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Hydrologic Engineering Center

Proceedings of a Seminar on

Attaining Water Quality Goals through Water Management Procedures

17 - 18 February 1982
Dallas, TX

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14. ABSTRACT
A seminar on Attaining Water Quality Goals through Water Management Procedures was held on 17 - 18 February 1982 in Tampa, Florida. The purpose of the seminar was to provide a forum for Corps of Engineers personnel who are routinely involved in water quality and water control work. Topics included evaluation of water quality impact, program management river and reservoir math modeling capabilities, water control strategies, operating constraints, objectives, dredging, data collection, laboratory analysis, data management, and data interpretation.

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17 - 18 February 1982

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University of Oklahoma
City/County of Oklahoma, Health Department

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FOREWORD

A two-day seminar on "Attaining Water Quality Goals through Water Management Procedures" was held in Dallas, Texas, on 17-18 February 1982. The Purpose of the seminar was to provide a forum for Corps of Engineers personnel who are routinely involved in water quality and water control work.

Topics addressed during the seminar included Evaluation of Water Quality Impacts; Water Quality Program Management; River and Reservoir Systems Math Modeling Capability; Water Control Strategies, Operating Constraints, and Water Quality Objectives; Dredging Experiences and Disposal of Dredge Materials. A panel included 2 papers each on Data Collection, Laboratory Analysis, Data Management and Data Interpretation. One paper on each subject is given by the field office staff and one by the research laboratory personnel. Case Studies included Reservoir Management Considerations, Unique Dredging Response near Mt. St. Helens, Turbine Venting Experiences, and Analysis of Hydrodynamics and Salinity in San Francisco Bay. Twenty-eight of the papers presented during the seminar are contained herein.

The conference room, individual rooms and all local arrangements were organized by Mr. David Brown from the Southwestern Division Office.

These seminar proceedings in addition to the general seminar coordination were organized by Mr. R. G. Willey of the Hydrologic Engineering Center. The seminar was co-sponsored by the Hydrologic Engineering Center and the Committee on Water Quality. Valuable assistance was graciously provided for coordination of the separate sessions by Messrs. Richard Jackson, Wilmington District; Dale Raven, NCD; Ed Lally, NAD; Robert Engler, WES; and Robert Watson, SAD.

The views and conclusions expressed in these proceedings are those of the authors and are not intended to modify or replace official guidance or directives such as engineer regulations, manuals, circulars, or technical letters issued by the Office of the Chief of Engineers.

R. G. Willey
Editor

SEMINAR

ON

ATTAINING WATER QUALITY GOALS THROUGH

WATER MANAGEMENT PROCEDURES

17-18 February 1982

Dallas, Texas

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THE COMMITTEE ON WATER QUALITY
By
Howard O. Reese[1]

The Corps of Engineers Committee on Water Quality was organized in 1975 and formally established by ER 15-2-10, 12 December 1975. Committee functions were expanded in 1977 to provide consulting services to Corps field elements, ER 15-2-11. These regulations were combined into one regulation, ER 15-2-10 dated 25 May 1979. This regulation outlines and describes the objectives and responsibilities of the Committee and the procedures to be used by Corps field offices in acquiring the Committee's consulting services.

Members of the Committee are appointed by the Chief of Engineering Division, Directorate of Civil Works, OCE. The current membership of eighteen is listed at the end of this paper. The list includes representatives from the Waterways Experiment Station, Cold Regions Research and Engineering Laboratory, Hydrologic Engineering Center, OCE, and ten division offices.

The responsibilities and objectives of the Committee are as follows:

1) Provide technical assistance and guidance in developing design and regulation criteria for Civil Works projects to meet water quality management objectives.

2) Determine problem areas to be addressed and recommend investigations and research needed to arrive at adequate solutions.

3) Promote coordination and communication among Corps offices.

4) Disseminate technical information - technology transfer.

5) Provide advisory consulting services on specific water quality problems as requested by Corps field offices.

The Chairman calls committee meetings whenever the problems for consideration warrant such action. Meetings are usually held semi-annually and they are hosted by one of the division offices or laboratories on an informal rotating basis. Due to travel and budget restrictions and because no problems required immediate action, no meetings were held in 1981.

1 Missouri River Division; Vice Chairman, Committee on Water Quality

A major part of the work accomplished by the Committee is performed by Work Groups. Work assignments are undertaken at committee meetings. If necessary, members of a Work Group meet independently of the committee meetings for a 2 or 3-day work session to complete their assignments. The Work Groups are as follows:

1) Work Group I - Gas Supersaturation

2) Work Group II - Field and Laboratory Procedures - Data Collection

3) Work Group III - Reservoir Operation for Water Quality Control

4) Work Group IV - Training, Technology Transfer and Consulting

This water quality seminar is the fourth seminar co-sponsored by the Committee and the Hydrologic Engineering Center (HEC). The primary purpose of a water quality seminar is technology transfer. Seminar proceedings are prepared and published by the HEC. They are distributed to Corps field offices and seminar participants. Copies of the proceedings are available for the following seminars:

1) Water Quality Data Collection and Management, 25-26 January 1977, Denver, Colorado

2) Water Quality Data Interpretation, 8-9 February 1978, Atlanta, GA.

3) Water Quality Evaluation, 22-24 January 1980, Tampa, Florida

An important function of the Committee is its consulting services which is provided to Corps field offices in an advisory capacity. The Committee assists in defining the scope and impacts of water quality problems and in evaluating alternative plans for solving the problems. Requests for consulting services should be submitted to the Committee Chairman through HQDA (DAEN-CWE-HY) WASH DC 20314. The Chairman selects members of the Committee and other individuals with appropriate experience to provide the requested assistance. Arrangements are made for the selected group to meet with the field office for briefings and discussions. Following the meeting, a letter report with conclusions and recommendations is furnished to the requesting office for their consideration. Consulting services provided to date are as follows:

1) Louisville District, Cave Run Lake Project, KY, May 1977

2) Chicago District, Chicago Underflow Plan, September 1980

3) St. Paul District, Pembina Reservoir Project, ND, July 1981

Another important function is to provide assistance with the preparation of engineering regulations and technical letters pertaining to guidance and direction on water quality management activities for civil works projects. Initial drafts are prepared and review comments are furnished on drafts prepared by others. To date, assistance has been provided on the following regulations:

1) ER 1130-2-415, Water Quality Data Collection, Interpretation and Application Activities, 28 October 1976.

2) ER 1130-2-334, Reporting of Water Quality Management Activities at Corps Civil Works Projects, 16 December 1977.

3) ER 1110-2-1402, Hydrologic Investigation Requirements for Water Quality Control, 15 September 1978.

4) ETL 1110-2-244, Water and Wastewater Laboratory Quality Control, 14 May 1979.

5) ER 15-2-10, Committee on Water Quality, 25 May 1979.

6) ER 1110-1-261, Control of Field Testing Procedures, 28 Sep 1979.

7) ETL 1110-2-252, Quality Control of Water Quality Field Sampling Activities, 30 June 1980.

8) ETL 1110-2-253, Measurement of Dissolved Gases to Determine the Degree of Nitrogen Supersaturation, 26 September 1980.

9) ETL 1110-2-268, Water and Wastewater Laboratory Inspections, 31 December 1981.

Members of the Committee should be contacted with any questions, concerns or suggestions you may have. These will be brought to the attention of the Committee for discussion and action, as appropriate.

Dr. Mark Anthony - ORD
Mr. John Bushman - OCE
Mr. David Cowgill - NCD
Mr. Richard DiBuono - NED
Mr. Earl Eiker - OCE
Dr. Robert Engler - WES
Mr. James Farrell - LMVD
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Mr. Charles Sullivan - SWD
Mr. Robert Watson III - SAD
Mr. R. G. Willey - HEC

EVALUATION OF WATER QUALITY IMPACTS FROM WATER RESOURCES MANAGEMENT PROGRAMS AND PROJECTS*

by

L.W. Canter**

Water quality impacts occur from many types of water resources management programs and projects, including the construction and operation of multi-purpose reservoirs and industrial complexes. Water quality impacts may be reflected by chemical changes or visible effects in terms of floating debris and the occurrence of dead fish. The purpose of this paper is to present a systematic approach for identifying and evaluating water quality and quantity-related impacts of water resources programs and projects. A conceptual framework for addressing water pollution impacts is shown in Figure 1. Specific information associated with each of the framework elements will be summarized. Examples of scientific approaches for accomplishing the various elements of the conceptual framework are also included.

IDENTIFICATION OF IMPACT-CAUSING FACTORS

It is necessary to identify impact-causing factors associated with the construction and operation of a proposed project. Information should be based on specific features of the alternative under consideration and professional knowledge and judgment. An initial activity should be the conduction of literature reviews on similar projects to the one under consideration. Since there is over ten years of experience in the conduction of environmental impact studies within the United States as well as numerous other countries, it is appropriate to review published literature and other reports related to the water pollution impact concerns of specific project types. To serve as an illustration, Table 1 contains example references on the impacts of impoundment and channelization projects. These references were identified through the conduction of computer-based literature searches based on selected descriptor words (Canter, 1980). Specific data bases which were searched included National Technical Information Service, Pollution Abstracts, Compendex (Engineering Index), and Biosis (Biological Abstracts).

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* Presented at the U.S. Army Corps of Engineers Seminar on Attaining Water Quality Goals Through Water Management Procedures, Dallas, Texas, February 17-18, 1982.

** Professor of Civil Engineering and Environmental Science and Co-Director, National Center for Ground Water Research, University of Oklahoma, Norman, Oklahoma, United States of America.

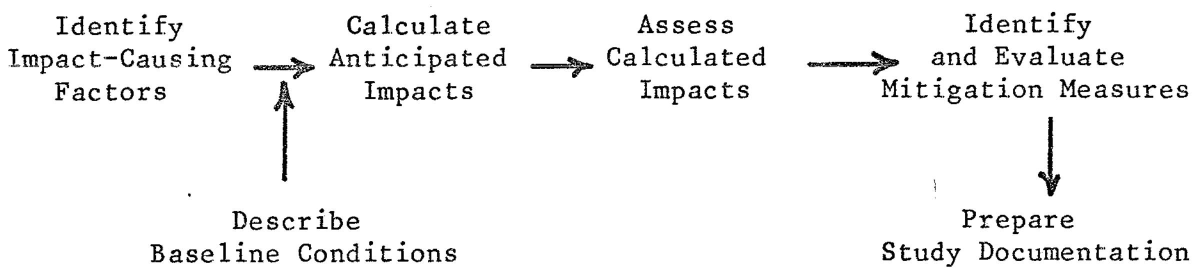


Figure 1: Conceptual Framework for Water Quality Impact Study

Table 1: Example References on Impacts of Impoundment and Channelization Projects

Project	Author (Year) and Comments
Impoundment	Armaly and Lepper (1975) -- Diurnal stratification in deep impoundments.
	Environmental Control Technology Corporation (1975) -- Prediction of water quality impacts from outboard engines.
	Keeney (1978) -- Impact prediction for proposed impoundment in southwestern Wisconsin.
	King (1978) -- Effects of hydraulic structures.
	Nelson, et al. (1976) -- Summary of impacts on fisheries.
	Raymond (1979) -- Effects on fish migration.
	Schreiber and Rausch (1979) -- Study of suspended sediment and phosphorus in Missouri flood detention reservoir.
	Yousef, et al. (1978) -- Prediction of mixing effects from boating activities.
Channelization	Benke, Gillespie and Parrish (1979) -- Study of impacts on invertebrates in Georgia.
	Duvel, et al. (1979) -- Study of ecological changes in six Pennsylvania streams.
	Headrick (1976) -- Effects on fish populations in Wisconsin.
	Huang and Gaynor (1977) -- Model presented for calculating flooding decrease.

If the project under consideration involves point source discharges, unit waste generation factor information should be assembled. There is an extensive literature base on unit waste generation factors for municipal and industrial wastewater discharges (Council on Environmental Quality, 1974; Nemerow, 1978). To serve as an example, brief information will be presented on the pollutant discharges from petroleum refineries. The total amount of water used in a petroleum refinery has been estimated to be 770 gallons per barrel of crude oil (Nemerow, 1978). Approximately 80 to 90 percent of the water usage is for cooling purposes only, and is not contaminated except by leaks in the lines. Process wastewaters, comprising 10 to 20 percent of the total, may include free and emulsified oil from leaks, spills, tank draw-off, and other sources; waste caustic, caustic sludges, and alkaline waters; acid sludges and acid waters; emulsions incident to chemical treatment; condensate waters from distillate separators and tank draw-off; tank-bottom sludges; coke from equipment tubes, towers, and other locations; acid gases; waste catalyst and filtering clays; and special chemicals from by-product chemical manufacture. In delineating information on wastewater characteristics five refinery subcategories, based on throughputs and process capacities, can be used as defined in Table 2 (U.S. Environmental Protection Agency, 1980). Table 3 presents ranges and median loadings in raw wastewater of conventional pollutants for the petroleum refining industry subcategories. Raw wastewater has been defined as the effluent from the oil separator, which is an integral part of refinery process operations for product/raw material recovery prior to wastewater treatment.

Non-point sources of water pollution have been recognized as potential major contributors to the total waste load within the aquatic environment, and it is vitally important in environmental impact studies to consider non-point sources along with point sources of water pollution. Table 4 contains some example references on non-point sources of water pollution, including urban and rural runoff and erosion and sediment.

DESCRIPTION OF BASELINE CONDITIONS

The second element involves assembling information on existing surface and ground water quantity and quality levels in the area of the project, particularly focusing on quality parameters related to anticipated water pollutants to be emitted from the construction and operational phases of the alternatives under consideration. Information gathering can be achieved through the usage of existing data collected by governmental agencies and/or the planning and conduction of specific baseline studies. Planning of baseline studies involves the development of a sampling network design, including selection of water quality and biological parameters for monitoring. Table 5 summarizes twelve steps which can be used for the design of a sampling network (Sanders, 1980). The twelve steps listed should be viewed as general guidance as opposed to specific rules for design in every environmental impact study.

Table 2: Subcategorization of the Petroleum Refining Industry Reflecting Significant Differences in Wastewater Characteristics (U.S. Environmental Protection Agency, 1980)

Subcategory	Basic Refinery Operations Included
Topping	Topping and catalytic reforming whether or not the facility includes any other process in addition to topping and catalytic process. This subcategory is not applicable to facilities which include thermal processes (coking, visbreaking, etc.) or catalytic cracking.
Cracking	Topping and cracking, whether or not the facility includes any processes in addition to topping and cracking, unless specified in one of the subcategories listed below.
Petrochemical	Topping, cracking, and petrochemical operations, whether or not the facility includes any process in addition to topping, cracking, and petrochemical operations,[a] except lube oil manufacturing operations.
Lube	Topping, cracking, and lube oil manufacturing processes, whether or not the facility includes any process in addition to topping, cracking, and lube oil manufacturing processes, except petrochemical operations.[a]
Integrated	Topping, cracking, lube oil manufacturing processes, and petrochemical operations, whether or not the facility includes any processes in addition to topping, cracking, lube oil manufacturing processes, and petrochemical operations.[a]

[a]The term "petrochemical operations" shall mean the production of second generation petrochemicals (i.e., alcohols, ketones, cumene, styrene, etc.) or first generation petrochemical and isomerization products (i.e., BTX, olefins, cyclohexane, etc.) when 15% or more of refinery production is as first generation petrochemicals and isomerization products.

Table 3: Raw Wastewater[a] Loadings in Net Kilograms/1,000 m^3 of Feedstock Throughput By Subcategory In Petroleum Refining (U.S. Environmental Protection Agency, 1980)

Characteristics	Topping subcategory Range[b]	Topping subcategory Median	Cracking subcategory Range[b]	Cracking subcategory Median	Petrochemical subcategory Range[b]	Petrochemical subcategory Median
Flow[c]	8.00 - 558	66.6	3.29 - 2,750	93.0	26.6 - 443	109
BOD_5	1.29 - 217	3.43	14.3 - 466	72.9	40.9 - 715	172
COD	3.43 - 486	37.2	27.7 - 2,520	217	200 - 1,090	463
TOC	1.09 - 65.8	8.01	5.43 - 320	41.5	48.6 - 458	149
TSS	0.74 - 286	11.7	0.94 - 360	18.2	6.29 - 372	48.6
Sulfides	0.002 - 1.52	0.054	0.01 - 39.5[d]	0.94[d]	0.009 - 91.5	0.86
Oil and grease	1.03 - 88.7	8.29	2.86 - 365	31.2	12.0 - 235	52.9
Phenols	0.001 - 1.06	0.034	0.19 - 80.1	4.00	2.55 - 23.7	7.72
Ammonia	0.077 - 19.5	1.20	2.35 - 174	28.3	5.43 - 206	34.3
Chromium	0.0002 - 0.29	0.007	0.0008 - 4.15	0.25	0.014 - 3.86	0.234

Characteristics	Lube subcategory Range	Lube subcategory Median	Integrated subcategory Range	Integrated subcategory Median
Flow[c]	68.6 - 772	117	40.0 - 1.370	235
BOD_5	62.9 - 758	217	63.5 - 615	197
COD	166 - 2.290	543	72.9 - 1,490	329
TOC	31.5 - 306	109	28.6 - 678	139
TSS	17.2 - 312	71.5	15.2 - 226	59.1
Ammonia	6.5 - 96.2	24.1		
Phenols	4.58 - 52.9	8.29	0.61 - 22.6	3.78
Sulfides	0.00001 - 20.0	0.014	0.52 - 7.87[d]	2.00[d]
Oil and grease	23.7 - 601	120	20.9 - 269	74.9
Chromium	0.002 - 1.23	0.046	0.12 - 1.92	0.49

[a] After refinery oil separator.

[b] Probability of occurrence less than or equal to 10% or 90% respectively.

[c] 1,000 m^3/1,000 m^3 of feedstock throughput.

[d] Sulfur.

Table 4: Example References on Non-Point Sources of Water Pollution

Topic	Author (Year) and Comments
Urban runoff	Hossain, Ramachandra and Delleur (1978) -- Development of model for direct runoff from urban watersheds.
	Larson (1978) -- Effect on water quality in a reservoir.
	McCuen, et al. (1978) -- Computer simulation model for estimating pollutant loading.
	Smith and Eilers (1978) -- Models for effects on receiving stream dissolved oxygen and hydraulic characteristics.
Rural runoff	Stay, et al. (1978) -- Non-point pollution from forest fertilization program.
	Unger (1978) -- Ecological effects from agricul-ture and silviculture activities.
	U.S. Environmental Protection Agency (1977) -- Summary of non-point models for wildland areas.
Erosion and sedimentation	Lusby (1979) -- Effects of grazing practices on runoff and sediment yield.
	Rickert and Beach (1978) -- Relationship of land management practices to erosion and sedimenta-tion.
	Whipple, DiLouie and Pytlar (1980) -- Influence of urban land use on erosion and sedimentation.

Table 5: Steps Related to Sampling Network Design (Sanders, 1980)

1. Determine monitoring objectives and relative importance of each.
2. Express objectives in statistical terms.
3. Determine budget available for monitoring and amount to be allocated for each objective.
4. Define the characteristics of the area in which the monitoring is to take place.
5. Determine water quality variables to be monitored.
6. Determine sampling station locations.
7. Determine sampling frequency.
8. Compromise previous objective design results with subjective considerations.
9. Develop operating plans and procedures to implement the network design.
10. Develop data and information reporting formats and procedures.
11. Develop feedback mechanisms to fine tune the network design.
12. Prepare a network design report.

A critical component in the conduction of baseline studies is associated with the parameters which should be monitored for determining baseline water quality characteristics. There are hundreds of water constituents which could be selected for monitoring, and it will be necessary to compromise between the number of parameters measured and the marginal difference that information on each parameter makes to subsequent interpretation and impact assessment. One approach which can be used in the selection of water quality parameters is to consider general recommendations for conduction of water quality surveys. Table 6 contains a reference list of parameters used for river water quality surveys (IHD-WHO Working Group on the Quality of Water, 1978). Another approach is to take information from the first element on the types of pollutants anticipated from the construction and operation of the proposed project and include those in the baseline monitoring program.

