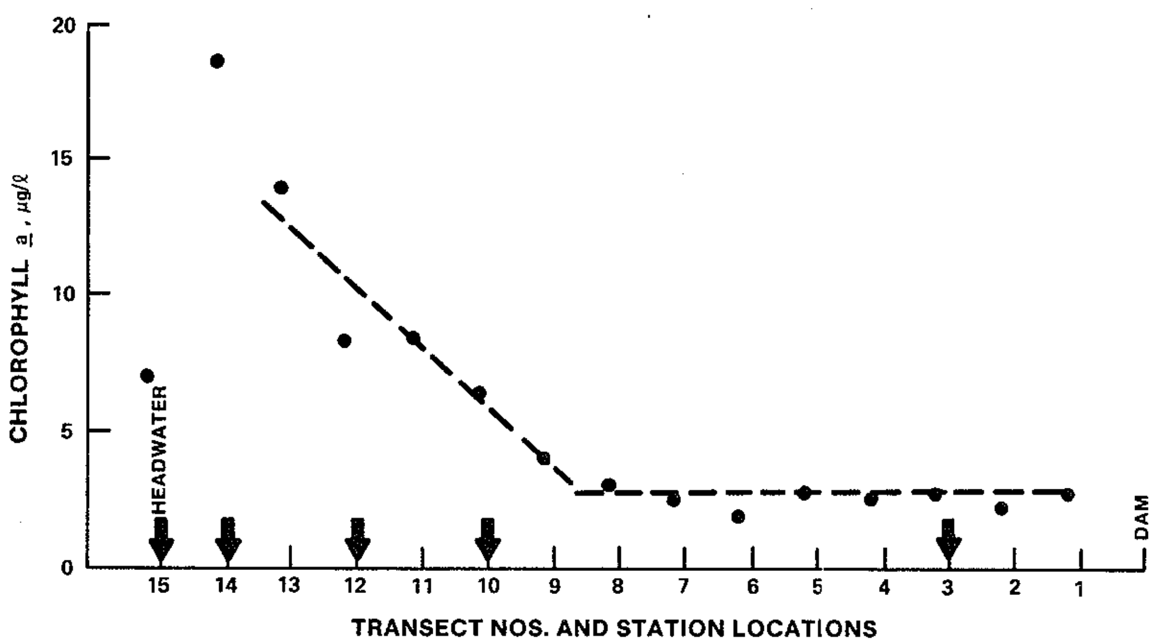

Figure 4. Representative sampling station locations selected to characterize longitudinal gradients in DeGray Lake (marked by arrows)

similar analyses of chemical and physical constituents and used to establish a cost-effective sampling design incorporating the longitudinal gradient for various constituents.

Placement of long-term monitoring stations without prior knowledge of a system and its variability may produce information of questionable reliability. The DeGray analysis pointed to the need for multiple sampling stations rather than a single sampling station in order to characterize existing water quality conditions. Utilization of the DBMS and statistical analysis thus provided insight to the advantages of water quality sampling designs that offer alternatives based on cost and precision.

CONCLUSIONS

The DBMS designed for the RFS provided a structured and secure methodology for the acquisition, maintenance, and utilization of large amounts of field and laboratory data. The DBMS also reduced or, in some cases, eliminated errors resulting from data transcription. The RFS DBMS provides the means for processing large amounts of data into meaningful information to be used in making appropriate cost-effective management decisions related to reservoir water quality.

DESCRIPTIONS OF RESERVOIR CHEMICAL PROCESSES

Rex L. Chen and Douglas Gunnison*

Destratification of hypolimnetic waters produces circulation that moves dissolved oxygen (DO) into the anoxic hypolimnion of reservoirs. Results from laboratory and field studies indicate that increasing the DO content of anoxic water results in decreased concentrations of the dissolved forms of manganese, iron, phosphorus, ammonium, and hydrogen sulfide. Effects of aeration on pH and redox potential are also important to chemical transformations in reservoir ecosystems.

Sufficient data are not available to evaluate the effect of destratification on availability of dissolved chemical species of interest in reservoirs. EWQOS Task IB.2 is addressing this problem, with particular emphasis on descriptions that characterize chemical reactions associated with interactions of dissolved particulate matter under aerobic and anaerobic conditions in reservoirs.

RESEARCH APPROACH

The literature was reviewed and a technical workshop was conducted to identify and develop descriptions of major aerobic reactions in aquatic environments and to recommend research concepts for laboratory and field efforts. Laboratory investigations have been undertaken to quantify chemical process rate coefficients using sediments from selected reservoirs. Emphasis has also been placed on evaluating the effects of aeration on rate coefficients for mathematical descriptions of dissolved-particulate interactions. Research is directed towards improving and verifying descriptive formulations depicting aerobic processes.