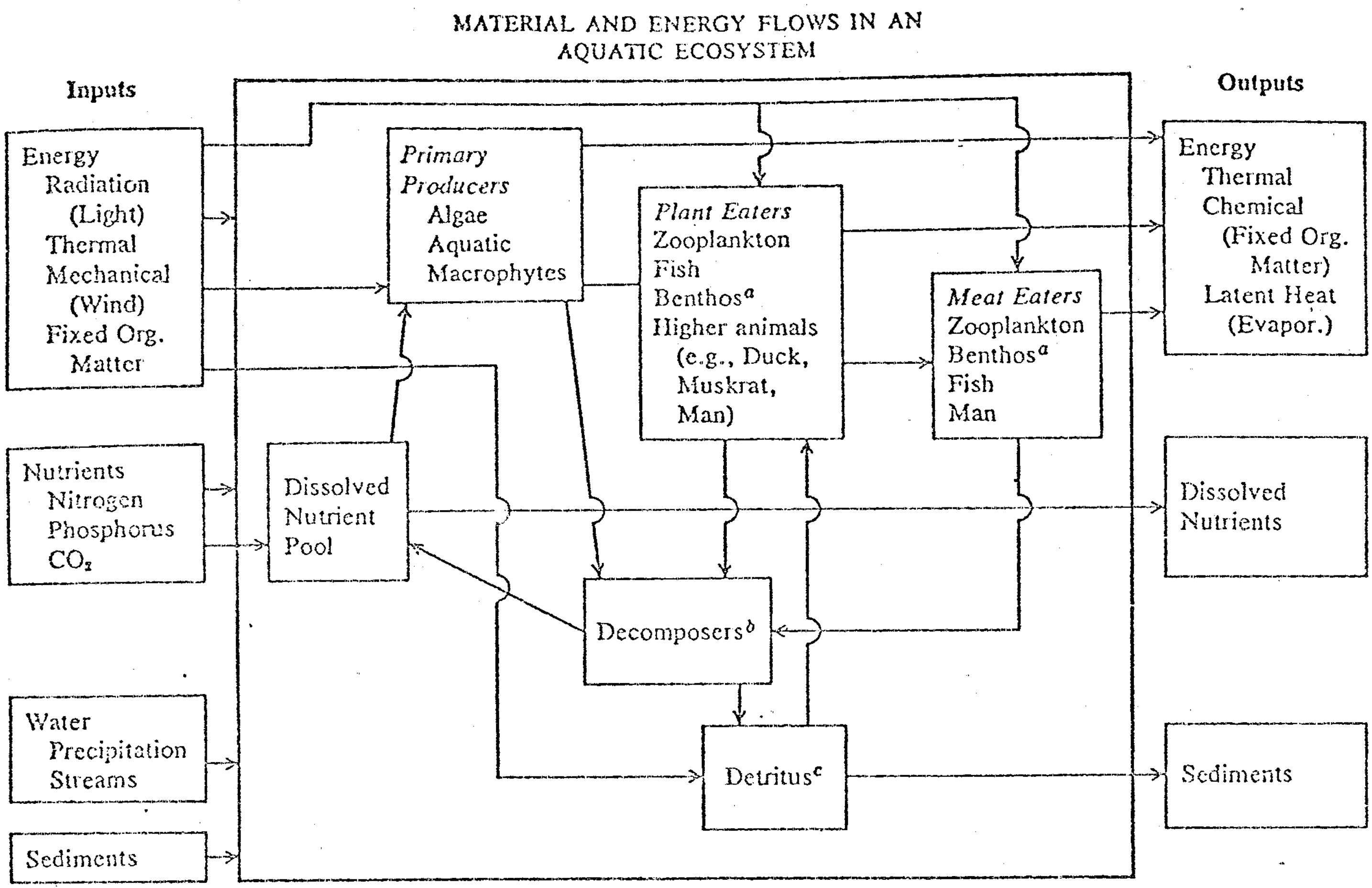
Selection of biological parameters is complicated due to system relationships in terms of material and energy flows. Figure 2 is a schematic diagram indicating material and energy flows in an aquatic ecosystem along with system inputs and outputs (Canter, 1979). Aquatic organisms include primary producers, plant eaters, meat eaters, and decomposers. Primary producers include algae, while plant eaters encompass zooplankton, fish, and benthic organisms. Meat eaters include zooplankton and fish as well as benthic organisms. A monitoring program related to water pollution impacts should include consideration of sampling of various planktonic and benthic forms, as well as fish.

An important aspect of describing the baseline setting is the interpretation of the extant or collected data. Interpretation can be based on water quality criteria, water quality standards which have been adopted for a given stream setting, or the quality and quantity requirements of existing or potential water users in the area. Professional judgment will have to be exercised in the data interpretation phase, particularly as related to biological parameters and characteristics. Due to the large number of water quality parameters which might be associated with a given project, presentation of summary information may be difficult. One approach which could be used is an empirical index which combines data from several parameters into one numeric indicator of water quality. The usage of water quality indices has been increasing in the United States and other countries (Ott, 1978). The most frequently used index in the United States is the National Sanitation Foundation Water Quality Index (WQI). The WQI was developed in 1970 using a formal procedure based on the Delphi technique, and it is composed of nine parameters --dissolved oxygen (DO), fecal coliforms, pH, BOD, nitrates (NO_3), phosphates (PO_4), temperature, turbidity, and total solids. Information on the nine parameters is aggregated into one index through the use of a geometric formulation as follows:

$$WQI = \prod_{i=1}^{n} I_i^{W_i}$$

Table 6: Selection of Parameters for River Water-quality Surveys (IHD-WHO Working Group on the Quality of Water, 1978)

		Chemical parameters			Biological parameters	
Type of survey	Physical parameters	Inorganic	Organic	Nutrients	Microbiological	Hydrobiological
Proposed for inclusion in all surveys	Colour pH Specific conductance Suspended solids Total solids		Chemical Oxygen Demand (COD) Total Organic Carbon (TOC)		Coliforms, total and faecal	
Recommended for collection of baseline data	Odour	Acidity Alkalinity Calcium, Ca Chlorides, Cl Dissolved oxygen Hardness Iron, Fe Magnesium, Mg Manganese, Mn Potassium, K Selenium, Se Silver, Ag Sodium, Na	Biochemical Oxygen Demand (BOD); immediate, 5-day, ultimate	Nitrate nitrogen, NO_3	Total plate count	
Recommended additional parameters where municipal and/or industrial pollution are expected	Floating solids	Arsenic, As Barium, Ba Beryllium, Be Boron, B Cadmium, Cd Chromium, Cr Copper, Cu Dissolved Carbon Dioxide, CO_2 Fluorides, F Hydrogen sulphide, H_2S Lead, Pb Mercury, Hg Nickel, Ni Vanadium, V Zinc, Zn	Cyanide, CN Dissolved organic carbon Methylene Blue Active Substances (MBAS) Oil and grease Pesticides Phenolics	Ammonia nitrogen, NH_3 Nitrite nitrogen, NO_2 Organic nitrogen Soluble phosphorus Total phosphorus	Faecal streptococci Salmonella	Benthos Plankton counts
Optional parameters for surveys of special purpose	Bed load Light penetration Particle size Sediment concentration Settleable solids	Aluminium, Al Sulphates	Carbon Alcohol Extract (CAE) Carbon Chloroform Extract (CCE) Chlorine demand	Organic phosphorus Orthophosphates Polyphosphates Reactive silica	Shigella Viruses: —Coxsackie A &B —Polio —Adenoviruses —Echoviruses	Chlorophylls Fish Periphyton Taxanomic composition



a. Organisms living at or on the bottom of bodies of water.
b. Fungi and bacteria.
c. Small particles of organic matter.

Figure 2: Material and Energy Flows in an Aquatic Ecosystem (Canter, 1979)

where I_i = sub-index value for ith. parameter.

W_i = importance weight for ith. parameter.

Importance weights for the nine parameters are listed in Table 7. Interpretation of parameter measurements is based on the usage of functional relationships, with the example for dissolved oxygen shown in Figure 3. Table 7 includes example calculations for the water quality index, with the resultant index being 39. The suggested stream classification system based on the water quality index is as follows: 0-25, very bad; 26-50, bad; 51-70, medium; 71-90, good; and 91-100, excellent (Ott, 1978).

CALCULATIONS FOR ANTICIPATED IMPACTS

The most important technical element in addressing water pollution impacts is the scientific prediction of the effects of various activities, with these predictions being based on appropriate calculations. Calculations can range from the use of mass balance approaches to sophisticated computer models. Qualitative projections can also be used in the absence of specific information on pollutants or modeling techniques. Water pollutants can be categorized into conservative, non-conservative, bacterial, and thermal groups (Canter, 1977). Different technical approaches are necessary depending upon pollutant group. Conservative pollutants refer to those materials not biologically degraded in the aquatic environment nor lost from the water phase due to precipitation, sedimentation, or volatilization. Non-conservative pollutants include organic materials, nutrients, and chemical substances that may undergo precipitation or volatilization or sedimentation. The key characteristic of non-conservative pollutants is that these materials are not conserved in the aquatic environment in their original state. Organic materials can be biologically decomposed by bacteria, while nutrient materials can be incorporated in aquatic biomass.

The basic modeling approach for conservative pollutants such as chlorides are mass-balances considering the influence of hydraulics on system flows and dilution factors. Modeling approaches for organic materials must include consideration of the changes in DO resulting from bacterial demand for oxygen in the decomposition process. A classical DO model developed by Streeter and Phelps in 1925 is as follows (Canter, 1977):

$$D_t = \frac{K_1 L_a}{K_2 - K_1}(10^{-K_1 t} - 10^{-K_2 t}) + D_a 10^{-K_2 t}$$

where D_t = dissolved oxygen deficit at any flow time t downstream, the flow time t expressed in days

= saturation dissolved oxygen concentration - actual dissolved oxygen concentration

Table 7: Calculations for Water Quality Index

Variable	Measurement	I_i(a)	W_i(b)	$I_i^{W_i}$
DO (mg/l)	60%	60	0.17	2.01
Fecal Coliforms (no./ml)	10^3	20	0.15	1.57
pH	7	90	0.12	1.72
BOD_5 (mg/l)	10	30	0.10	1.41
NO_3 (mg/l)	10	50	0.10	1.48
PO_4 (mg/l)	5	10	0.10	1.26
Temp. Deviation (^oF)	5	40	0.10	1.45
Turbidity (JTU)	40	44	0.08	1.35
Total Solids (mg/l)	300	60	0.08	1.39
			WQI =	38.8

Notes: (a) subindex values are from functional relationships, see Figure 3 for one example.

(b) importance weights are from the Delphi study to solicit opinions from over 100 water quality professionals in the United States.

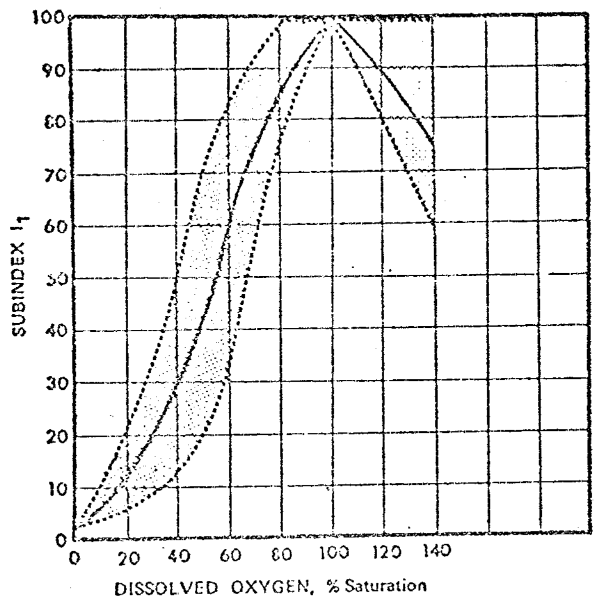


Figure 3: Functional Relationship for Dissolved Oxygen (Ott, 1978)

K_1 = coefficient of deoxygenation, day^{-1}

K_2 = coefficient of reaeration, day^{-1}

L_a = ultimate BOD in the stream following mixing, mg/l

D_a = dissolved oxygen deficit upstream of waste discharge, mg/l

The saturation dissolved oxygen concentration is a function of temperature, pressure, and salt content. It should be noted that K_1, K_2, and L_a are influenced by temperature. In addition to the Streeter-Phelps model, numerous other techniques have been developed based on the classical Streeter-Phelps approach. Table 8 contains references on several additional models for water quality and quantity impact prediction.

Bacterial pollution can also be addressed through the application of a specific model relating the aquatic environment characteristics and the bacterial death rate. This approach involves the prediction of bacterial self-purification, with this defined as the decrease of bacteria of all types, and especially those of fecal origin, as a function of flow distance or flow time in a river (Phelps, 1944). The mathematical relationship that describes bacterial self-purification is as follows (Canter, 1977):

$$B_t = B_0 10^{-Kt}$$

where B_t = bacterial residual after any time t, days

B_0 = initial number of bacteria in stream

K = bacterial death rate, day^{-1}

Impact calculation approaches are also available for addressing the biological characteristics of the aquatic ecosystem. Table 9 summarizes some references on models for biological impact prediction. The first two examples represent aquatic habitat approaches in which a series of identifier parameters are used to develop an aquatic habitat index similar in concept to the WQI. Numerous ecosystem models have been developed for the aquatic environment, with several listed in Table 9. The models allow for calculation of chemical cycling as well as bioconcentration in aquatic organisms. Qualitative impact projections can be made in the absence of specific models. For example, Hazen, et al (1976) presented summary information on 47 case studies of California water projects that altered streamflows and causally affected fish and wildlife. This information would be useful for both impact identification and projection.

In summary relative to impact calculations, there is considerable technology available for determining anticipated changes in water

Table 8: Example References on Models for Water Quality/Quantity Impact Prediction

Topic	Author (Year) and Comments
Lake and reservoir models	Baca, et al. (1974) -- Multi-segment deep reservoir water quality simulation model for prediction of algal and DO-BOD dynamics.
	Ford and Stefan (1980) -- Mixed-layer model for seasonal temperature predictions in lakes.
	Orlob (1977) -- Literature review of mathematical modeling of surface water impoundments.
	Snodgrass and Holloran (1977) -- One-dimensional temperature-oxygen model for reservoirs.
Estuary models	Ozturk (1979) -- Modeling of dissolved oxygen in estuaries.
Ground water	Prickett (1979) -- Summary of ground water modeling techniques.
	Walton (1979) -- Review of several types of analytical models for ground water evaluation.
Non-point pollution	U.S. Environmental Protection Agency (1976) -- General summary of procedures for predicting impacts of urban stormwater.
	Zison, Haven and Mills (1977) -- Methodology for assessment of point and non-point pollution on rivers, impoundments, and estuaries.

Table 9: Example References on Models for Biological Impact Prediction

Topic	Author (Year) and Comments
Habitat approach	U.S. Army Corps of Engineers (1980) -- Systematic methodology for aquatic and terrestrial ecosystem evaluations.
	U.S. Fish and Wildlife Service (1979) -- Procedural manual for estimating and comparing development project impacts on fish and wildlife resources.
Ecosystem models	Green (1978) -- Model for the Chesapeake Bay eco-system with submodels on wetlands, plankton, seagrasses, other benthos, and fish trophic levels.
	Najarian and Harleman (1977) -- Model of nitrogen-cycle dynamics in an estuarine system.
	Snedaker (1978) -- Simulation models for determining pollutant impacts on marine biota.
	Taylor (1979) -- Model for predicting chemical pollutant toxicity in fish.
	Vieth, DeFoe and Bergstedt (1979) -- Model for estimating bioconcentration of organic chemicals in fish.

quality and aquatic biology that might occur as a result of the construction and operation of a given project type. However, it should be noted that the considerable exercise of professional judgment is involved in the selection of an appropriate model or models, and the interpretation of the results of the model applications.

ASSESSMENT OF CALCULATED IMPACTS

Assessment or interpretation of the significance of identified impacts represents a vital element in the conceptual framework for addressing water pollution impacts. This element requires the considerable exercise of professional judgment along with water quality criteria or standards and other scientific information. Typical criteria or standards give consideration to multiple uses of water resources and the quality requirements associated with the uses. Within the United States water quality standards have been established for stream segments, river basins, lakes, estuaries, and coastal areas. In addition, there is growing usage of ground water quality standards. A sound approach for impact assessment is to evaluate the calculated impacts relative to existing and resultant water quality if the project is implemented.

One of the difficult areas is related to interpretation of anticipated changes on the aquatic ecosystem. There are some laws and executive orders within the United States which address aquatic biological features, including Executive Order 11990 (Protection of Wetlands); Coastal Zone Management Act of 1972; Deep Water Port Act of 1974; Endangered Species Act Amendments of 1978; Fish and Wildlife Coordination Act of 1966; Marine Mammal Protection Act of 1972; Marine Protection, Research and Sanctuaries Act of 1972; and the Clean Water Act of 1977. Most of these regulatory documents provide general guidance for protection of the aquatic environment; however, specific standards for aquatic species or species diversity are not included. The most appropriate technical approach to utilize in aquatic ecosystem impact assessment involves the application of specific biological principles and recommended criteria.

IDENTIFICATION AND EVALUATION OF MITIGATION MEASURES

One of the most valuable results of a study of water pollution impacts can be the identification of mitigation measures which could be utilized in the planning, construction, or operation of a given project so as to minimize undesirable effects on the water environment. Mitigation may include avoiding the impact altogether by not taking a certain action or parts of an action; minimizing impacts by limiting the degree or magnitude of the action and its implementation; rectifying the impact by repairing, rehabilitating, or restoring the affected environment; reducing or eliminating the impact over time by preservation and maintenance operations during the life of the actions; and/or compensating for the impact by replacing or providing substitute resources or environments (Council on Environmental Quality, 1978).

Appropriate mitigation measures must be identified on a project specific basis. However, some general examples can be cited for minimizing water pollution impacts. One appropriate approach is to attempt to minimize the non-point source pollution that would occur during the construction phase of a project. Table 10 identifies several references associated with minimizing impacts from construction activities as well as other non-point sources of pollution. For those project types which involve discharge of wastewaters, appropriate treatment could be included as mitigation. It is beyond the scope of this paper to completely review wastewater treatment processes and their cost-effectiveness; however, excellent references are available on this topical area (Council on Environmental Quality, 1974; Nemerow, 1978).

As illustrated in Figure 1, it is necessary to evaluate the effectiveness of proposed mitigation measures by making appropriate impact calculations for the project with mitigation, and then assessing the significance of the resultant changes on the baseline environmental setting. There may be several iterations required in evaluating the effectiveness of mitigation measures.

PREPARATION OF STUDY DOCUMENTATION

The end product of a study of water pollution impacts should be a report which addresses the findings and provides appropriate interpretation. This report should be incorporated in the overall environmental impact study report for a given project. The water pollution impacts report should summarize the impact-causing factors, baseline environmental setting, impact calculations and assessment, and mitigation measures. The report should incorporate technical writing principles. Examples include clear delineation of study objectives; inclusion of visual display materials such as maps, tables, figures, and photographs; and appropriate referencing of data sources and utilized scientific methodologies. Information should be provided on the bases for impact assessment and evaluation of appropriate mitigation measures.

SUMMARY

Water quality impact prediction and assessment can be achieved by the application of existing technology and professional knowledge and judgment. However, many environmental impact studies have not used available scientific methods for impact prediction and assessment. Some possible reasons for this lack of extensive use include lack of knowledge about available approaches on the part of many practitioners, non-existence of current technology during the early years following the initiation of environmental impact studies, and general reluctance to use approaches perceived to be difficult and time-and cost-consuming.

Usage of scientific methods and techniques is expected to increase as a result of the expanding knowledge base for conduction of studies of

Table 10: Example References on Mitigation of Impacts

Topic	Author (Year) and Comments
Construction	Anton and Bunnell (1976) -- Guidelines for minimizing erosion from construction projects.
	Darnell (1977) -- Summarizes mitigation of construction project impacts in wetland areas.
Non-point pollution	Bammi, Bammi and Paton (1976) -- Linear programming model to allocate land use so as to minimize undesirable impacts.
	U.S. Environmental Protection Agency (1978) -- Impacts of land clean-up and restoration following chemical spills.
	Walter, Steenhuis and Haith (1979) -- Effects of soil and water conservation practices on minimizing non-point source pollution.
	Whalen (1977) -- Guidance for controlling non-point pollution.
	Whisler, et al. (1979) -- Summarizes agricultural management practices in terms of minimizing runoff and sediment production.

water quality impacts, and the emphasis being given to public justification and accountability in project planning and decision-making. Opportunities for increased scientific emphasis in the analysis of water quality impacts include:

(1) Use of computer-based literature searches to identify water pollutant and flow-related impact factors.

(2) Development and conduction of cost-effective baseline monitoring programs which have been planned based on the type of project and anticipated impacts.

(3) Use of water quality indices and indicators of biological quality and aquatic habitat.

(4) More extensive analyses of hydraulic/quantitative impacts and the development of information on cumulative impacts associated with project plans.

(5) Conduction of worst case analyses such as those related to accidental releases or spills of toxic materials.

(6) Systematic analyses of the cost-effectiveness of mitigation measures.

(7) More extensive analyses of potential water use limitations resulting from water quality changes.

(8) Development of better information relating water quality or quantity changes and resultant aquatic ecosystem changes, including emphasis on material cycling and toxic effects.

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WATER QUALITY PROGRAM MANAGEMENT

by

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Although the title of my presentation is "Water-Quality Program Management," it would perhaps be more appropriately entitled, "How Does District Program Management Affect the Attainment of Water-Quality Objectives?" Obviously such a topic could take days to explore, and one of the purposes of this seminar, as you will have noted by now, is to do just that. So my comments today are merely an overview of these proceedings, an overview that, I hope, will indicate the salient features of an effective water-quality program for the district.

For those of you who are fairly new to this discipline and expected to walk away from this seminar with a magic recipe or cookbook for water-quality programs, you will have discovered that no such magic exists. Each investigation requires a different approach. The only assurance of success is to have truly knowledgeable and dedicated people whose understanding of the problems goes well beyond the purely operational level. In this sense, everyone involved in the work is a manager--not just those with supervisory titles.

Little, if any, guidance is available. And the guidance that is available is no substitute for experience and judgement. The only substantive recommendation is to make use of key indicators or environmental controls. In any natural system there are certain controls known to determine the behavior and distribution of other environmental properties or components. If these controls can be identified, together with the agents that govern water-quality behavior at a given site, program design and management become far less complicated.

For Corps projects, the critical variables always include basin hydrology, lake hydrodynamics, and types and methods of withdrawal. Temperature and dissolved oxygen are critical for determining density gradients and thermodynamic drive.

The work must be done in district offices by people who know the projects, understand the problems, are willing to define objectives, and are able to carry through on the studies.

To succeed, we must have people from the right disciplines, well-trained, with proper experience and a lot of grit. As a typical government agency, the Corps tends to resist both change and the development of new disciplines, and this resistance must be overcome. We must be the doers if our water-quality objectives are to be met.

Many problems associated with, and serving as obstacles to, otherwise successful programs can be lumped into two basic categories: internal and external.

(1) Internal problems result from the need for program design, logistics, quality control, coordination, equipment, and other factors. Briefly stated, the basic internal needs have to do with people, equipment, and support.

(2) External problems originate with individuals not directly involved in water-quality activities, who have a tendency to grossly oversimplify a number of things, including day-to-day operating problems during stratification periods, hydrological/hydraulic procedures and effects, complicated decision-making processes, and the basin-wide environmental effects of reservoir systems.

Problems from both sources must be addressed if the program is to be successful.

Although the need for combined quantitative and qualitative control of water from man-made lakes has been established, the steps involved in meeting this need are difficult to negotiate. Both scientific and engineering disciplines are needed, combined with the judicious use of both conventional and innovative techniques. Water Quality is a field in which all concerned scientists and engineers have a distinctive and responsible part to play--not just within the water-control elements, but also within other elements of the Engineering, Operations, and Planning divisions. These divisions, especially, should be better informed than others concerning the possible effects that project operations might give rise to, and either train themselves, or ask questions of the right people, so that balanced views can be taken of the possible risks entailed. A whole raft of issues is involved.

Auguste Comte wrote that "no one can really be master of any science unless he studies its special history." Fortunately, the history of Water-Quality within the Corps is relatively recent; but, unfortunately, that history has been neglected. Until efforts fostered chiefly by the Committee on Water Quality were begun, quality considerations in many cases were placed in the "weak stepsister" category. Further, attempts were made to "retread" personnel trained in other disciplines and mold them into water-quality staff. From a district perspective, I disagree with both concepts. One should either be in or out of the water-quality business--there is no middle ground if the mission is to be a success. This holds true in other disciplines, so why not in Water Quality? We who are in the business must make our own history. Excessive reliance on the methods, tools, and techniques of the past will not work.

What makes a successful program? Mostly personal effort. First, you have to know your field; second, determine what's needed; third, convince decision makers; fourth, gain support; and fifth, implement the program.

A water-quality study can be very indefinite in scope and overall cost. It is important, therefore, that a program be implemented that converges on key impact issues affecting water quality at the site under study; otherwise, large amounts of useless data and unnecessary costs will result. These key impact areas, like the key environmental controls referred to earlier, must be defined in initial phases of the project and incorporated into a focused management program.

Management decisions must be based on sound impact assessments and not on more or less arbitary assumptions. The goal is to provide sound technical information that is appropriate and adequate for decision-making. The approach, then, is to define items affecting water characteristics that are most important to resource planning and management.

Criteria for evaluating the adequacy of sampling scope and mehods include

(1) impact identification,

(2) impact measurement,

(3) impact interpretation, and

(4) impact quantification.

The ultimate objectives and priorities of a program would be predicated on these and other criteria, including

(1) the significance of given impacts or issues,

(2) the resources available to further evaluate given impacts,

(3) the alternative action available to either mitigate or eliminate the impacts,

(4) the probability of a given impact's occurence and the resulting damage or loss,

(5) public or agency involvement, and

(6) administrative constraints.

One other very important point must be mentioned. It is obvious that not all impacts or deviations in water-quality behavior can be predicted; therefore, the sampling format must be designed to detect seasonal and other pertinent variations. Some impacts from reservoir construction and operations are subtle, while others are more obvious.

In the Huntington District, program design and function center on the time-phased use of data for impact assessment, project-operation purposes, report preparation, and other applications. Data are needed for both short-term and long-term uses. Under adverse or emergency conditions, or during periods of thermal stratification, data are needed for immediate applications. The time needed for the use of data for other purposes, such as report preparation, will vary, but will in any case be longer. In situations calling for immediate application, on-the-spot decisions can be based on the first series of data and courses of action determined. Afterward, these decisions can be continued or altered as other types of data become available. In addition, emphases can be shifted to study areas of greater interest or those that become critical.

The primary program focus should be on water-control management. With a truly flexible program, feedback interactions will occur between management activities and program objectives. Special program strengths should be developed concerning the use of computers, the rapid dissemination of data and reports, and aggressive reservoir regulation activities. Indispensible to such activities is the use of _in situ_ or "in place" probes, chiefly because of data pertinence and timeliness.

Present-day technology has brought in its wake a new risk--that of choice. Technology is what we make of engineering and scientific knowledge, and technology is firmly established in the realm of politics and the public. We must ask ourselves the questions--How do we choose? Who will decide? Which possibilities among a bewildering array should be fostered? What will the ultimate outcome be? No difficulty would arise in providing answers if resources of people, time, and money were unlimited, because all bases could be covered. So choice becomes the key word, but it must be remembered that choice and controversy march together.

Some scientists and engineers still live and dream in an ivory tower. We do not have that luxury. In the real world the key to effective program design is "appropriateness." There can be no doubt that the bulk of our technology is in the public arena, and that effects are far-reaching. Because Water-Quality is a new and emerging discipline, this public arena is in many cases a meeting ground for innovative engineering practices and applied research and development. While there is a need here for dreamers, all dreams must be tempered with the often cold, harsh realities of the real world. Leonardo Da Vinci, as usual, made the point exceedingly well and with a minimum of words:

> Wisdom is the daughter of experience. . . . No human enquiry is worthy of the name of science unless it comes through mathematical proofs. And if you say that the sciences which begin and end in the mind possess truth, this is not to be conceded, but denied for many reasons. First because in such mental discourses there enters no esperienza, without which nothing by itself reaches certitude.

According to the translator of this passage, the word esperienza wavers in meaning between experience and experiment.

Our work, together with its consequences, is bringing water-quality activities into a quantitative framework. The need for using models, applied-research-and-development tools, and ongoing conventional techniques demonstrates the need for combining theoretical, experimental, and observational approaches. Since nearly all Corps elements are responsible for vast sums of money, it is essential that we identify the distinctions among these three approaches.

A good model is a framework within which we, as program managers, can begin to organize our assessments. With it, we can step beyond the mere examination of field evidence and the use of inductive inference to make generalizations.

To sum up, then: If, in combination with our theoretical and modeling capabilities, we do not continue to develop a secure anchorage in our operational experience, it is conceivable that we shall all be overtaken and washed to sea in a tidal wave of uncoordinated information. Without a sound description of key controls and variables, an adequate understanding of environmental processes is impossible. Furthermore, such an understanding would in any case be useless to us without the methods and means for applying it to the projects under our management.

No one but you and I can provide the synthesis we need--a definitive synthesis of our district's various water-quality programs. And perhaps it will be useful to remember that enthusiasm and pride are essential to any effort of importance, and that the reward of enthusiasm and pride is often satisfaction and a quality product.

Environmental and Water Quality Operational Studies (EWQOS) - Status

by
Jerome L. Mahloch[1]

Introduction

The central objective of the EWQOS program is the development of new technology or procedures for the planning, design, construction, and operation of water resource projects to meet environmental quality objectives while simultaneously attaining authorized project purposes. It is interesting to note the close parallel between the theme for this seminar and the objective of EWQOS, which demonstrates the timeliness of R&D and its importance to water resource development for the CE. If one further delves into the topics covered by this seminar, other similarities related to the intrastructure of EWQOS and the objectives of specific R&D tasks are apparent. Within the seminar topics, field methods, mathematical modeling, water control procedures, and case studies are of preeminence. Key terms within these topics include compatibility, constraints, conflicts, objectives, and policy issues.

The origin of EWQOS lies in the identified need of field offices for information (in the form of technology or procedures) to solve environmental quality problems associated with water resource development and management. Conflicts that existed, and which continue to arise, result in delays to projects, conflicts with authorized purposes, and redesign or modification of project features. These are manifested in lost benefits and added expenditures to complete projects, in many cases with an uncertain outcome. Products of the EWQOS program are expected to greatly aid in the solution of many, although certainly not all, of the major environmental quality problems currently faced by the CE. During the conduct of the program, concepts such as compatibility of environmental goals and water resource project purposes, minimization of conflicts and additional constraints, and clear definition of objectives have been recognized and play a paramount role in the program. Establishment of a Field Review Group (FRG) for the program during the inception of EWQOS and program management under their guidance ensure that these concepts and perspectives of the field offices are recognized and addressed during R&D.

The organization of EWQOS, which is divided into research projects and field studies, also reflects the organization of sessions within this seminar. This organization reflects classical organization patterns for R&D in which a firm foundation of knowledge (in this case provided by field studies) results in the development of tools, such as mathematical models, or procedures (including design) that can be implemented to solve problems. The field studies yield valuable information in and of themselves, including sampling procedures, tools, and designs, guidance on analytical procedures, data management and interpretation, that can be directly applied to many problems facing field offices. The field studies form the most critical element within EWQOS because in studying operational projects information is obtained that

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completes a feedback loop with other R&D, resulting in improved technology and providing verification that ensures that products are credible and reflect the most recent knowledge.

Status of EWQOS

EWQOS was initiated in FY 1978 and is currently projected to be completed in FY 1985. During the past four years there have been significant accomplishments within the program, most notably in the selection and conduct of field studies that play a central role in EWQOS R&D. Due to the length of time required to conduct these field studies many of the results are just now coming to fruition and during FY 81 there was a dramatic increase in the publication and distribution of information based on program results. In recounting the status of EWQOS, I will concentrate on major accomplishments and projected R&D plans, specifically for FY 1982. The project framework used to organize EWQOS is presented in Table 1.

TABLE 1

EWQOS Organization

Project Number	Project Title
I	Predictive Techniques
II	Reservoir Project Operations
III	Reservoir Project Engineering
IV	Environmental Assessment Techniques
V	Waterway Project Impacts
VI	Waterway Project Design/Construction
VII	Field Studies
VIII	Program Management

The most significant accomplishment related to predictive techniques has been the development of a one-dimensional reservoir water quality and ecological model (CE-QUAL-R1). The user manual has recently undergone field office and OCE review and will be distributed shortly. Efforts are continuing to improve sections of the model, principally the chemistry portion, and to obtain a rigorous verification by means of test applications. The LARM model was selected as the basis for a two-dimensional reservoir model and work is currently progressing on improving selected hydrodymanic features plus the addition of a water quality module. A two-dimensional riverine model has been selected for use within the program and work is centering on obtaining field data sets on which to base improvements and verification. A comprehensive data base for a large number of reservoir projects has been compiled and data analysis is ongoing. This analysis is expected to yield simplified techniques on reservoir water quality responses to loading, specific and applicable to reservoir projects, as well as substantial information on the statistical properties of reservoir water quality data. The predictive techniques are expected to significantly improve the Corps' ability to solve water quality problems associated with projects and to provide a sound basis for making decisions related to alternatives for solving these problems.

Research and development related to reservoir operations is making progress in numerous areas. Background work on development of methods for nuisance algae control has been completed with the publication of the proceedings of a national workshop on this topic. Preparatory field studies at Eau Galle reservoir are continuing and experimental testing of promising methods will be initiated this FY. Long term field studies associated with reservoir releases have been completed and data analysis is proceeding for preparation of a technical report this FY. An annotated bibliography and literature review organized by release problem category have been published to provide easy access to information on these problems. Documentation on impacts of peaking hydropower projects on tailwater ecology will be provided this year. Work on reservoir regulation has produced a technique for optimizing single reservoir operations and a second generation version of HEC-5Q is available for considering basin or multiple project operations. Work will continue in both areas this year to improve these techniques. A national workshop on the environmental effects of fluctuating reservoir pool elevation, which considered wildlife, fisheries, and revegetation for erosion control, was held last year and the proceedings will be available this FY. Field studies on the use of revegetation are continuing and have produced guidance on the most promising plant species to use as well as procedures for establishment and maintenance. Laboratory studies on site preparation are continuing and are being coordinated with projects being filled to obtain verification data. Guidance on site preparation and filling strategies will be available this FY. R&D related to project operation is directed at solving high-priority operational problems resulting from environmental goals or constraints. In many cases these problems are common to a large number of reservoir projects; consequently, benefits to be obtained by solving these problems are large. Emphasis is being placed on cost effectiveness of the solution and minimizing constraints on project operation flexibility that may be imposed by environmental objectives.

Work related to reservoir engineering is oriented to improving water quality both within the reservoir pool and in their releases. Reaeration of various release categories including conduits, locks, and hydraulic jumps has been studied and predictive models are being developed. Work is continuing on nitrogen supersaturation and an improved D'Auost saturometer has been developed for field office use. Aeration of hydropower releases has been closely coordinated with TVA and a literature review of this subject will be available this year. Field tests of reaeration methods for hydropower projects will be initiated this year. Development of a two-dimensional selective withdrawal model has been completed and verification will be performed this year. Physical model studies of various outlet work configurations are continuing and will be published this FY plus work on optimizing minimum number of ports for design of a selective withdrawal system under a given set of constraints. Work on reservoir destratification, mixing, and aeration systems will be completed this FY along with the appropriate design guidance. A report on the environmental considerations associated with reservoir pool modifications by these techniques will also be published. Improved design procedures for meeting water quality objectives for reservoir projects are required to avoid costly trial and error approaches, redesign, or postconstruction modification to meet water quality objectives. Procedures being developed are also designed to minimize operational constraints and to consider other environmental aspects of the reservoir project.

Project IV involving environmental assessment techniques will be completed this year. Numerous reports have been published under this project related to various aspects of project planning for environmental considerations. A draft EP on technique review and selection for environmental quality evaluation has been provided to OCE for review. The products of Projects IV are designed to facilitate environmental planning for water resource projects.

Efforts related to the environmental impacts of waterway projects and the associated design and construction procedures to ameliorate these impacts are being performed under Projects V and VI. Work in project V is concentrating on synthesizing the results of the waterway field studies and verification of results through a series of short-term field studies. Numerous reports have been published and additional reports on the field study results are scheduled for this year. Two reports on methods to achieve environmental objectives in the design and construction of waterway projects based on available experiences are under review and will be published as interim guidance this year. Work in Project VI this year will concentrate on providing environmental quality guidelines for the design and construction of dikes and streambank protection projects.

Field studies of reservoir and waterway projects are well under way. The long-term field studies of the lower Mississippi River and Tennessee-Tombigbee Waterway Projects have been completed. Efforts are presently being directed at examining the results and providing guidance for sampling or monitoring the environmental features of waterway projects. Several documents will be published this year on this topic. Two of the four reservoir field study efforts, Red Rock and DeGray, have been completed and work is continuing at West Point and Eau Galle with emphasis on the latter. The reservoir field studies are also providing guidance on the sampling or monitoring of reservoir projects. This FY reports on the importance of storm events, sediment chemistry, and inflow processes will be prepared based on reservoir field study results.

Technology Transfer

The EWQOS program is dedicated to providing the best available technology to field offices to solve environmental quality problems being addressed under the scope of the program. To accomplish this objective in the most effective manner, a program of tehnology transfer has been developed and implemented. This program coupled with coordination efforts and continual review by field offices will ensure that this objective is attained. Technology transfer is being approached in a three-phase effort. The first phase includes publication of information exchange bulletins, workshops, training courses, technical briefings, and one step R&D services. This is an active phase, designed to make program results available to field offices as rapidy as possible. The second phase includes technical reports, users' manuals, handbooks, guidance documents such as EC's, EP's, and ETL's, and technical journal articles. This phase takes longer to accomplish, but documents program results in a referencable manner and provides interim guidance as well as technical credibility. The third phase relies on input to or publication of Engineering Manuals (EM) or Environmental Engineering Manuals (EEM) plus an information management system. This phase constitutes formal field office guidance based on established or well verified program results. Currently, EWQOS will be providing at least three EEM's in the series: reservoir water quality, shallow draft navigation, and flood control channels. These EEM's will provide synthesis of the majority of program results in an easy to use manner adaptable to field office requirements. The information management system will provide a method to access all referencable material generated within the program in a comprehensive manner.

Summary

EWQOS is providing R&D and a program of technology transfer to solve high-priority environmental problems associated with water resource development by the CE. The conduct of the program ensures that results are technically sound and are founded on sufficient data obtained by field studies of operational projects. Review and coordination procedures established will ensure that planning, design, construction, and operational procedures developed will be compatible with project purposes, minimize constraints and conflicts, and promote sound water resource development. Finally, technology transfer ensures that information provided to field offices will be useful, cost effective, and meet needs through application and feedback on program results.

RESERVOIR WATER QUALITY DATA COLLECTION

By
Christina C. Meshaw [1]

INTRODUCTION

Some of the purposes of Federal reservoir projects, i.e., water supply, recreation, and fish and wildlife conservation require that certain water quality goals be met. Even so, the Corps of Engineers has no legal authority to see that water quality goals are attained in its reservoirs. The most effective thing the Corps of Engineers can do then is to collect reliable data on reservoir water quality conditions for the use of pollution control agencies.

Reliable water quality data results, in large part, from properly designed and conducted data collection programs. The standard methods of water quality data collection can be found in publications of Federal agencies and the American Public Health Association (1-7). Corps of Engineers guidance on water quality data collection is contained in ER 1130-2-415, ETL 1110-2-252, and EC 1110-2-233. Data collection guidance in ER 1130-2-415 is minimal, but the guidance in ETL 1110-2-252 is fairly comprehensive and is drawn partly from two of the previously mentioned references (3, 5). EC 1110-2-233 is the most recent Corps of Engineers directive on water quality data collection and is the only Corps of Engineers guidance mentioned herein which presents a statistical approach to determine numbers and locations of sampling stations and the number of samples per station.

The purpose of this paper is to describe a water quality data collection program for B. Everett Jordan Lake, which was designed to produce reliable data using primarily standard methods.

WATER QUALITY DATA COLLECTION PROGRAM
B. EVERETT JORDAN LAKE

B. Everett Jordan Lake was authorized for flood control, water supply, recreation, water quality control, and fish and wildlife conservation. It was the subject of litigation for many years prior to its impoundment in September 1981 and water quality was the central issue of the litigation. Concurrent with the litigation, a Section 208 Areawide Waste Treatment Management Study (208 Study) conducted by the Triangle J Council of Governments (COG)included part of the reservoir's drainage. The major water quality concerns about the reservoir, which emerged from the litigation and the 208 Study, were eutrophication, bacteria, trace metals, and mercury in fish.

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Out of the 208 Study grew a watershed planning task force whose charge was: "To develop a work program to achieve water quality goals in . . . the New Hope arm of B. Everett Jordan reservoir." Members of the task force include:

Triangle J COG
- Counties
- Municipalities

North Carolina Department of Natural Resources & Community Development
Water Resources Research Institute
Corps of Engineers

The Corps of Engineers role as a member of the task force is to monitor post impoundment water quality and to transfer information on water quality conditions in the reservoir to the pollution control agencies.

In the months preceding impoundment, we drafted a scope of work for a data collection program to address the concerns of eutrophication, bacteria, and trace metals. The data collection program scope of work was coordinated informally and formally with six agencies which have responsibilities for pollution control and/or monitoring. The coordination was extensive so that we could fulfill commitments made in the Final Supplement to the Final EIS and the litigation, fulfill our role as a member of the task force, and prevent duplication of effort among agencies monitoring programs.

The objectives of our data collection program are to:

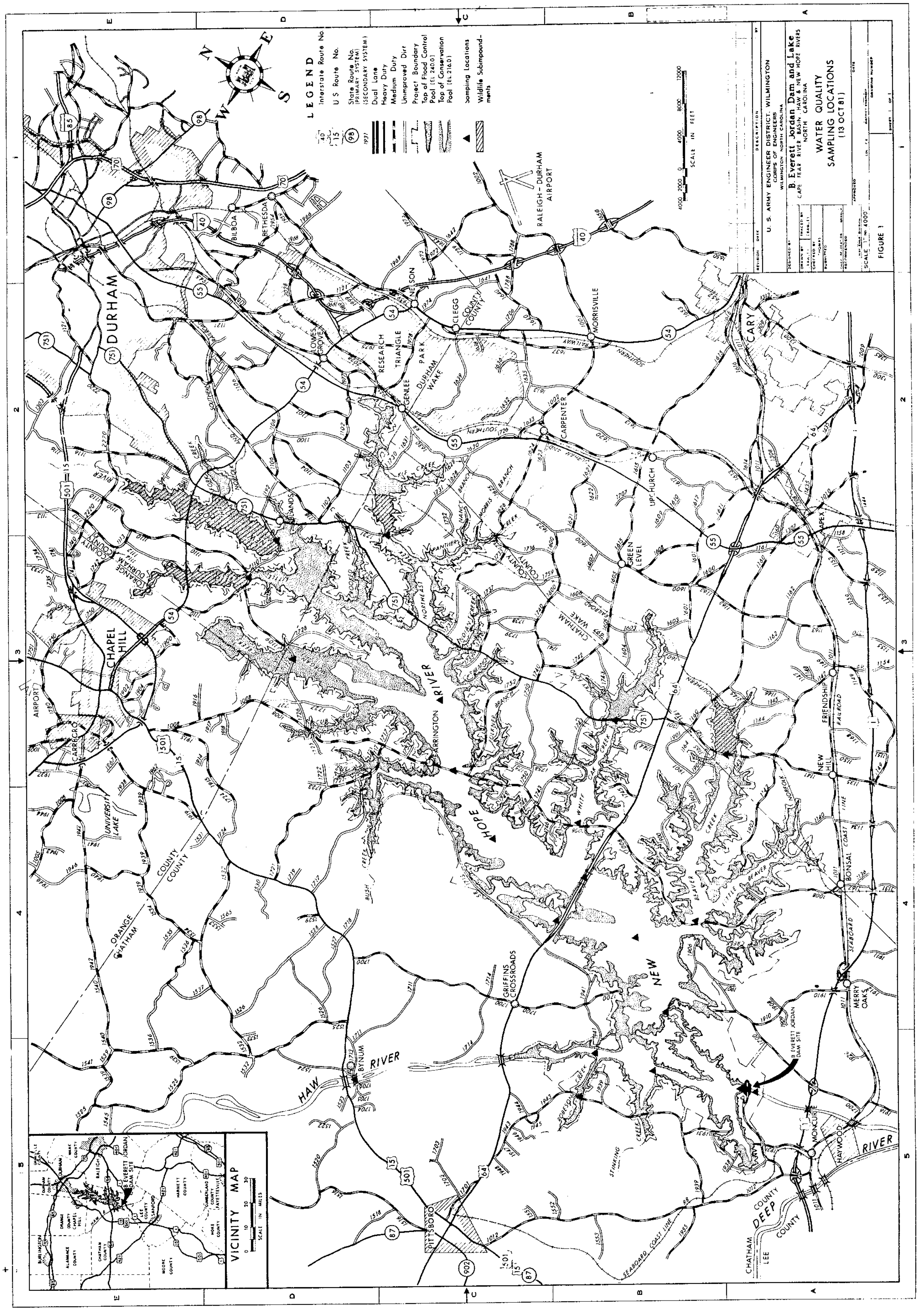
1. Define first-year impoundment water quality conditions for future comparisons.