The literature review coupled with the laboratory investigations of oxidation processes will allow formulation of a realistic conceptual model of aerobic processes that, along with appropriate process rate data, can serve as a basis for an aerobic subroutine for the numerical reservoir water quality model CE-QUAL-R1. This aerobic subroutine will provide Corps project offices with the ability to predict the water quality during and following the processes of destratification in reservoirs.

LABORATORY INVESTIGATIONS

Several chemical reactions occurring in sediment-water systems during destratification are being investigated in the laboratory:

- Nitrification
- Nitrogen mineralization/immobilization
- Ferrous iron oxidation
- Manganeous manganese oxidation
- Sulfide oxidation
- Ortho-phosphate phosphorus disappearance
- Carbon transformations

These oxidation reaction processes in sediment-water systems have been investigated using sediments from existing Corps reservoirs and soils from areas that may be impounded. The soils and sediments were obtained from the following areas:

Reservoir	Location
Twin Valley Reservoir	St. Paul District
DeGray Reservoir	Vicksburg District
Eau Galle Reservoir	St. Paul District
Bloomington Reservoir	Baltimore District
Brown's Lake	Waterways Experiment Station
Beech Fork Reservoir	Huntington District

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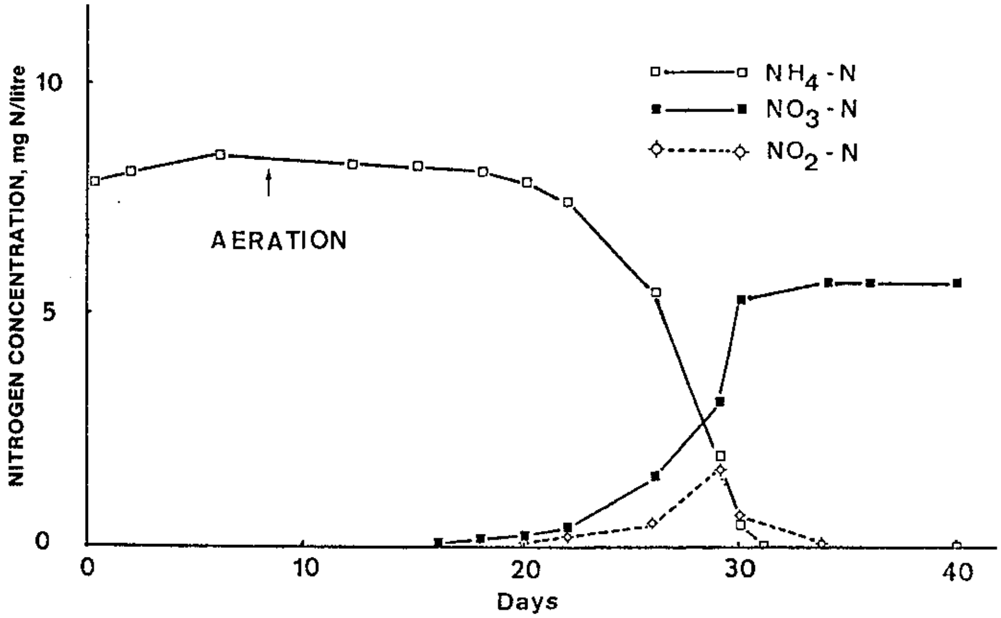

Figure 1. Typical pattern of nitrogen transformations in the water of a sediment-water system incubated under simulated aeration at 10°C.

Large-scale reaction chambers (described by Gunnison et al. in Vol. E-80-4 of this bulletin) with minor modifications to simulate reservoir systems under destratification were used to evaluate the rate of aerobic chemical interactions in sediment-water systems. A small-scale sediment-water model system containing 4 ℓ of sediment and 12 ℓ of simulated reservoir water in an 18-ℓ cylinder was also used. The DO concentrations in the cylinder were precisely maintained at either 5 ± 0.5 or 8 ± 0.5 mg/ℓ to simulate the estimated average DO-concentration range in destratified bottom water of most reservoirs.

Data being obtained in laboratory aeration studies include the kinetics of nutrient and metal (iron and manganese) interactions at the sediment-water interface under aerobic conditions. At the start of the experiment, the sediment-water system was maintained under anoxic conditions for a period of time prior to aeration. Nutrient and metal transformations effected by oxygen were monitored after aeration. A typical pattern of nitrogen transformations in an anoxic sediment-water system during the period of aeration is presented in Figure 1. Concentration and distribution of various parameters in the water of a Beech Fork sediment-water system are summarized in Table 1.