2. Identify water quality problems.

3. Assist the State and local agencies responsible for watershed pollution control in evaluating the need for and impacts of control measures.

Some information on the physical characteristics of the reservoir will illustrate the basis for our selection of sampling sites. The two major tributaries of the reservoir are the Haw and the New Hope Rivers (see map). The Haw River provides 80 percent of the average annual inflow to the reservoir, but 90 percent of the reservoir storage volume is on the New Hope arm of the reservoir. There are three restrictions to water circulation on the reservoir. The restrictions are: State Road 1008 and U.S. 64 (causeway road fills) and the natural topographic constriction just above the confluence of the Haw and New Hope Rivers. A recent study of John H. Kerr Reservoir (8) indicated that such restrictions may have contributed to the distinct horizontal gradient in water quality with distance downstream of the reservoir inflow points.

There are 125 point source discharges in the drainage basin upstream of the reservoir. The discharges listed below are of major concern due to their proximity to and drainage into the New Hope arm of the reservoir:


U.S. ARMY ENGINEER DISTRICT, WILMINGTON
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA
B. Everett Jordan Dam and Lake
CAPE FEAR RIVER BASIN, HAW & NEW HOPE RIVERS
NORTH CAROLINA
WATER QUALITY
SAMPLING LOCATIONS
(13 OCT 81)
FIGURE 1
LEGEND
Interstate Route No.
U S Route No.
State Route No. (PRIMARY SYSTEM)
(SECONDARY SYSTEM)
Dual Lane
Heavy Duty
Medium Duty
Unimproved Dirt
Project Boundary
Top of Flood Control Pool (EL 240.0)
Top of Conservation Pool (EL 216.0)
Sampling Locations
Wildlife Subimpoundments
SCALE IN FEET
VICINITY MAP
SCALE IN MILES
DURHAM
CHAPEL HILL
CARRBORO
CARY
APEX
PITTSBORO
MORRISVILLE
RESEARCH TRIANGLE PARK
RALEIGH-DURHAM AIRPORT
NEW HOPE RIVER
HAW RIVER
DEEP RIVER
UNIVERSITY LAKE
B. EVERETT JORDAN DAM SITE
MONCURE
HAYWOOD
MERRY OAKS
BONSAL
NEW HILL
FRIENDSHIP
GREEN LEVEL
UPCHURCH
CARPENTER
NELSON
BILBOA
BETHESDA
BYNUM
GRIFFINS CROSSROADS
FARRINGTON
ORANGE COUNTY
CHATHAM COUNTY
DURHAM COUNTY
WAKE COUNTY
LEE COUNTY

Plant	Receiving Stream	Unit of Govt.
Triangle	Northeast Creek	Durham
Third Fork	Third Fork Creek (New Hope River)	Durham
Hope Valley	Third Fork Creek (New Hope River)	Durham
Sandy Creek	Sandy Creek (New Hope River)	Durham
New Hope	New Hope River	Durham
Mason Farm	Morgan Creek	Orange Water & Sewer Auth. (OWASA)

Altogether, 27 sampling sites were selected for the data collection program. There are eight inflow stations. One characterizes the Haw River inflow and the others characterize inflows to the New Hope arm of the reservoir. Three of the inflow stations on the New Hope arm of the reservoir receive input from the point source discharges mentioned above, while the remaining four stations receive nonpoint source pollution only. The outflow station located just downstream of the dam describes the reservoir releases. The 12 sampling stations on the reservoir itself were selected to characterize longitudinal and vertical water quality gradients. In addition, six beach sampling stations will be sampled for coliform organisms. All of the sampling locations are accessible by bridge or by boat.

For most parameters, two different sampling frequencies were selected. Monthly sampling occurs from November to March which is the high flow and nongrowing season. Biweekly sampling occurs from April to October which is the low flow and growing season. Parameters and sampling frequencies are listed in table 1. Exceptions to the sampling frequencies mentioned above are that the trace metals are sampled monthly, the major cations are sampled biannually, and coliform organisms are sampled biweekly from 1 May to 30 September to conform with the North Carolina water quality standards.

Streams will be sampled using an American Public Health Association (APHA) bucket sampler except that bacteria will be collected with a Kemmerer sampler. The streams will be sampled at midpoint and middepth because they are small and well mixed. ISCO samplers will be placed at Morgan Creek, New Hope Creek, and Northeast Creek to get a picture of the 24-hour variation in water quality associated with the point source discharges. Sampling on the reservoir for the temperature, dissolved oxygen, pH, oxidation-reduction potential and conductivity will occur at 2 meter intervals at each sampling station during the growing season and at 3 meter intervals at each station during the nongrowing season. Most other sampling on the reservoir will be with a Kemmerer sampler. Nutrients will be sampled at the surface and at 2 meter intervals at stratified stations and at the surface and just above the reservoir bottom at nonstratified stations. Metals and most other physical-chemical parameters will be sampled just below the reservoir surface and just above the reservoir bottom. Phytoplankton and chlorophyll *a* samples will be a depth integrated composite from the euphotic zone. Bacteria will be sampled just below the reservoir surface.

Containers for all samples will be polyethelyne except that samples for bacteriological analyses will be placed in sterile glass containers.

TABLE 1
PARAMETERS AND SAMPLING FREQUENCY
B. EVERETT JORDAN LAKE

1. PHYSICAL-CHEMICAL.

a. Biweekly sampling Apr to Oct and monthly sampling Nov to Mar.

Temperature (F)
Dissolved Oxygen (F)
pH (F)
Conductivity (F)
ORP (F)
Secchi Disk
Depth (F)
% Light Transmission (F)
BOD_5 (river stations only)
Turbidity
Residue, total nonfilterable
Residue, total filterable
(NO_2+NO_3)-N
NH_3-N
Total Inorganic N (C)
TKN
Total Organic N (C)
Total N (C)
Total Phosphorus
Total Dissolved Phosphorus
Dissolved Orthophosphate Phosphorus
Total Organic Carbon
Dissolved Organic Carbon
Total Alkalinity
Color (surface samples only)
Chlorid
Sulfate

Note: On the ISCO composite samples taken on Morgan Creek, New Hope Creek, and Northeast Creek, the analyses will be for total phosphorus and total organic carbon, and not the dissolved forms.

TABLE 1 (cont.)
PARAMETERS AND SAMPLING FREQUENCY
B. EVERETT JORDAN LAKE

1. PHYSICAL-CHEMICAL (cont.)

b. Monthly sampling year-round.

Arsenic (T)
Cadmium (T)
Chromium (T)
Copper (T)
Lead (T) (D)
Mercury (T)
Nickel (T)
Selenium (T)
Silver (T)
Zinc (T)
Iron (T)
Manganese (T)

c. Biannual sampling.

Potassium (T)
Sodium (T)
Calcium (T)
Magnesium (T)

2. BACTERIOLOGICAL - Biweekly sampling Apr to Oct and monthly sampling Nov to Mar.

Total Coliform
Fecal Coliform
(Note: Recreation areas will be sampled from 1 May - 30 Sep only.)

3. PLANKTON - Biweekly sampling Apr to Oct and monthly sampling Nov to Mar.

Identification
Density
Chlorophyll *a*

(F) Field measurement
(C) Calculated
(T) Total
(D) Dissolved

Filtration, in a departure from standard methods, will be by GF/F glass microfiber filter with 0.7 micron particle retention. The GF/F glass microfiber filter is being used to permit rapid filtration in the field.

Samples for nutrients will be preserved with sulfuric acid. Samples for bacteria and phytoplankton will be preserved on ice and samples for metals will be preserved with redistilled nitric acid.

All samples, except those for bacteriological analysis, will be stored in the dark at 4° C upon return to the laboratory. Bacteriological analyses will commence immediately upon return to the laboratory.

All samples will be identified with date, time, station number, and depth of collection.

Field personnel who will be participating in the data collection are well trained, experienced, and observant.

Besides the Wilmington District, Corps of Engineers, five other Federal, State, regional, and local agencies are contributing to the first year post-impoundment water quality study of B. Everett Jordan Lake. The U.S. Geological Survey is operating and maintaining a stream gage and water quality station on the Haw River just upstream and just downstream of the reservoir which will provide a record of reservoir inflow and outflow quantity and quality. The State of North Carolina, Division of Environmental Management, Technical Services Branch, is cooperating in the study by sampling reservoir sediments to assess deposition, scour, and accumulation of benthic deposits. The State is operating and maintaining two automatic water quality monitors jointly funded by the District on the two major tributaries of the reservoir. These stations will allow us to quantify nutrients and solids loading to the reservoir under high flow conditions. Also, the State will continue to sample streams in its ambient stream monitoring network which are located upstream of the reservoir and which will provide additional information on reservoir inputs and outputs of nutrients, metals, and solids, etc. The State added a new station on Little Creek at N. C. 54 to their ambient monitoring network, at our request. Upstream discharges self-monitoring data will be made available to us by the State to enable us to quantify point source biochemical oxygen demand and nutrient loads to the reservoir.

The Triangle J Council of Governments (COG) encompasses six counties; four of which directly affect the reservoir via point and nonpoint source pollution. The COG is participating by lending us four ISCO automatic water quality samplers free of charge for the duration of the study.

The City of Durham and the Orange Water and Sewer Authority will be collecting self-monitoring data on their wastewater treatment plant effluents which are discharged to the New Hope arm of the reservoir. The data will be furnished to the State and ultimately the District. The City of Durham is voluntarily monitoring trace metals in its wastewater treatment plant effluents, and has agreed to share data with us. This will enable us to determine what portion of the trace metal load to the reservoir is attributable to their discharges.

CONCLUSIONS

In designing a water quality data collection program, standard methods should be used in conjunction with Corps of Engineers guidance. Data collection programs should be coordinated with the pollution control/monitoring agencies prior to implementation. The payoff will be ready acceptance and use of the results of the study by all agencies involved. Additional benefits are that a more comprehensive study may result than a District can afford alone and duplication of effort among agencies can be eliminated.

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WATER QUALITY LABORATORY ANALYSIS

By

Richard J. DiBuono[1]

A USER'S PERSPECTIVE

Antiseptic appearing, but sometimes foul smelling, physical plant that takes in megabucks and gives out only micrograms.

In reality, however, this creation of the Chemist's mind has the potential to supply the basic information needed by the Corps engineer or scientist to make the many analyses and determinations related to water quality considerations in the planning, design or operation of water resources development projects.

The perspective I have and wish to share with you has developed from about 12 years of working with an in-house Division Water Quality Lab, with a Regional EPA Laboratory, with the Cold Regions Research and Engineering Laboratory's water lab and to only a small degree with private laboratories. Anne Strong, Chief of the Analytical Laboratory Group at WES will be addressing the inspections of laboratories in the second part of this session and will probably provide more information on considerations particularly important to dealing with contracted laboratories.

USER'S NEEDS

What the user needs from the Water Quality Laboratory is data on the physical and chemical characteristics of water and/or water sediment samples that are representative of the water body being sampled. The key word here is REPRESENTATIVE. To insure that he or she is actually the recipient of data which reflect as closely as possible the quality conditions of the stream or lake or other water body under study necessitates the user must coordinate with the laboratory director or chemist at all stages of the data collection effort.

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USER-LABORATORY COORDINATION

What I would like to do in this brief period is discuss some of the important links between the lab and the user and suggest ways the user can minimize problems in the procurement of laboratory services and assure the goal of obtaining representative data.

At the very outset of the planning of data collection program, the capabilities of the laboratory must be determined. The program must be realistic and it will usually be limited by the following laboratory constraints:

A. IN A CORPS LABORATORY -

1. Limited full-time staff and seasonal help.

2. If the lab also provides the field sampling services, there are limitations associated with planning the geographical spread and number of sampling sites.

3. Type of laboratory equipment . . . special one-time analysis of a particular parameter often cannot be accomplished because of the expense of or unavailability of the sophisticated equipment. Renting or borrowing the equipment may not be the answer for if the lab personnel are inexperienced in its use inaccuracy may result.

4. Seasonal conditions such as ice cover and thermal stratification/destratification in a lake create a situation where the sampling and analysis must be performed in a compressed period of time and place a burden on the laboratory.

5. The present 2-year budget cycle places limitations on the laboratory's ability to respond totally to a new or dynamic water quality monitoring program having had its resources fixed by the budget estimates of two years earlier.

B. CONTRACTING FOR LABORATORY SERVICES -

Although some of the constraints mentioned here can be eliminated through the use of contract laboratory services, this can present a new set of limitations on the data collection program planning:

1. Variability in data representativeness, reliability and validity can result from the use of different contractors to collect the same parameters.

2. Due to present methods of awarding contracts the firm which your office has most confidence in and feels most comforable dealing with may not get the open-end contract each year.

3. Each new contractor may not be as familiar with what to expect in the way of the ranges of data from a particular geographic area and

thus removal of "outliers" by the laboratory or through office interpretation is made more difficult.

4. Adjustments to the collection program cannot always be made quickly or even at all since the contract laboratory may have a substantial workload from other clients. All of these factors which affect the planning of the data collection program can be recognized and taken into account through dialogue between the user and the laboratory. The result will be the achievement of a realistic plan.

DESCRIBING THE DATA COLLECTION PROGRAM

In presenting the data development assignment to the laboratory, it is very important to clearly describe the specific parameters desired and the tolerable detection limits on the analytical procedures to be employed. This obviously requires the user to coordinate with the laboratory to learn what the analytical methodologies are and to understand the connection between cost of analysis and detection limits.

The user, for example, must know whether he or she is interested in only the dissolved fraction of a particular constituent in the water sample or in the suspended faction as well. A very clear way to communicate this information to the laboratory is by listing the specific parameter description and providing the pertinent Storet Code:

For example:

Total Nitrogen, mg/l as n	00625
Nitrite-nitrate nitrogen, mg/l as N	00630
Total Phosphorus, as P	00665
Orthophosphate, mg/l as PO_4	00660
Silica, dissolved, mg/l as SiO_2	00955

In thus describing the parameters there can be no confusion on the part of the chemist as to what analyses are desired.

The detection limits needed in the analyses communicated to the laboratory using this same list by simply adding a column labeled something such as: "Desirable Minimum Detection Limits." In selecting these limits the user has available to him the advice of the laboratory and certain basic references on analytical methods such as:

1. National Handbook of Recommended Methods for Water Data Acquisition published by the USGS Office of Water Data Coordination, 1977.

2. Methods for Chemical Analyses of Water and Wastes, published by the Environmental Protection Agency, 1979.

3. Standard Methods for the Examination of Water and Wastewater, 15th edition, published in 1981 by the American Public Health Assocation, the American Water Works Association and the Water Pollution Control Federation.

Thre are other references to be sure, but these are the most generally used and accepted.

CONTROLLING THE LABORATORY ANALYSIS PROGRAM

Of principal importance to the user of laboratory services is the assurance that quality control is being exercised from the time of sampling to the reporting of the parametric concentration value. Unfortunately for the Corps, the concern for quality control at the outset of the agency's involvement in environmental quality matters in the late sixties took a back seat to simply "getting out there in the field and make water quality measurements." To overcome this situation and all the attendant problems associated with specious or nonrepresentative data has been a goal of the Chief's Office and the Committee on Water Quality.

The first step taken was to prepare and publish Engineer Technical Letter 1110-2-244, titled: "Water and Wastewater Laboratory Quality Control" in May 1979. Responsibility for laboratory quality control is vested with the Laboratory Director not the User. The ETL delineates responsibilities the Lab Director has in properly staffing the lab with qualified professionals, with providing the required facilities, with properly equipping and instrumenting the lab, with the selection of reliable and appropriate analytical methods and with the execution of quality control procedures.

The user must have a dialogue with the Lab Director and chemist to assure himself or herself that these quality control measures are being executed. Ideally, an independent third party professional experienced in laboratory operations should perform reviews of the laboratory activities and report findings to the user. The third party could be the Division Lab Director in the case of a District Lab or contract laboratory, or lacking this option could be a hired professional from another Government Lab (e.g., EPA Regional Lab) or private lab. However, in these days of limited budgets and reduced staff levels the hiring of the quality assurance person may not be possible and the coordination directly between the user and the lab is made even more important.

The second step to achieve quality control taken by OCE and the Water Quality Committee probably should have been the first, at least in terms of the normal order in developing a piece of water quality data, and that was the issuance of Engineer Technical Letter 1110-2-252, titled: "Quality Control of Water Quality Field Sampling Activities" in June 1980. This ETL places the responsibility for field sampling quality control with the field sampling team. The goal of the Q/C Program is to obtain a representative sample and deliver it unchanged to the laboratory. Obviously, all the Q/C exercised in the lab is for naught if a nonrepresentative sample is brought to the lab for analysis.

Again the user must take steps to assure that the collection, preservation, handling and identification of the samples are being performed properly. Periodically accompanying the sampling team is one means to accomplish this. Again, the use of a third party professional is another means.

SUMMATION

In summation, the user cannot treat the Water Quality Laboratory as a black box in which data requests are received at one end and perfectly understandable and reliable data come out the other. The user must coordinate with the lab from the point of planning the data collection program to the point of execution of the analyses in order to achieve the goal of receiving valid, representative data.

WATER QUALITY DATA MANAGEMENT

By

Jackson K. Brown[1]

My experience in managing water quality data begins in 1970 when the Nashville District formed its Water Quality Section. Since then, I have watched our data management system evolve from stuffing papers in filing cabinets to computerized storage and retrieval. Basically, this paper deals with the end product of that evolution process, the system we presently use in the Nashville District.

My first problem in preparing this paper consisted of defining what data management is. In looking at the agenda for the seminar, it is obvious data management involves getting field and laboratory results in a form suitable for interpretation. To be more specific, I have prepared a list of what I have found to be the most important tasks involved in data management:

1. Assemble field and lab data in machine-readable form.

2. Assemble supporting data.

3. Enter data onto computer and convert it to proper format.

4. Check all information entered and correct errors.

5. Calculate values from observed data.

6. File printouts of data.

7. Develop and maintain programs and files.

8. Maintain logs showing availability of data.

9. Exchange data with others.

10. Other.

The best tool available for managing large amounts of numerical data is the computer. One of the first steps in data management must involve getting the information in machine-readable form. This process should begin during the collection of the data. In Nashville we record our field data on forms which can be given directly to key-punch operators. Another available option is the use of data loggers to record information on cassette tapes. Since both of the labs we normally use to analyze our samples, the Ohio River Division Lab

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and our own District Water Quality Lab, use Wang mini-computers to process data, there is no problem in getting our lab results in machine-readable form. The main thing to try to avoid at this stage is transposing data by hand. In general, the more information you have to transpose by hand, the less efficient is your data management system.

The second task listed is assembling supporting data. Supporting data includes such hydrologic parameters as stage and discharge. Each time we sample one of our lake stations, we record the water surface elevation. When we sample the tailwaters of one of our dams, we record the instantaneous discharge. This information is normally obtained from our Reservoir Regulation Section after the field sheets are brought into the office. We prefer not to burden our field crews with collecting this type of information during sample collection. Of course, we record and process this information because we know it will be needed in interpreting the water quality data.

The third task consists of getting the data on the computer and converting it to the proper format. The format in which the data is written on our field sheets is significantly different form the format in which it is stored on the computer. To convert it to the proper format, we have a program which takes the data as recorded in the field and develops all codes and other information required for storage.

The fourth task, checking the information to be stored, is one of the most important features of data management. In general, we do not store data which we consider to be outside acceptable limits of accuracy. Admittedly, there is a danger of developing a biased data base by throwing away questionable or unrepresentative values. On the other hand accepting everything will result in a significant amount of garbage stored in the system.

We use editor programs for checking information as much as possible, but this does not eliminate the need for manual checking as well. Editor programs are useful for such things as making sure station identification and parameter codes are valid and dates, times and depths are reasonable. They are also useful in pointing out unusually high or low values for specific parameters, but someone still has to look at these values and decide whether or not to accept them.

Laboratories generally complicate the checking process by providing test results in a piece-meal fashion for several months after sample collection. In many cases a value cannot be adequately checked until additional information is received. For example, one week the lab might give you a dissolved phosphorus concentration of 50 ug/l. The next week they may give you a total phosphorus concentration for the same sample of 30 ug/l. Individually, these two values look fine, but when put together, it's obvious something is wrong. So, in addition to checking each piece of data separately as we receive it, we also put everything together after all lab results have been received and check it again.

The fifth task listed is calculating values from observed data. For instance, we take temperature and D.O. data and compute percent D.O. saturation. We also have a program to compute percent light transmittance from photometer readings. Another example of this type of computation is the calculation of gas saturation values from saturometer data.

The sixth task involves obtaining and storing printed copies of the data. In addition to having the data stored on the computer, we also maintain a file of printouts in our office showing the checked data. These printouts are very useful in quickly answering many of the questions which occur in normal day-to-day operations. It is undesirable to be in the position of having to make a computer retrieval to answer simple questions.

The seventh task consists of developing and maintaining programs and files for data management. The programs most often used in data management are storage and retrieval programs and programs for editing data and changing formats. Some of these programs access files containing station description information and criteria used to edit data. In general, the more sophisticated the data handling system, the greater will be the amount of time spent in developing and maintaining data management programs and files.

The eighth task includes maintaining logs showing the availability of data. With these logs it is possible to monitor the flow of data and determine when all essential information has been received and checked. It is also necessary to know what information is stored in the files. One of the most useful programs for this in our system is a statistics program, which was developed for data interpretation. This program is run against our entire data base once or twice a year. In addition to statistics, we obtain a list of all stations in the data base, the parameters sampled at each station, the number of values collected for each parameter, and the beginning and ending dates of sample collection. As mentioned previously, it is considered undesirable to have to make a computer retrieval to answer every question which occurs. For example, if I need to know whether we have collected any mercury data from a specific project, I can look at a few printouts from the statistics program and find out in less time than it would take me to even log on the computer.

The ninth task involves exchanging data. The data management system needs to be capable of responding to outside requests for data. In addition, there is a regulation (ER 1130-2-334 dated December 1977) which requires all districts to contribute to STORET. In performing a detailed water quality survey, it may be desirable to use data collected by others. Two of the most important sources of outside data for Corps offices are the WATSTORE and STORET systems. The capability should exist for retrieving data from these and other systems not only on printouts, but in machine-readable form as well. Obtaining the data in machine-readable form allows it to be converted to a format compatible with your own data mangement system without transposing it by hand.

In addition to the nine tasks discussed previously, there are other features which must be considered in data management. One of the most important considerations is security. The capability to edit or drop data must be limited to a few qualified individuals. The data base must also be protected from system hardware problems. Another feature which may be desirable is an accounting system for laboratory costs.

The remainder of this paper will be devoted to discussing the types of water quality data we manage. Basically, we are concerned with two types of data: grab sample data and continuous record data. In Nashville we use the AURAS system, which was developed by the Ohio River Division, to manage our grab sample data. AURAS is presently maintained on the INFONET system. Each value or concentration stored in AURAS requires the following information for identification:

a. STORET parameter code (5 digits)

b. station identification code (9 digits)

c. date by year, month and day (6 digits)

d. time (4 digits)

e. depth (3 digits)

In addition to several basic AURAS programs we have found INFONET's editor and system commands, such as the "SORT" command, very useful in manipulating data.

The format we use for continuous record daily values is essentially the input format used by HEC programs (8X, 9F8.0). A typical file contains one year's record of daily values for such parameters as mean daily discharge, midnight headwater elevation, or maximum or minimum daily water temperature. The file's name describes the information stored in the file. Continuous record files are maintained on tape bundles. All of our conversion programs are designed to get data in one of these two formats and, of course, our plotting and data interpretation programs are set up to read the data in these formats.

There is another type of continuous record data which we have recently begun to work with. This is hourly data collected by water quality monitors and transmitted to us via GOES satellites. The challenge here is to prepare the information for interpretation in real time. My experience to date indicates this is not a difficult problem if the water quality monitors provide accurate data. Unfortunately, parameters such as D.O. and pH tend to drift out of calibration unless probes are cleaned on something like a weekly basis during warm weather. This means it's necessary to either visit the monitors at frequent intervals, which is expensive, or estimate the magnitude of the error and adjust the reported values accordingly. If the latter approach is adopted and the real time data are used for operational decisions, the reasons for adjusting or ignoring the data should be documented.

In summary, this paper has discussed the types of data and most important tasks involved in the management of water quality data. Although there are many systems available for data management, the system used would have to incorporate many of the features and concepts presented in this paper to be considered efficient.

WATER QUALITY DATA INTERPRETATION

by

Clinton A. Beckert[1]

INTRODUCTION

The final step in any scientific investigation is data interpretation. It is perhaps the most important and yet most difficult phase of the investigation to perform. This is in part due to the fact that the initial program design, sample analysis, and data management all bear on the validity and manageability of the data. Often the individual or individuals responsible for interpretation of the results do not have a thorough understanding of all aspects of the program design. Under other circumstances, questions may be raised which the sampling program was not designed to answer. Even if the individual(s) responsible for interpretation have been involved with the program from its inception, and are using the data as they were intended, it is important to determine the reliability of data before they can be evaluated.

The purpose of this paper is to review the various steps leading to successful data interpretation, and to offer some interpretative techniques. The major topics to be discussed include:

a. The need for familiarity with the study area.

b. The importance of ascertaining precision and accuracy of data set.

c. Evaluation of the appropriateness of the data to answer proposed questions.

d. The use of various interpretative techniques.

It is realized that it is not possible to cover all subjects relative to data interpretation; however, it is hoped that the topics discussed will be of value to those in the position of data interpretation, and perhaps this discussion will bring to mind additional points which might otherwise have been overlooked.

The Need for Familiarity with the Study Area

Due to the nature of many water quality investigations, data acquisition may require several years. In the case of team investigations, personnel changes will undoubtedly occur, often resulting in the responsibility for data interpretation resting with individuals not familiar with all aspects of the projects. In order to adequately evaluate the significance of the

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results, it is imperative to have a very good understanding of the study area, the location of the sampling sites, and the types of samples taken.

Numerous watershed characteristics may influence water quality; these include soil type, hydrologic conditions, basin topography; weather patterns, etc. Similarly, the exact location of the sampling sites within the basin must be known. Are the sites upstream or downstream of point sources of pollution? Are they upstream or downstream of dams? Are they taken within the main channel or out of the main channel? If lake or reservoir samples are being taken, are they taken at midpool or headwater locations?

Finally, the types of samples taken have a bearing on the results. Are they grab samples, composite samples, depth samples, etc.? Are they taken at the same time each day, on the same day each week, etc.? Each of these facts must be taken into account in evaluating the results of any study.

Ascertaining the Precision and Accuracy of a Data Set

Prior to evaluating the results of a study, one must determine the validity of the data. For instance, are the samples handled properly in the field and laboratory before being analyzed? What degree of sophistication is used in the analysis (Level I, II, or III)? Obviously, data obtained using Level I analytical techniques are not suitable for use where Level III precision and accuracy is required.

Another area of concern is the type of quality control measures which are followed. Throughout the investigation, several methods of quality control including replicate sample collection, spiked sample analysis, adequate standard analysis, and interlaboratory comparisons should be incorporated into the normal analytical process. Before interpreting the data, one should be aware of such procedures and the results.

Two very simple, yet useful, methods of verifying the accuracy and "reasonableness" of data are the anion-cation balance and the use of the proven relationship between specific conductance and total dissolved solids. In theory, the sum of the cations in any given sample should exactly equal the sum of the anions when both are expressed in milliequivalents/liter. In practice, however, inequalities often appear depending on the accuracy of the various analyses performed. One may graphically plot the results of such an analysis using a control chart. Acceptable limits have been established as plus or minus one standard deviation (8) using the following formula:

$$\sum \text{anions} - \sum \text{cations} = \pm\ (0.1065 + 0.0155 \sum \text{anions})$$

An example control chart is present in figure 1 using data from the Des Moines River, Iowa (1). One should expect a fairly uniform distribution of points on such a graph. If clustering of the points is observed, or if an apparent excess of anions or cations appears, a systematic error in the analytical procedures may exist, or a significant constituent of the water sample may be lacking from the list of parameters analyzed.

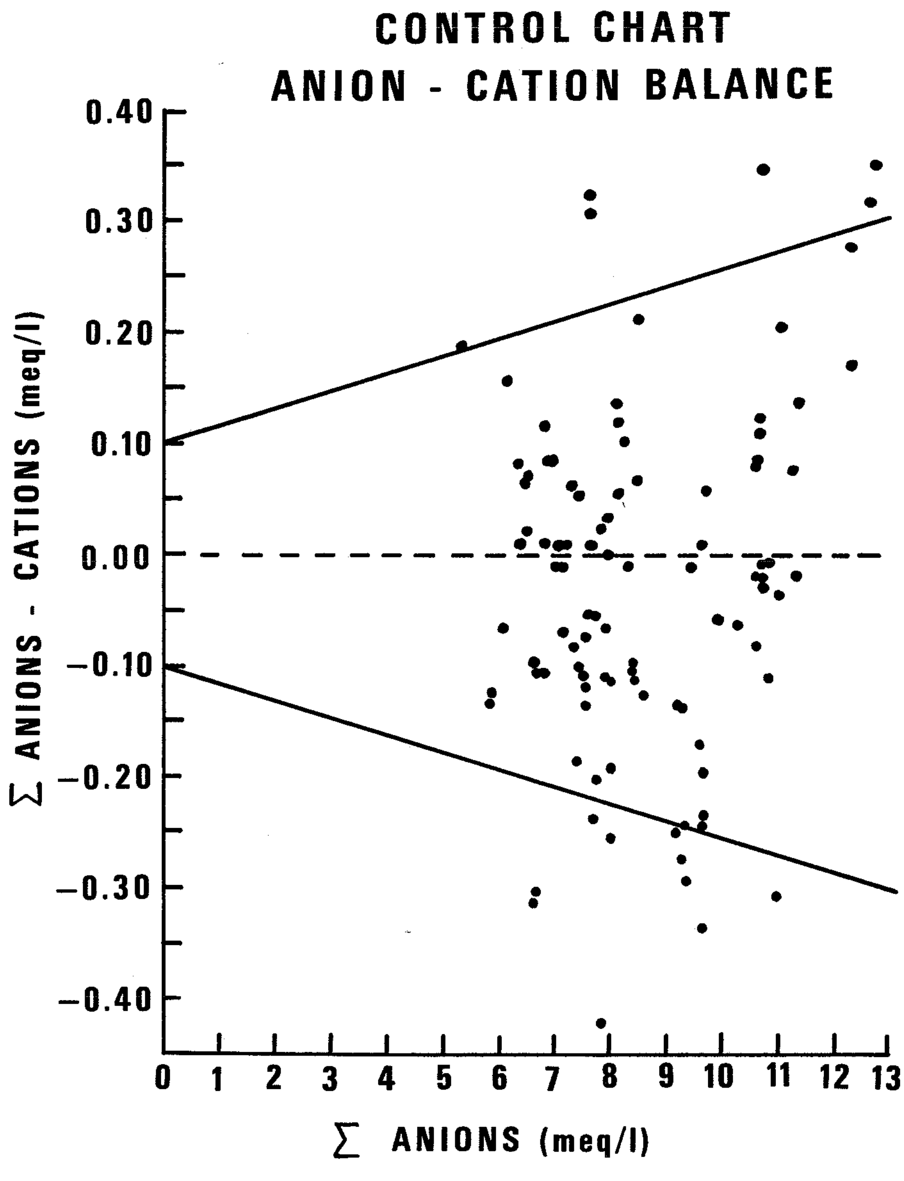

Figure 1. Ion balance control chart, Des Moines River, IA., 1979-1980.

A second procedure which may be useful in indicating the "reasonableness" of data is a comparison of specific conductance and total dissolved solids data. Specific conductance is a measure of a solution's ability to conduct an electrical current. As such, it is dependent upon the concentrations of dissolved materials in the solution. It has been demonstrated that a very predictable linear relationship exists between these parameters for any given water body (5), (6). One may evaluate a data set by plotting specific conductance versus total dissolved solids and observing the scatter of points. This has been done using 3 years of data (figures 2-4); 2 years of data from the Des Moines River under varying flow conditions, and 1 year's data from the Mississippi River. One should note that in all cases the correlation between the two parameters is very good despite the fact that they were taken under varying hydrologic conditions and from different river basins. If such plots resulted in a scatter of points, one should investigate the possibility of analytical errors or any unusual water quality characteristics which might affect this relationship.

Apppropriateness of Data Set

Far too often the original intent of the sampling program is ignored once the investigation is begun. Frequently this leads to data being used to answer questions or predict responses, while the original sampling program design never intended the data to be used in this manner. This may result in the data being misused due to inadequate sampling frequencies or inappropriate collection procedures. No single sampling program can be adequately designed to suit all purposes; one must keep in mind the original objectives of the study and employ caution when using the data to answer additional questions.

Interpretation and Presentation of Data

Only when one has become adequately familiar with the study area and has determined that the data is accurate and appropriate to answer the questions raised, can meaningful data interpretation proceed. Numerous techniques for data interpretation are available; many beyond the scope of this paper. The following examples serve only as a brief introduction to the subject and in no way are intended to discuss it in its entirety.

One of the simplest, yet most informative, means of presenting data is a simple chemograph (i.e., parameter vs. time). This allows one to quickly observe trends in the data as well as determine the maximum and minimum values. It is always useful to provide a tabular listing of the data in addition to any graphical presentation. Often it is useful to plot data for two stations on one plot (upstream and downstream of a point discharge, for example) for comparison purposes.

Statistical analyses are often very useful and, with the accessibility of preprogramed calculators and minicomputers, relatively easy to perform. Some of the more meaningful analyses include mean, standard deviation, least square regression, multiple linear regressions, nonlinear regressions, and Duncan's New Multiple-Range Test. A requisite in using statistical tools, however, is that the data be normally distributed;

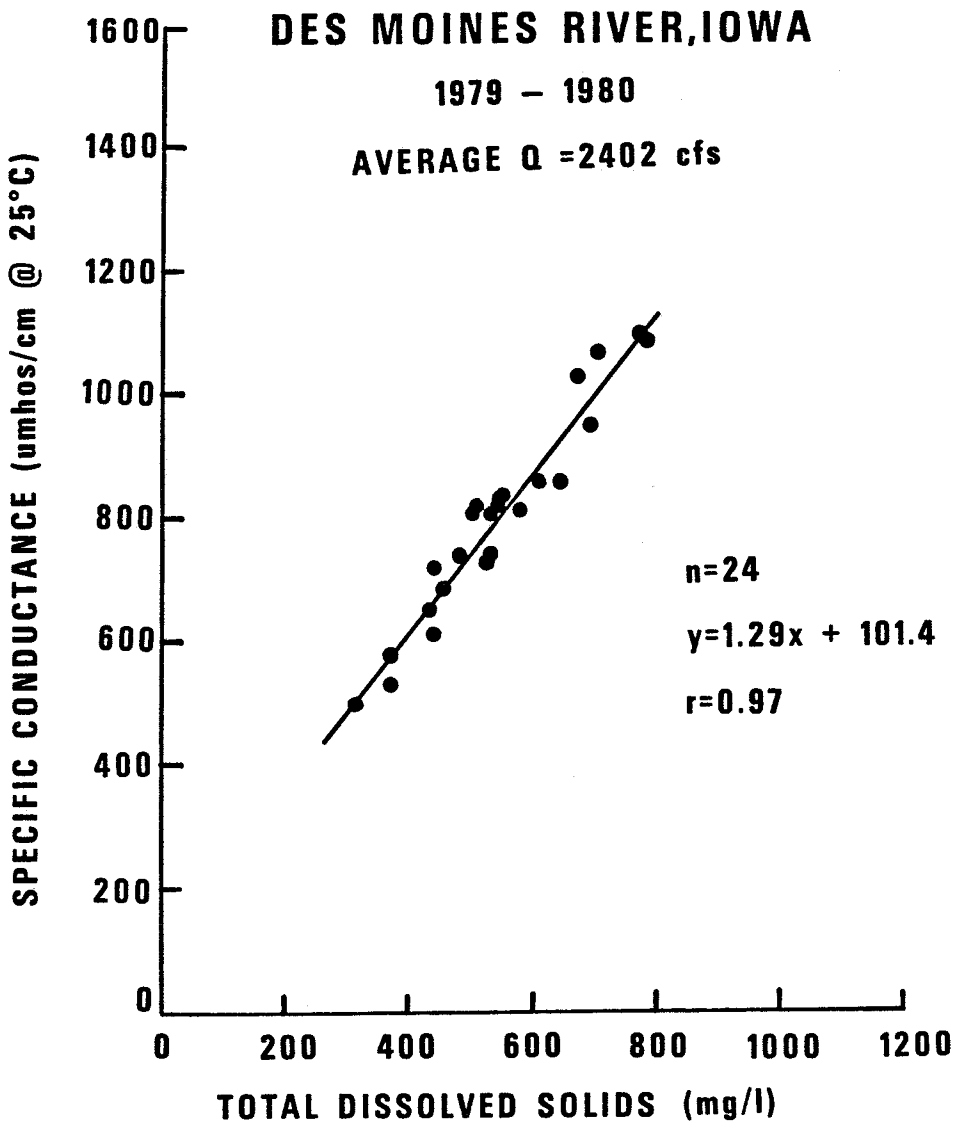

Figure 2. Specfic conductance versus total dissolved solids, Des Moines, IA., 1979-1980.

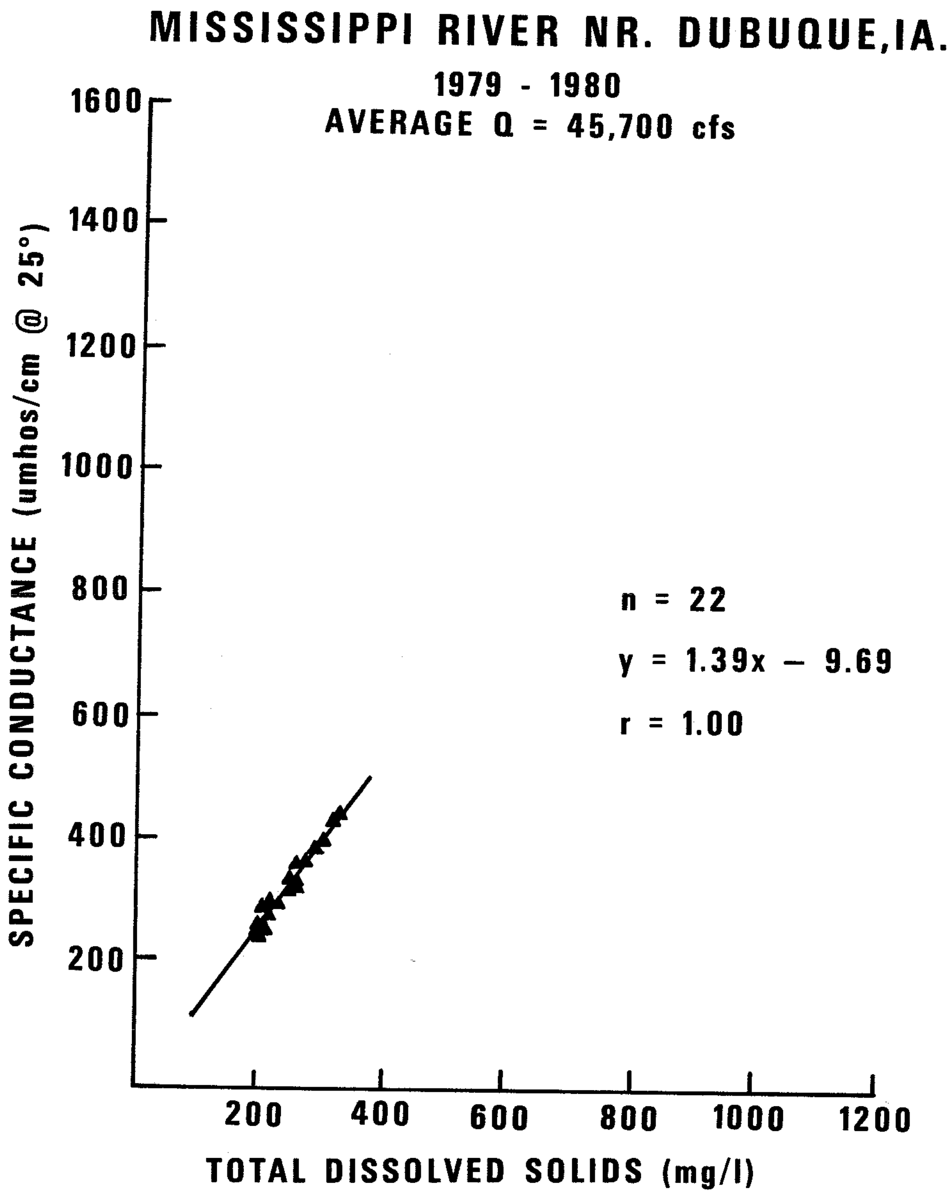

Figure 4. Specific conductance versus total dissolved solids, Mississippi River, 1979-1980.