FUTURE ACTIVITIES

Field studies have been initiated at Eau Galle Reservoir to provide verification of the chemical reaction rates for aerobic processes in sediment-

TABLE 1. CONCENTRATION OF DISSOLVED OXYGEN AND NUTRIENTS IN WATER OF A BEECH FORK SEDIMENT-WATER SYSTEM*

	Concentration, mg/ℓ									
Aeration Days	**DO**	**Total Kjedahl Nitrogen**	**NH_4—N**	**(NO_2 + NO_3)—N**	**Total Phosphorus**	**OPO_4—P**	**Soluble Fe****	**Soluble Mn****	**Total Carbon Inorganic**	**Total Carbon Organic**
0	0.0	1.68	1.29	0.05	0.14	0.19	4.82	2.14	10.25	9.58
1	4.2	1.73	1.17	0.07	0.75	0.51	1.43	1.96	8.85	8.30
3	7.4	1.30	1.02	0.08	0.10	0.01	1.82	1.64	7.72	8.33
8	7.2	1.00	0.53	0.69	0.11	0.06	1.26	0.05	4.98	8.72
14	7.5	0.38	0.08	1.29	0.12	0.03	1.30	0.05	2.07	4.21
28	7.8	0.46	0.07	1.11	0.11	0.05	—	—	2.07	4.21

*Incubated under simulated destratification at 20°C.

**Water samples were filtered through 0.1-μm membrane filters.

water systems being obtained in laboratory investigations.

SUMMARY

The objective of Task IB.2 is to develop conceptual descriptions of chemical processes in reservoir ecosystems. A thorough review of existing literature is being followed by laboratory and field investigations to provide oxidation reaction-rate data. These data will subsequently be used to construct a water quality model for evaluating interactive chemical processes that occur in reservoirs during conversion of anoxic hypolimnetic waters to aerobic conditions. Application of the aerobic model (subroutine) in the numerical water quality model CE-QUAL-R1 to various Corps projects using data generated from this task offers a viable means for examining the effectiveness of various management strategies on problems associated with stratification/destratification. Work in Task IB.2 is resulting in valuable rate data that can be used in predicting and evaluating the effects of reaeration on various chemical processes of interest that affect water quality in reservoirs.

DRAFT USER'S MANUAL FOR RESERVOIR MODEL

Joseph Wlosinski*

A draft User's Manual for a numerical one-dimensional model of reservoir water quality (CE-QUAL-R1) has been prepared as part of the EWQOS Program Task IC.1. The model describes or predicts the vertical distribution of thermal energy and 22 biological and chemical materials in a reservoir through time. Model output includes both vertical in-lake and downstream release concentrations. Output can be produced in either a tabular or graphical form.

Some examples of the types of water quality problems that can be addressed with the CE-QUAL-R1 model include:

- ★ Onset, extent, and duration of thermal stratification.
- ★ Location of selective withdrawal ports required to meet downstream temperature objectives.
- ★ Effect of structural modifications on water quality.
- ★ Development of anoxic conditions.
- ★ Development of algal blooms.
- ★ Effects of storm events on in-pool and release water quality.
- ★ Effects of project operation changes such as altered release levels, destratification, or change in minimum or maximum release rates.

CE-QUAL-R1 has been used during its developmental phase to study preimpoundment and postimpoundment water quality, as well as the effects of reservoir operations on water quality.

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The main text of the User's Manual is separated into four parts:

- Part I: Introduction to CE-QUAL-R1, its major usages and attributes, and historical development.
- Part II: Model capabilities, assumptions and limitations, and basic equations.
- Part III: Detailed description of each subroutine.
- Part IV: Description of the various coefficients, constants, and updates required to use the model, how to calibrate the model, and how to interpret model output.

The five appendices contain the following:

- Appendix A: Listing of the FORTRAN code for CE-QUAL-R1
- Appendix B: Glossary of variables and coefficients used in the model
- Appendix C: Example of a data deck showing card images
- Appendix D: Example of sample output
- Appendix E: Information on the thermal portion of the model (the thermal portion is actually a stand-alone model that can be used to calibrate the water budget and thermal predictions)

The manual will be published in loose-leaf format and has been structured for ease of periodic update. Revisions will be distributed automatically to all holders of record.

A draft of the manual has been submitted to OCE and the EWQOS Field Review Group. The manual will be released after their review and approval.

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