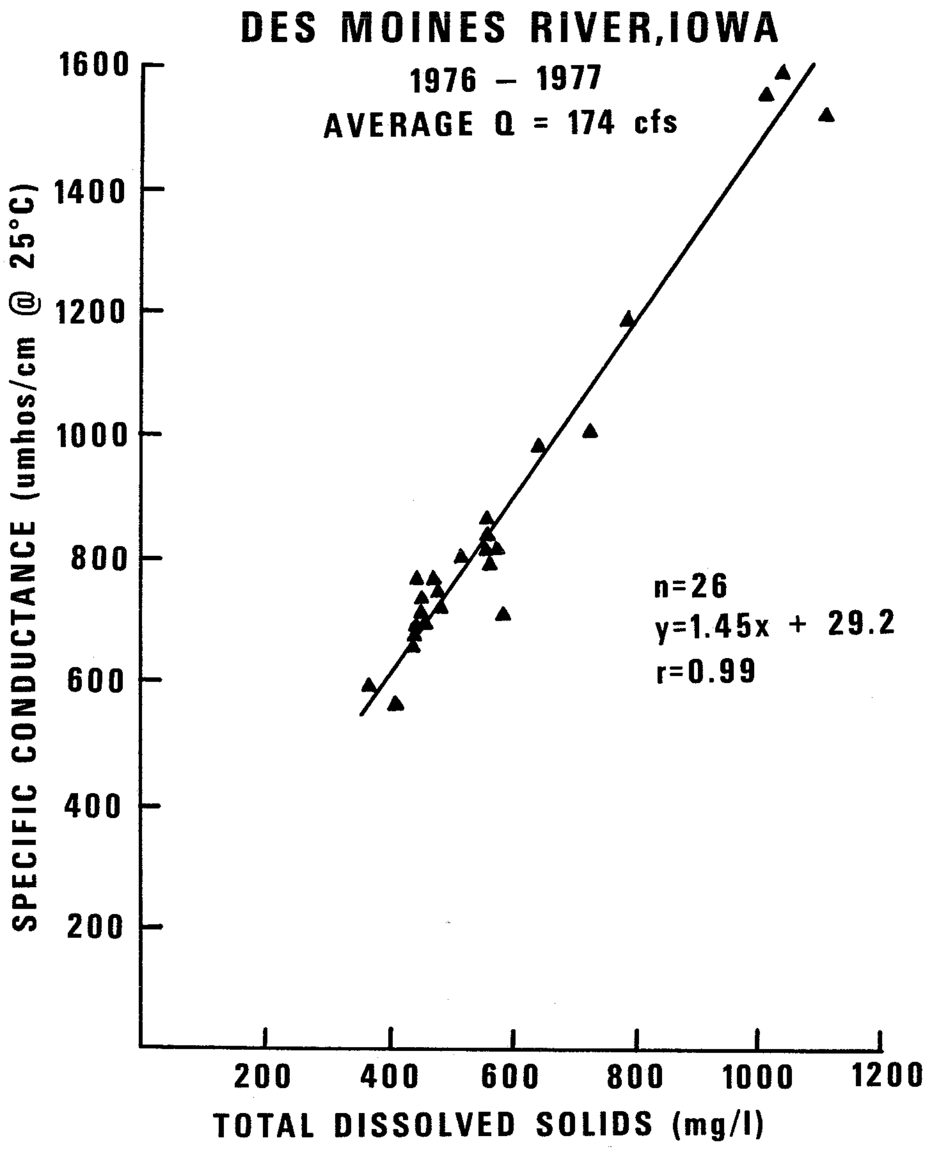

Figure 3. Specific conductance versus total dissolved solids, Des Moines, IA., 1976-1977.

that is, that no biases exist in the data collection and analysis procedures. Of course we know this is not true. Most routine sampling programs call for a single sample to be taken during the day. However, it is common knowledge that parameters such as dissolved oxygen, pH, temperature, alkalinity, carbon dioxide, etc., vary diurnally. Thus, there exists an aproximate 24-hour cyclic variation in values. Figure 5 depicts this normal variation in dissolved oxygen, observed at a single station along the Des Moines River, Iowa (7). Most individuals take these variations into account in data analysis. However, it may not be generally known that similar variations in additional parameters may be experienced downstream from point sources of pollution. Figure 6 depicts total phosphorus data collected at three locations along the Sandusky River, Ohio (10). One notices two specific phenomena from these data. First, immediately downstream from the point source of pollution a well defined diurnal variation is evident. As one moves downstream, the variation attenuates. Secondly, the concentrations are significantly lower at the downstream stations. It is obvious that not only the choice of sampling station location but also the sampling time, to a large extent, affects the results. Samples collected at certain times every day may have concentrations higher or lower than the average for the 24-hour period. It might also be assumed that the lower concentrations observed at the downstream stations are a result of dilution. The authors point out, however, that no increase in flow is observed between the upstream and downstream stations; thus the lower concentrations are a result of phosphorus deposition and biological uptake. This example points out the many complexities involved in analyzing a single parameter at a given location.

A relatively common statistical approach used to quantify the relationship between parameters is linear regression analysis (figures 2-4) or nonlinear regression analysis. Figure 7 depicts the relationship which normally exists between phytoplankton constituents in the Des Moines River, Iowa (2). Using this type of analysis, one can see that a very good, positive relationship exists between total phytoplankton counts and diatoms counts. It is evident that when total phytoplankton counts are the highest, diatoms comprise the vast majority of the phytoplankton in the stream. This would indicate that although phytoplankton concentrations may be quite high, objectionable algal forms such as blue-greens will probably not pose a problem.

Often it is desirable to compare concentrations of a particular parameter at several different locations and determine if a meaningful difference exists between locations. This may be accomplished using the means for the parameter of interest and a technique termed Duncans New Multiple-Range Test (9). Basically the technique consists of performing an analysis of variance and estimating the standard deviation of the mean from the error mean square:

$$S_{\bar{x}} = \sqrt{\text{error mean square}/n}$$

Where: $S_{\bar{x}}$ = standard deviation of the mean

n = number of sample values

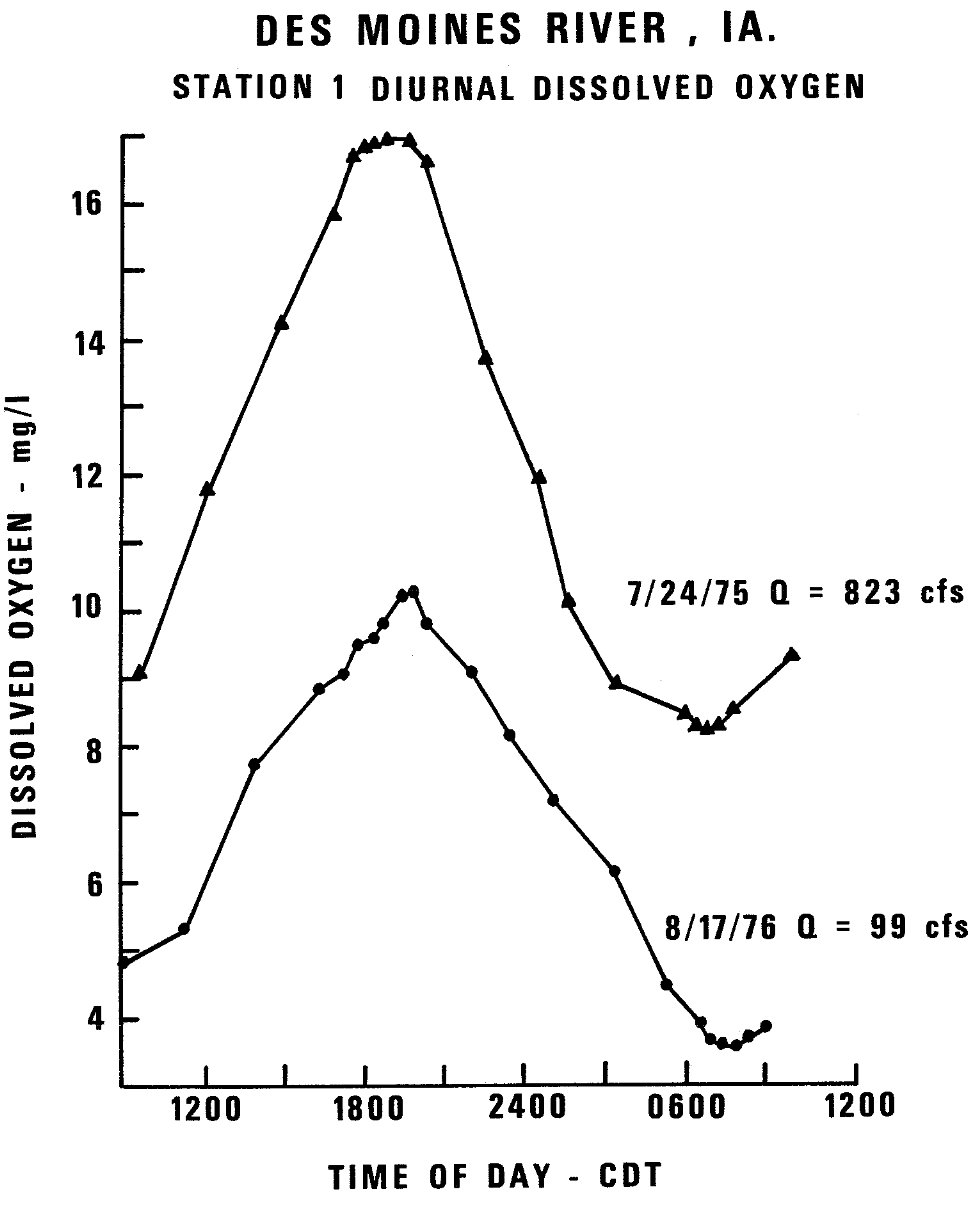

Figure 5. Diurnal dissolved oxygen concentrations, Des Moines River IA., 1975-1976

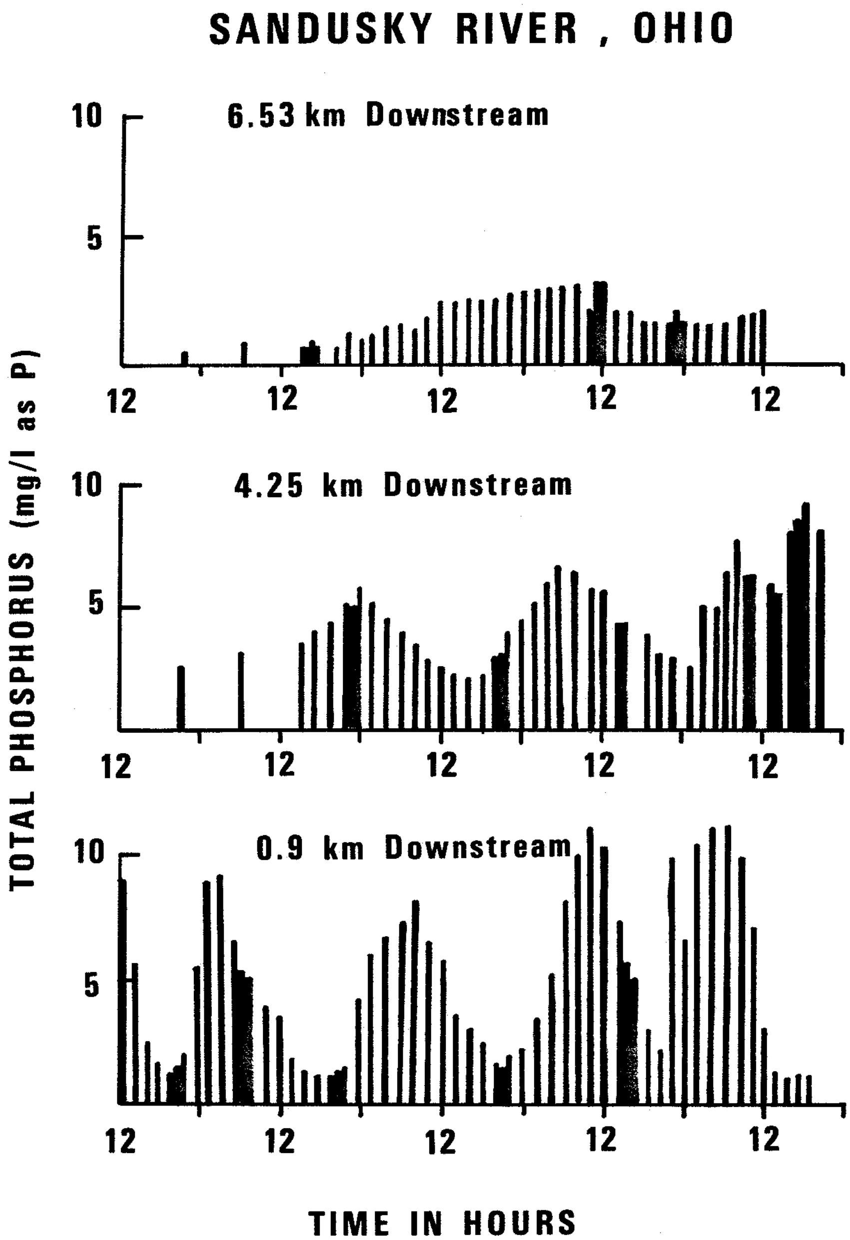

Figure 6. Diurnal total phosphorus concentrations, Sandusky River, Ohio, modified from Yaksich, et al. 1980.

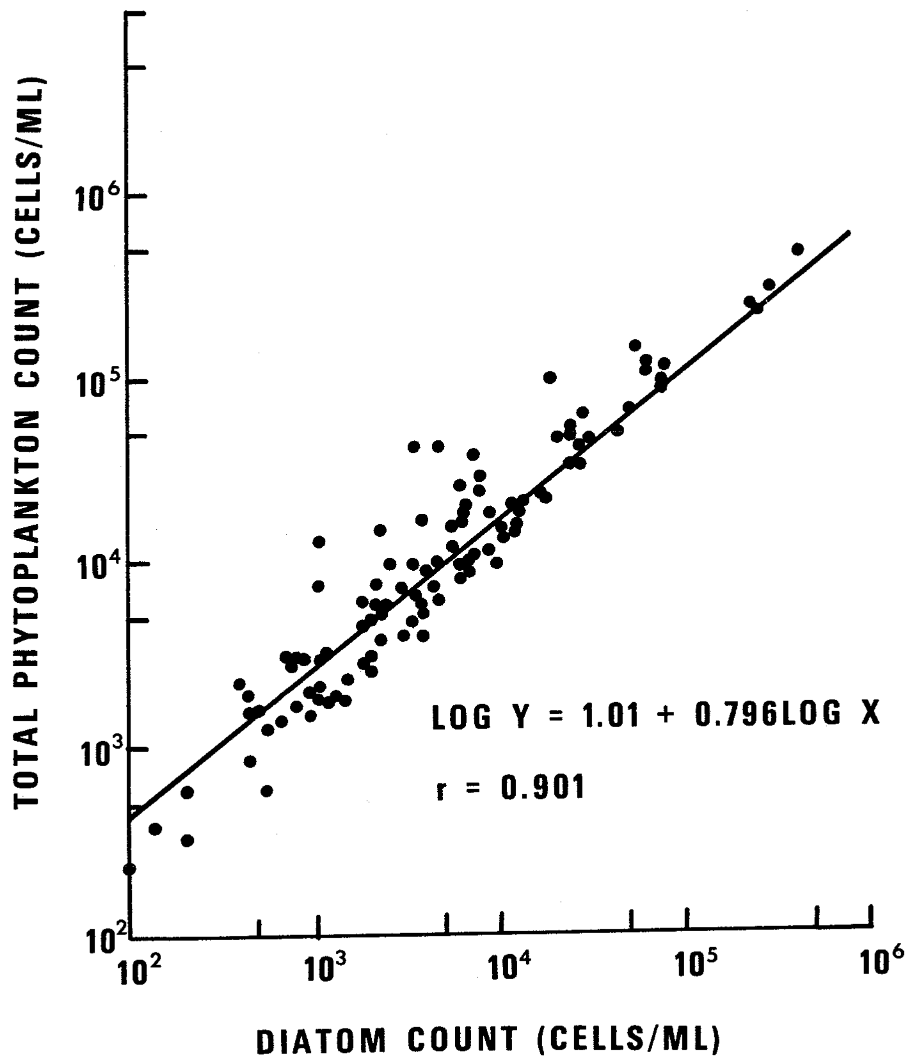

Figure 7. Total phytoplankton versus diatom all counts, Des Moines River, IA., from Beckert, 1982.

One then choses a significance level (or protection level) against finding a significant difference between two means when, in fact, the means are equal. Using this technique, any number of means may be directly compared and it is possible to determine if they are significantly different from one another.

In addition to directly using the data obtained from sample analysis, it may be possible to mathematically calculate concentrations of other parameters. For instance, many sampling programs analyze for total ammonia concentrations. It is the un-ionized form of ammonia (NH_3), however, which is toxic to fish (3). Under natural conditions an equilibrium exists between ionized and un-ionized ammonia:

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

Factors determining the concentrations of un-ionized ammonia include total ammonia concentration, pH, and water temperature (4). The percent of the total ammonia which is present in the un-ionized form may be determined by:

$$\% \, NH_3 = \frac{1}{10^{pk_a - pH} + 1}$$

$$pk_a = 0.09018 + \frac{2729.9}{T\ (°K)}$$

A graphical presentation of this relationship is shown in figure 8. It can be seen that relatively low ammonia concentrations can lead to toxic conditions (>0.02 mg/1) when pH and temperature are high; while little un-ionized ammonia is present when pH values are below 8.

In conclusion, data interpretation is a very complex yet important step in any water quality investigation. It is dependent upon a thorough knowledge of the entire collection-analysis system as well as the use of proper interpretive techniques. Only by carefully considering these topics will a successful study result. Examples of a few factors affecting data interpretation and a few interpretative technqiues have been discussed. The exact methods which should be employed depend on individual cases, just as the conclusions drawn depend, to a large extent, on professional judgment.

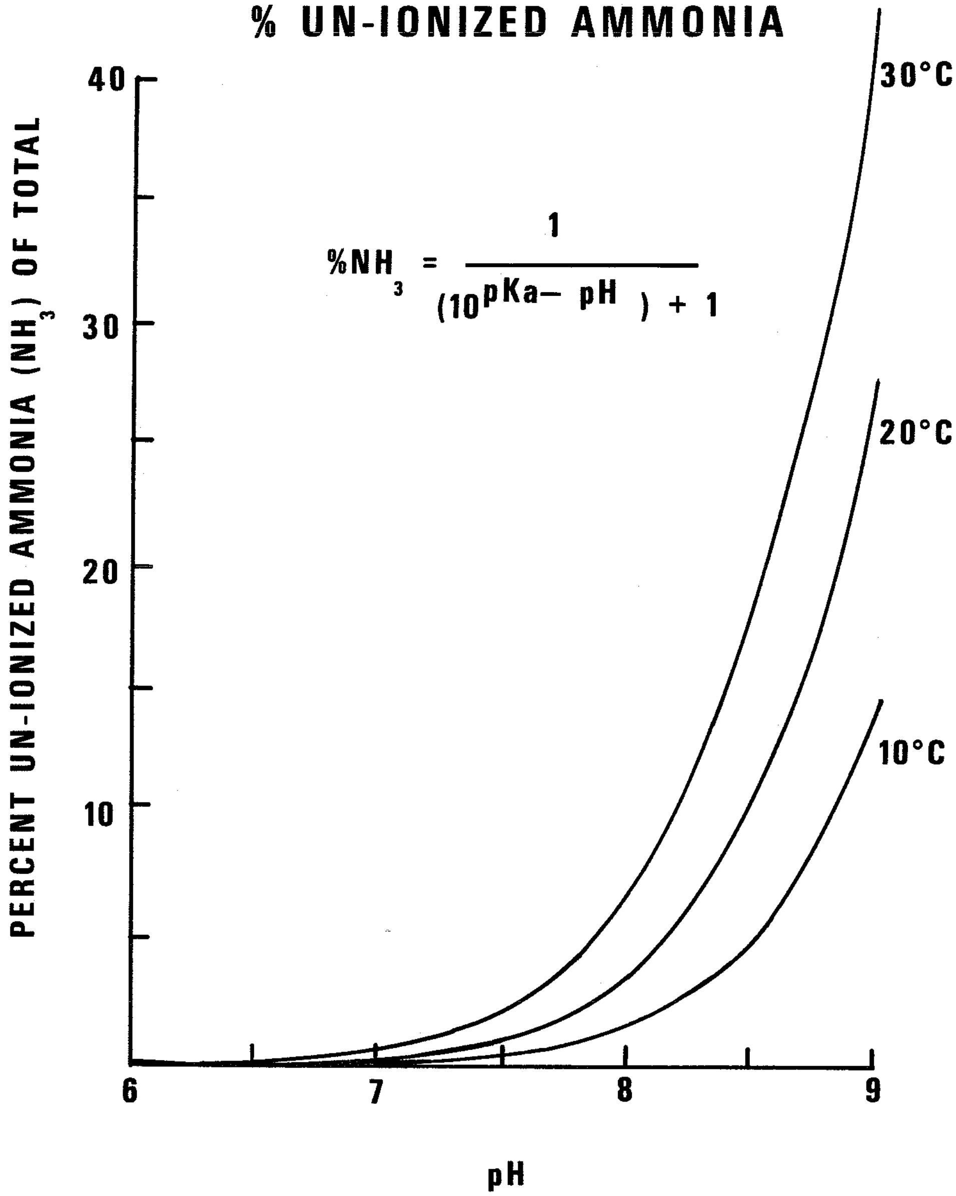

Figure 8. Un-ionized ammonia calculation.

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Sampling Design: A Necessary First Step to Data Collection

by

Gary E. Saul[1]
Robert H. Kennedy[2]

Millions of dollars are spent annually conducting or sponsoring monitoring programs designed to estimate water quality conditions in rivers, lakes, and reservoirs. Associated with these estimates are the problems of uncertainty and nonrepresentativeness which are often overlooked in the final assessment of the data. Uncertainty reduces the informational content of data and results from poor sampling design, sample variability, analytical error, as well as inherent variability. Representativeness is the degree to which sampled portions are "typical" of the entire water body. The gathering of representative samples minimizes or eliminates biases associated with "convenient" sampling (e.g., sampling at bridges).

Since the assessment of water quality conditions of an entire water body must be based on the analysis of a relatively limited number of samples, it is extremely important that a statistically sound sampling design be established. This will insure that meaningful information is obtained. Sampling designs are often inappropriate because of ambiguous objectives, inadequate knowledge about the system, or manpower and funding constraints. One successfully used technique for designing water quality monitoring programs involves the use of preliminary sampling or pilot studies. Pilot studies, while being expensive to conduct, can be effectively used to identify heterogeneities in reservoirs which then can be used to design less expensive, less intensive, statistically-sound long-term monitoring programs. The advantages of using an appropriate sampling design for water quality assessment given by Reckhow (5) are:

1. Sampling becomes more efficient. Samples are only collected if they reduce uncertainty; thus, characteristics should not be sampled if uncertainty in their estimates cannot be reduced further within given budget constraints.

2. Sampling design stimulates thinking about the issue of concern, and leads to a better definition of informational needs.

3. Sampling design leads to an explicit quantification of the uncertainty in the estimates of the characteristics sampled.

Although sampling design and the problems of uncertainty and representativeness have recently received attention (3,4,6,7,8,11), water quality sampling design for reservoirs has not been adequately addressed. This is due, in part, to the tacit assumption that lakes and reservoirs are similar. However, reservoirs are advectively dominated systems which exhibit longitudinal, as well as lateral and vertical gradients (1,2,9). Recent work in

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the Environmental and Water Quality Operational Studies (EWQOS) has emphasized the design of effective water quality sampling programs for reservoirs with pronounced longitudinal gradients (10). Ongoing studies at four CE impoundments will be used to assess sampling designs and establish basic criteria for cost-effective sampling designs for district needs. While the establishment of statistically sound sampling designs requires additional time and expense, the informational value of the data collected can be significantly increased, and in many cases the total cost of long-term monitoring programs can be reduced.

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LABORATORY ANALYSES

By

Ann B. Strong [1]

INTRODUCTION

With the severe restrictions being placed on the Civil Works budget and manpower, it is becoming increasingly important that we obtain the most cost-effective laboratory services available, whether from the Division laboratories or from contractors. This means that laboratory analyses must be considered in the initial planning stages of a water quality project rather than as an after thought. If the work is to be done by a Division laboratory, communication, coordination, and response to problems is much easier to accomplish than with a contractor laboratory where the scope of work may not allow for variances. In either case a clear understanding of the data desired and the limitations of the procedures must be succintly defined in order for the project to operate smoothly. This is a fairly simple task with routine water quality monitoring programs, but research and development projects are not always so clear cut. Several ER's and ETL's have been issued providing policy for Corps laboratory analyses. ER-1110-8100 dated 30 August 1974 set up the general guidelines under which the division laboratories operate designating that they provide water quality investigation analysis services. On 28 September 1979, laboratory responsibilities were further clarified in ER-1110-1-261 which assigned technical supervision of laboratories performing testing for the Districts to the Division laboratories and included an inspection program for district, project, and contractor owned and operated laboratories including subcontractors. ETL-1110-2-244 dated 14 May 1979 provided general guidance for laboratory quality control for water and wastewater and ETL-1110-2-252 specified quality control procedures to be employed by Corps field offices engaged in field sampling of surface waters and sediments for the evaluation of their physical and chemical characteristics. More recently, ETL-1110-2-268 dated 31 December 1981, entitled Water and Wastewater Laboratory Inspections was issued as part of the Corps quality assurance program to obtain more responsive and reliable data.

The WES serves as LMVD's Division laboratory and in this role has made numerous laboratory inspections. We have seen a definite improvement in the quality of contractor laboratory data since the inception of the inspection program. Based on the findings of one of these inspections, the New Orleans District recently terminated a contract with a laboratory

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that was unable to perform at an acceptable level of competence. WES supplied standard reference samples to the contractor laboratory and twenty of twenty-five parameters fell outside acceptable limits. Other inspections have revealed the lack of proper equipment, instrumentation, procedures, and quality control. The ETL on laboratory inspections recommends that inspections be made prior to issuing a contract to eliminate "after-the-fact" actions.

LABORATORY SELECTION

There are several considerations that should be made in preparing a scope of work or contract for chemical analyses. These include: (1) selection of analytical techniques, (2) reporting specifications, (3) cost, (4) quality control, and (5) laboratory or contractor selection.

Analytical Techniques

The selection of analytical techniques for routine water quality programs should be based on the following criteria:

(1) The method is capable of providing the desired precision and accuracy.

(2) The method uses equipment and skills available to most environmental laboratories.

(3) The method has established validity (Standard Methods[1], EPA approved[2], or USGS[3], etc.).

(4) The method is sufficiently rapid.

Reporting Specifications

Reporting specifications should be clearly stated to include:

(1) Time frame.

(2) Concentrations units.

(3) Detection limits.

(4) Methodologies used.

(5) Special analysis problems.

(6) Supporting quality control data.

Cost

Cost factors, while very important, should not be the controlling factor in laboratory selection. A survey made several years ago yielded the range of costs shown in Table 1.

Quality Control

Quality control is a very important consideration. We feel the miminum requirements of a quality assurance, quality control program should address the following:

(1) Skilled personnel.

(2) Written and validated methods.

(3) Proper laboratory facilities.

(4) Provision of representative samples and controls.

(5) Use of quality glassware, reagents, etc.

(6) Calibration, adjustment, and maintenance of equipment.

(7) Use of control samples and standard reference material.

(8) Observation of criticial analyses.

(9) Review of critique of results.

(10) Tests of internal and external proficiency.

(11) Use of replicate and spiked samples.

(12) Interlaboratory comparison.

(13) Response to user complaints.

(14) Monitoring of results.

(15) Procedures for corrections.

The laboratory should be responsive to all of these factors aimed at providing the accuracy and precision necessary for producing representative and reliable data.

Contractor Selection

The areas of expertise required for meeting project goals should be compared to current and past performance by the laboratory under consideration.

Technical competence and experience using the procedures and instrumentation specified should be carefully weighed.

ANALYTICAL RESULTS

Positive identification and quantification of elements and compounds is not always as simple or as clearly defined as procedures indicate. Complex matrices encountered in water samples with high solids content, sediment samples, and biological materials often mask instrument responses or give false positive readings. Many of these problems have been resolved and documented - particularly the analyses of metals. The major difficulties arise from identifying multicomponent mixtures of organic compounds where standards may not be readily available especially if isomerization of the parent compound has taken place due to aging, organic degradation or some other cause. Overlapping peaks frequently occur in gas chromatograph/mass spectrometry spectra even when high resolution capillary columns are used. Subsequently the project manager should be aware of such problems and the limitations of analyses.

CONCLUSIONS

Laboratory analyses for water quality parameters may provide data for meeting analytical requirements specified in some of the Federal Regulations such as the Clean Water Act, the Safe Drinking Water Act, or the Resource Conservation and Recovery Act; or the data may be used to support some particular research activity. Regardless of the purpose, the data obtained should be a quality product responsive to the Corps needs and goals.

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Table 1

Analytical Costs by Parameter*

Parameter	Average Cost**	Range of Cost**
Alkyl Benzene Sulfonates	$15.00	-
Acidity (total)	4.48	$ 2.50 - 9.00
Aluminum	10.96	4.00 - 20.00
Ammonia	11.81	3.00 - 30.25
Antimony	12.89	5.00 - 35.00
Arsenic	16.29	6.00 - 35.00
Bacteria	13.97	2.50 - 45.00
Barium	10.42	4.00 - 20.00
Beryllium	11.25	4.00 - 20.00
Bicarbonate	7.50	3.00 - 15.00
Bioassay	Generally Quoted Upon Request	-
Biological Oxygen Demand	27.19	10.00 - 115.00
Boron	17.31	7.00 - 35.00
Bromide	12.17	5.00 - 20.00
Cadmium	9.35	2.50 - 16.50
Calcium	7.56	2.00 - 20.00
Carbon	15.71	5.00 - 35.00
Carbonates	7.50	3.00 - 15.00
Carbon Chloroform Extract	62.50	35.00 - 90.00
Carbon Dioxide	9.50	5.00 - 22.00
Chemical Oxygen Demand	14.38	7.50 - 33.00
Chloride	5.79	3.00 - 20.00
Chlorinated Hydrocarbons	42.50	20.00 - 70.00
Chlorine	21.05	1.50 - 100.00
Chlorophyll	11.00	3.00 - 25.00
Chromate	8.75	3.00 - 16.50
Chromium	9.05	4.00 - 20.00

(Continued)

*Personal communication, 1977, J. Westhoff, research chemist, WES.
**1977 prices.

Table 1 (Continued)

Parameter	Average Cost	Range of Cost
Cobalt	$ 9.30	$ 4.00 - 9.30
Color	7.30	1.50 - 25.00
Copper	7.88	2.50 - 20.00
Cyanide	19.93	5.00 - 40.00
Detergents	12.50	7.50 - 20.00
Dissolved Oxygen	4.60	2.50 - 8.00
Fluorides	12.00	3.50 - 25.00
Hardness	4.85	1.50 - 10.00
Hydrogen Sulfide	10.00	5.00 - 15.00
Hydroxides	7.00	3.00 - 15.00
Iodine	12.00	10.00 - 15.00
Iron	8.24	2.50 - 20.00
Lead	10.47	2.50 - 20.00
Magnesium	8.56	4.00 - 20.00
Manganese	9.20	2.50 - 20.00
Mercury	17.50	11.00 - 35.00
Methane	15.00	11.00 - 35.00
Molybdenum	10.88	4.00 - 20.00
Nickel	9.40	2.50 - 20.00
Nitrate	8.17	3.00 - 16.50
Nitrite	7.50	5.00 - 12.00
Total Kjeldahl	18.05	6.00 - 30.25
Odor	13.67	1.00 - 30.00
Oil and Grease	27.75	7.00 - 150.00
PCB's	33.33	25.00 - 40.00
Pesticides	49.00	20.00 - 75.00
pH	3.05	1.50 - 5.00
Phenols	21.11	5.00 - 36.50
Total Phosphorus	9.00	6.00 - 12.50
Orthophosphorus	5.57	2.00 - 10.00
Potassium	8.77	2.00 - 20.00

(Continued)

Table 1 (Concluded)

Parameter	Average Cost	Range of Cost
Selenium	$20.72	$ 5.00 - 55.00
Silica	10.03	4.00 - 20.00
Silver	10.70	4.00 - 20.00
Sludge Volume Index	12.00	10.00 - 14.00
Sodium	8.95	2.00 - 20.00
Total Solids	7.00	4.50 - 11.00
Volatile Solids	6.63	1.50 - 16.50
Dissolved Solids	7.23	4.50 - 14.00
Suspended Solids	7.00	2.00 - 13.50
Settleable Solids	5.85	2.00 - 12.00
Specific Conductance	3.95	1.50 - 5.00
Specific Gravity	8.13	1.50 - 20.00
Strontium	20.79	4.00 - 75.00
Sulfate	8.75	4.00 - 18.00
Sulfide	11.23	5.00 - 25.00
Sulfite	7.89	3.00 - 12.50
Surfactants	18.04	10.00 - 28.00
Tannin and Lignin	14.86	7.50 - 25.00
Taste	50.00	20.00 - 100.00
Thallium	12.20	4.00 - 20.00
Thiocyanate	12.50	10.00 - 15.00
Tin	11.15	2.50 - 20.00
Turbidity	3.89	1.50 - 6.00
Vanadium	11.11	4.00 - 30.00
Volatile Acids	20.00	-
Zirconium	21.67	10.00 - 35.00
Zinc	9.63	2.50 - 20.00

APPLICATION OF DATABASE MANAGEMENT TECHNIQUES TO RESERVOIR WATER QUALITY STUDIES

by

Gary E. Saul[1]

ABSTRACT

The magnitude and diversity of data collected during water quality sampling programs often preclude the use of manual methods of storage and analysis. Therefore, a critical phase in the planning and operation of such programs is the establishment of a comprehensive database management system, the objective of which is to establish a protocol that encompasses data acquisition, maintenance, and utilization while providing data consistency, validation, storage, and analysis. The Statistical Analysis System was selected as the operational component of a database management system applied to a reservoir research program because of its data management capabilities, numerous statistical procedures, and ease of use. This paper describes the general theory of database management systems, the Statistical Analysis System, and an application to a reservoir water quality sampling program.

INTRODUCTION

The U. S. Army Corps of Engineers (CE) is conducting the Environmental and Water Quality Operational Studies (EWQOS), the objectives of which are to improve our understanding of relations between the design/operation of civil works projects and water quality and to identify possible ameliorative actions. A major portion of this program, the Reservoir Field Studies (RFS), involves the collection of limnological information at four representative CE reservoirs. These data, collected during short-duration, intensive studies as well as during routine monitoring efforts describe numerous hydrological, morphological, meteorological, and water quality attributes of each lake. The objectives of these studies and, therefore, the analyses vary considerably as do the ultimate uses of the data. Thus, a critical phase in the planning of the RFS was the establishment of a comprehensive Database Management System (DBMS).

DATABASE MANAGEMENT SYSTEMS

A database is a collection of interrelated data to be stored and used for multiple applications (5). Database management systems are a combination of persons, methods, and materials used to process data from a data base into usable information for decisionmaking (2). A DBMS has the advantages of reducing data redundancy, increasing data sharing capacity, maintaining data integrity, providing better data management, and reducing time to satisfy new requirements (1, 3).

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The design of any database should begin with conceptualization. The conceptual database is an abstraction of the physical database and should have the following attributes: availability, synchronization, integrity, hardware and software, protection and recovery, and security. The designers of the database should consider whether or not the data will be available to all interested parties. A consideration linked closely to availability of the data is the possibility of synchronous use of the information by more than one party. Integrity of data residing in a database is paramount. The best DBMS design and all analyses are worthless if the data are not valid. Hardware and software, being machine dependent, many times dictate the type and ease of use of an overall database management system. All databases should ensure that the data are protected in case of power or machine failure, and can be recovered without undue loss of personnel time. This may be easily accomplished with periodic tape backups of the database. Security of the data is also extremely important. Once the data integrity has been established, the data should not be changed without the database managers knowledge. If users of the data are permitted "read only" capability, then the possibility of inadvertent alteration of the data can be eliminated.

An effective DBMS encompasses all aspects of data acquisition, data maintenance, and data utilization (Figure 1) (6). Data acquisition is comprised of the network design, sample collection and laboratory analysis. The design of a monitoring network involves the planning of the sampling strategy for field efforts and includes determination of sampling period and frequency, number and location of sampling sites, and variables to be measured. Sample collection involves taking field measurements, assuring proper methods of sample collection and preservation are used, and appropriate field measurement documentation is accomplished. The laboratory analysis of water samples consists of analytical techniques, operational procedures, quality control and data recording.

Data maintenance is the handling of all data after collection and before analysis. Data handling includes coding, keypunching, data file establishment, and verification.

The third phase of the overall system design, data utilization, is comprised of data analysis and the utilization of generated information. Data analysis includes the statistical techniques and manipulative procedures used to reduce large amounts of data into discrete packages of meaningful information. Information utilization is the synthesis of analyzed data resulting in information transfer.

STATISTICAL ANALYSIS SYSTEM

The Statistical Analysis System (4) software permits an open-ended approach to research data base management and includes statistical analysis procedures and report writing capabilities. SAS may be run in batch or interactive modes on IBM 360/370 and compatible machines under OS, OS/VS, and VM/CMS operating systems. The general characteristics of SAS are listed in Table 1.

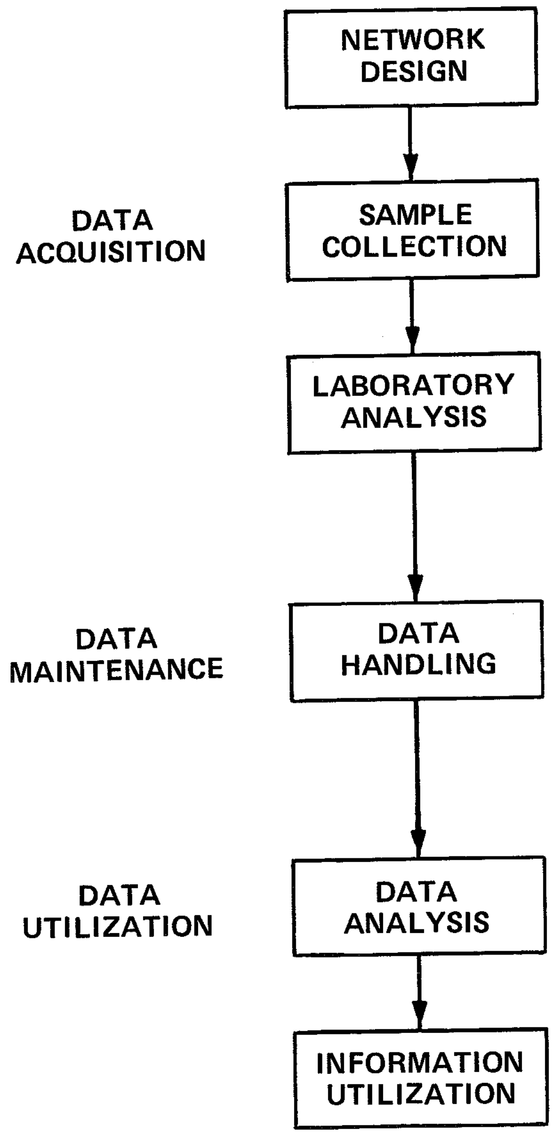

Figure 1. A conceptual data base management system design.

Table 1. Characteristics of the Statistical Analysis System (SAS).

1. Batch or interactive modes.
2. End-user friendly.
3. Sequential files.
4. Program interface with Fortran, PL/1, Assembler.
5. Static or dynamic data.
6. Numeric or character data.
7. Statistical analysis capabilities.
8. Complex mathematical capabilities.
9. Report generation.
10. Graphic capabilities.
11. Good documentation.
12. Technical support available.
13. Continuing system enhancements.

The capabilities of SAS can be broadly divided into database management utilities and data analysis techniques. Flexible input, data description and manipulation, file manipulation, and internal programming and program language interfacing are among the many data management utilities available in SAS. Data may be entered by list input, column input, or formatted input with multiple observations per line or one observation per several lines and may reside on various devices (i.e., cards, magnetic tape, disk). SAS retains 17 significant digits for numeric variables which can be outputed in standard, exponential, hexadecimal, or packed decimal format. Alphanumeric variables may have a maximum of 200 characters which can be outputed in standard, characters with blanks, character hexadecimal, or variable length format.

SAS handles data description by documenting the variable name, whether the variable is numeric or character, number of bytes in stored field width, input and output formats and a 40 character descriptor. In addition, up to 1000 generations of data manipulation steps and appropriate comments can be saved along with the data for documentation purposes. SAS allows data to be manipulated by modifying variables, creating new variables or observations, deleting variables or observations, and data transformations.

The file management capabilities of SAS are similar to many data base models (i.e., relational, heirachial, network) and are an integral part in database management. SAS allows subsetting, concatenating, match merging, interleaving, sorting, and updating of files. Thus, the complete file system can be manipulated to allow the use of only the data desired. In conjunction with the file manipulation capabilities, internal programming may be used to enhance the file restructuring process. External program language interfacing with Fortran, PL/1, and Assembler languages are also permitted in SAS.

The SAS has over 75 statistical procedures available for data analysis. The procedures cover a broad range of standard and sophisticated analyses in the areas of descriptive statistics, analysis of designed experiments, regression, multivariate statistics, and econometric and time series analyses. SAS also provides the option of writing your own procedures in matrix algebra and interfacing with the Biomedical Data Processing System (BMDP).

Once the data have been analyzed, the results can be presented either graphically or in a report form. The user-oriented graphics procedures provide methods for presenting statistical results, such as histograms, pie charts, scatter plots, and regression lines and diagnostics. In addition to standard graphics, color and three-dimensional graphic techniques are also available. Further, customized report output, such as tables for data presentation are possible using SAS.

RESERVOIR FIELD STUDIES APPLICATION

The RFS system uses available computer facilities (IBM 4331) and SAS to provide a meaningful framework for the aquisition, maintenance, and utilization of RFS data. SAS has met the needs of the RFS by providing a flexible and end-user friendly statistical package in the DBMS. The DBMS developed by the RFS is divided into Data Acquisition, Data Maintenance, and Data Utilization (Figure 2). Communication between these phases is necessary to ensure steady flow through the system and proper design and upkeep of the DBMS.

The initial phase of the RFS DBMS is data acquisition. Scientists, statisticians, and technicians are responsible for ensuring that the data collected are reliable, valid, and will meet study objectives. To maintain research standards the RFS personnel establish guidelines for the three areas of data acquisition: experimental design, field collection, and laboratory analysis. Guidance in experimental design is provided in the establishment of station locations, variables to be measured, and sampling frequency. Field collection is provided guidance in sampling technique, sample preservation, and sample transportation. Laboratory analysis guidelines establish methods of analysis, analytical techniques, and quality control. Field and laboratory elements are provided data code forms which are customized for field and laboratory analyses and provide a direct link between the recording of data, in the field or laboratory, and the keypunching of data for computer storage. This link avoids the use of field and laboratory notebooks, and the resulting possible transcription errors.

The main function of data maintenance is the overall coordination of collected data, and includes receiving raw data, keypunching, editing, filing, documentation, and storage. When field sampling and laboratory analyses have been completed, the code forms are reviewed for completeness. Photocopies of the code forms are then sent to be keypunched and temporary raw data files are established. The original forms are filed by reservoir, study type, and data type for future reference. The flexibility of SAS input statements allows for ease of transferral from raw data files to SAS data files.

The editing of SAS data files, including data manipulation and file management is the next step in data maintenance. SAS's simple language, program control statements, and program interfacing have alleviated the need

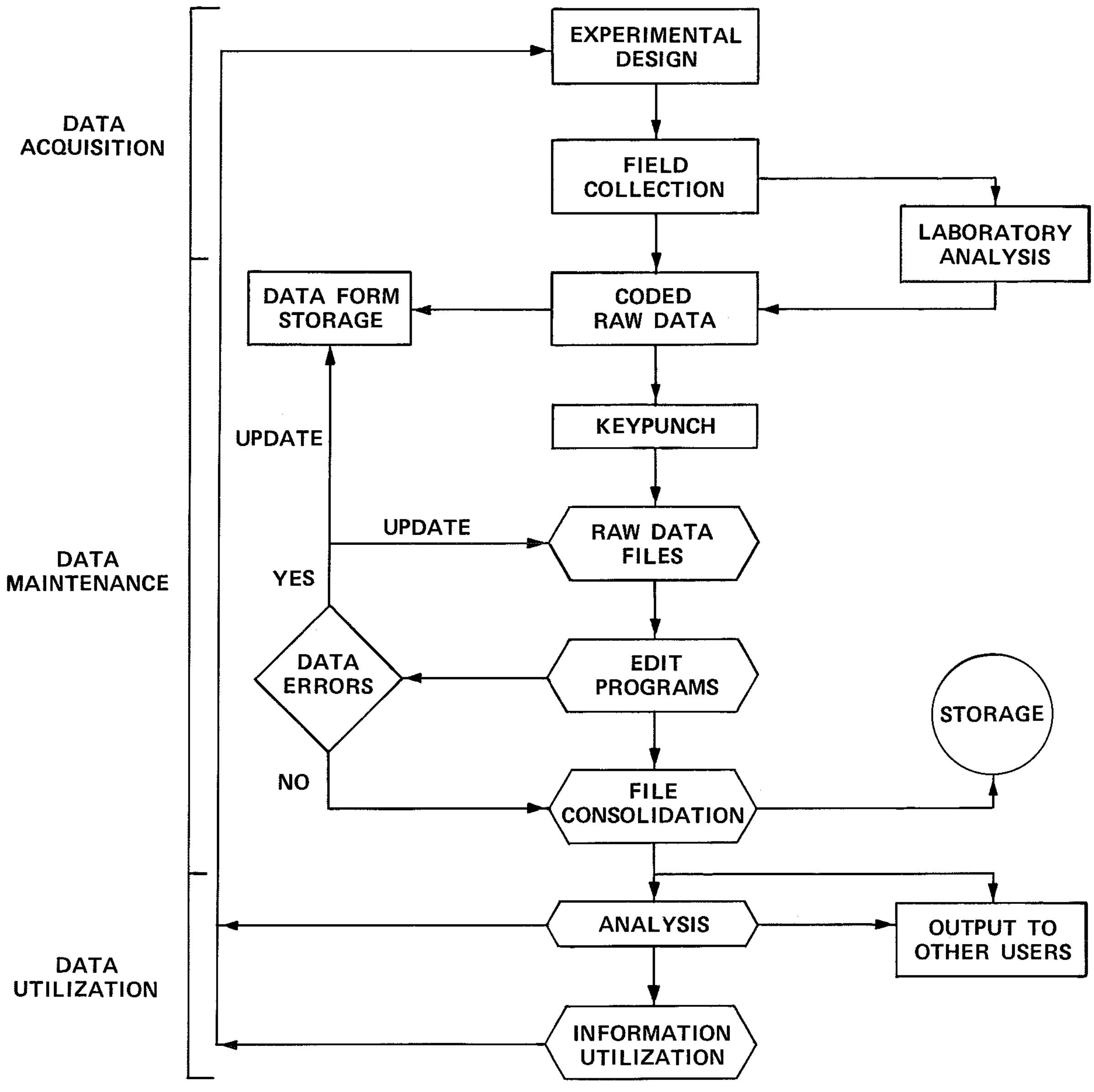

Figure 2. The Reservoir Field Studies database management system.

for complicated programming. Editing programs written in SAS examine all input data for a variable's presence/absence, proper numeric or character value structure, and satisfaction of various conditional statements. While many errors can be detected in this 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 are sent to the person responsible for the collection of the data for verification. Verified printouts are then returned for file updating. Changes made in computer files are also made on original code forms to ensure consistency of all data records. Data verification is an iterative process and the data may be checked several times before final acceptance. Once the data have been verified, the SAS files are consolidated to produce files of logically grouped study areas and variables (Table 2).

The final step in data maintenance is the storage of all data files from the RFS program. Data that are utilized regularly are maintained online on one central disk. The disk consists of 5 mini-disks, one for each of the four reservoirs and one for miscellaneous reservoir data files. The central disk ensures the availability of RFS data to all users. The users simply link to the appropriate mini-disk from their own userid. Security of RFS data files is maintained by providing a read only option to all linked users. Protection of RFS data files is provided by a tape backup on the system.

Data utilization including output to other users, statistical analysis, graphic display, and information utilization is the final phase of the RFS' DBMS. SAS's statistical procedures, graphics, and report writing capabilities have provided the RFS with a means for processing large amounts of data into meaningful information. The RFS uses SAS's report writing capabilities for displaying the data in various formats, as requested by other users or as necessitated by the RFS's own needs. The RFS has also used many of the SAS statistical procedures in the analysis of study results and for feedback into the experimental design of existing and proposed field studies. SAS graphics have provided the means for exploratory data analysis and for presentation of research results.

CONCLUSIONS

The objective of the RFS DBMS was to provide a system which encompassed the theoretical attributes of DBMSs while providing direct methods for reducing and analyzing data for RFS purposes. The DBMS structure was designed to accommodate SAS, and the overall retrieval and utilization processes were greatly simplified by the use of a common language throughout.

Table 2. Consolidated Data File for Each RFS Study Site

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-met stations

V LIMNOLOGY

- Water quality
  - in situ
  - chemical
  - physical
  - biological

VI SEDIMENT QUALITY

- Chemical
- Physical

VII SPECIAL STUDIES

- Storm Events
- Transect Surveys
- Inflow Events
- Etc.

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Water Quality Data Interpretation - Laboratory Response

by

Robert H. Kennedy [1]

Reservoirs, like all lakes, are complex ecological systems or ecosystems. Composed of numerous highly interactive biotic and abiotic components, they possess structural and functional attributes which are often apparent to the observer as pattern. These patterns, which occur in space and/or time, can, when adequately described, provide the observer with a means by which system attributes or characteristics may be partially inferred. These insights are, in turn, useful in identifying possible causal relationships and their potential role in determining water quality conditions. While detailed assessments of processes and events must await intensive study, definition of pattern provides a framework for increased understanding.

Lakes which stratify thermally (and chemically) often exhibit characteristic vertical gradients, the importance of which has historically been the focus of many limnological studies. However, many lakes and reservoirs also exhibit marked horizontal gradients which are often overlooked. Formed by the impoundment of rivers and confined to old river valleys, reservoirs are commonly long, narrow, dendritic lakes which receive a majority of their water and material loads from a single tributary source located distant from the point of outflow. While tributary nutrient and suspended sediment concentrations are often high, sediment transport and deposition play important roles in determining the ultimate impact of such loads on the reservoir. The result is the establishment of dynamic spatial or longitudinal patterns which are persistant through time. While, for ease of understanding, the occurrance of such patterns may allow reservoirs to be conceptually divided into a well-mixed, riverine zone, a zone of transition, and a lake-like or lacustrine zone, gradients occur along spatial and temporal continua and are influenced by complex processes such as inflow mixing, internal mixing, withdrawal, and sedimentation.

Gradients in upstream reaches of a reservoir are strongly influenced by hydrology, inflow quality, and lake morphology, and are often the most pronounced. Nutrient- and sediment-laden inflows, while initially well-mixed, plunge below surface waters at a location dictated by density differences and inflow velocity. Below this point, surface waters are less turbid and often highly productive. Plunging inflows continue downstream as interflows or underflows where reduced light availability and high organic carbon concentrations lead to reduced oxygen levels and concomitant chemical changes (eg. reduction of nitrate to ammonium). The result is a highly complex pattern in water quality, changes in which are strongly coupled with inflow mixing events and short-term variations in hydrology.

Internal mixing processes and inputs from secondary tributaries located along the lake's axis further complicate pattern. Mixing, which results in both horizontal and vertical transport of water and material, occurs in response to disturbances generated by wind and tributary inflows. When stratified lakes are exposed to mild disturbances, mixing is often restricted to the epilimnion.

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However, more severe disturbances result in internal motion (e.g. seiches) and thermocline erosion, events which can cause the upward transport of material from hypolimnion to epilimnion. Such occurrances are of greatest importance when marked chemical differences exist across the thermocline. Entrance mixing associated with secondary tributaries provides a mechanism for localized mixing and may influence pattern in isolated portions of the lake (e.g. coves and embayments).

Unlike natural lakes, reservoir discharges are normally controlled and occur at depths well below the surface. In addition, design-related requirements for holding and withdrawing water often mean that inflow and outflow events are temporally separated. In the case of many hydropower projects, major withdrawal events are compressed into one or more "pulsed" discharges. These events result in mixing and often have dramatic impacts on water quality patterns in the lower reaches of reservoirs.

An understanding of mechanisms responsible for the establishment of pattern is an important start toward understanding reservoir dynamics and provides a useful framework for interpreting water quality data. Recurring patterns in time (e.g. seasonal, annual, etc.) or space (e.g. longitudinal gradients) indicate a degree of predictability and are thus of importance in formulating or evaluating management decisions. In turn, sample design for continuing or planned studies should allow characterization of pattern as it relates to study objectives. Lake-wide and/or localized pattern also provides a guidepost for formulating special studies aimed at defining processes or investigating specific problems.

RIVER AND RESERVOIR SYSTEMS
WATER QUALITY MODELING CAPABILITY1/

R. G. WILLEY2/

INTRODUCTION

Background

During the late 1960's and early 1970's, water quality mathematical modeling consisted of reservoir temperature and stream temperature, dissolved oxygen and biochemical oxygen demand analysis. The U.S. Army Corps of Engineers was extremely active in the area of reservoir temperature analysis during this period.

Several reservoir temperature models were developed either by or for the Corps [1, 2, 3 and 4]. These same models are not only still available today, but also are widely used for water temperature studies within the Corps and by consulting engineering firms worldwide.

Changing Objectives

By the mid-1970's, the Corps became involved in Urban Studies (formerly called Wastewater Management Studies). A need was apparent for a water quality model capable of analyzing more water quality parameters both within the reservoir and in the stream system. The stream analysis requirements suggested a need for nonsteady, nonuniform hydraulics.

These needs were met by contracting with a consulting firm to develop a comprehensive package of computer programs called "Water Quality for River-Reservoir Systems," (WQRRS) [5]. The evolution of the WQRRS package of programs is discussed elsewhere by the author [6].

In general, the WQRRS programs perform one dimensional analysis of rivers or reservoirs for a variety of water quality parameters. The hydraulics and hydrodynamics of the system are first calculated and then the water quality parameters are modeled. The water quality parameters are interrelated to approximately model an aquatic ecological system.

A less complex river water quality model has also been developed for studying long periods (i.e., many years) of water quality conditions. This model, called "Receiving Water Quality" (RWQM) [7] has been used very little and must be considered as relatively untested.

1/ Presented at the U.S. Army Corps of Engineers, Committee on Water Quality Seminar, "Attaining Water Quality Goals through Water Management Procedures," Dallas, Texas, February 1982.

2/ Hydraulic Engineer, U.S. Army Corps of Engineers, The Hydrologic Engineering Center, Davis, California.

By the late 1970's, the Corps interest in modeling hydropower and real-time operations problems influenced the expanded development of an existing computer model which was capable of simulating reservoir system operations for flood control [8]. The expanded version was called "Simulation of Flood Control and Conservation Systems - HEC-5" [9].

In general, the HEC-5 program is capable of simulating multipurpose reservoir systems having up to 35 impoundments. A system operation method is used which maintains a balance of storage in the various impoundments. The balance is achieved by user input specification of reservoir storage levels.

In 1979, contracting was initiated to develop and interface water quality routines with the HEC-5 program. The program version which includes water quality is called HEC-5Q [10]. It was decided to have the capability to analyze up to eight water quality parameters at ten reservoirs and thirty control points. The water quality routines begin the analysis with a "best" set of simulated flows from HEC-5 for the reservoir system. Determination is then made of the best level of outlets to use at each reservoir to take advantage of water quality stratification in the reservoir, if a multilevel outlet structure exists for providing water quality control. If this set of flows can't meet the user-specified target water quality conditions at each control point, a modified pattern of impoundment releases is determined. This calculation uses a nonlinear optimization which will release desired flows but also meet (if practical) the desired water quality conditions.

RESERVOIR TEMPERATURE ANALYSIS

The state-of-the-art in reservoir temperature models has changed very little since the mid-1970's. The models previously referenced are all readily available within the Corps. These models have varying degrees of documentation available and user support.

The "Thermal Simulation of Lakes" program (THERM) [4] is probably the most popular, and has good documentation and user-assistance availability. This program can satisfactorily be used for most design-oriented engineering studies without program modification. THERM evaluates the thermal vertical stratification of the impoundment including the effects of the inflow and discharge as shown in Figure 1. The heat exchange at the surface layer due to atmospheric conditions is evaluated and a resultant water temperature profile is determined. The THERM program is readily available for distribution with documentation or is available at the Corps' Boeing Computer System (BCS) library which is accessible by virtually all Corps offices. This program has been successfully applied to numerous projects for many years.

RIVER-RESERVOIR ECOLOGICAL ANALYSIS

The development of the WQRRS package [5] has evolved over a ten year period into a set of complex, comprehensive water quality models. The WQRRS users manual documents three separate but integrable computer programs as shown in Figure 2: reservoir water quality, stream hydraulics and stream water quality.

The stream hydraulics program has two steady flow computation methods and four hydrologic and hydraulic routing techniques for the users selection.

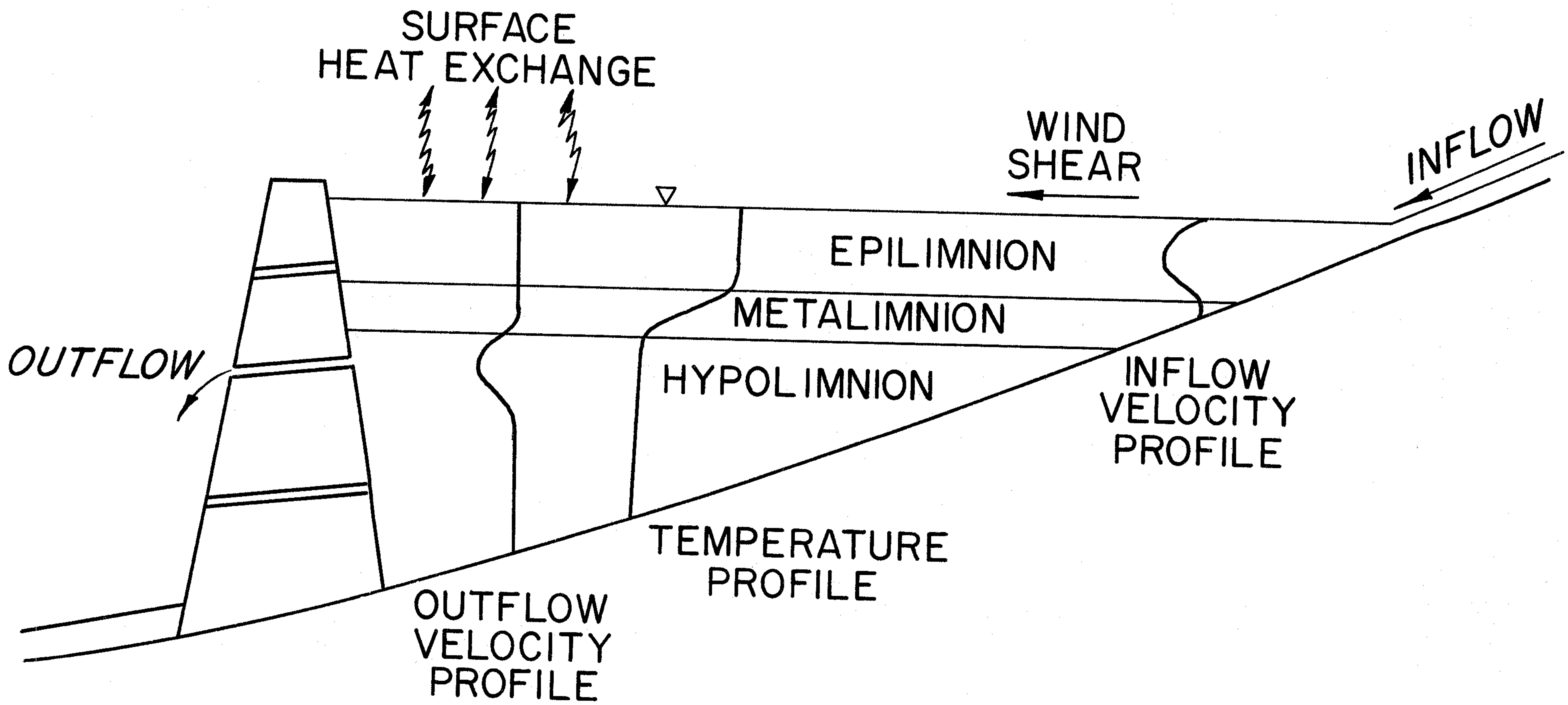

Figure 1

STRATIFIED RESERVOIR

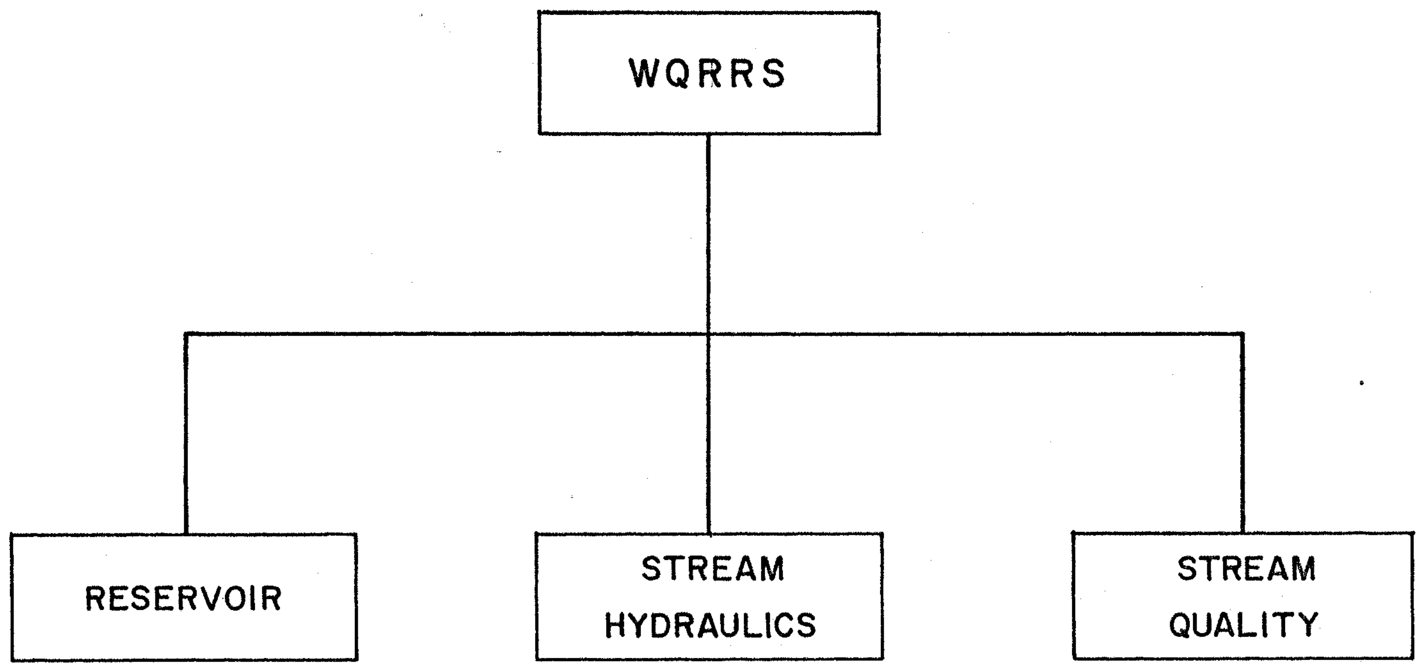

Figure 2 WATER QUALITY FOR RIVER-RESERVOIR SYSTEMS MODEL

The water quality programs are one dimensional aquatic ecologic type models. The user selects the model structure for any of the more than 23 water quality parameters depending on the choice of river or reservoir programs. River and reservoir systems like those shown in Figure 3 can be easily evaluated with WQRRS. The reservoir model evaluates isoquality horizontal layers and the river model uses isoquality longitudinal elements as shown in Figures 4 and 5 respectively.

The model structure can be anything from a water temperature only calculation to a chemical-biological model. The biologic analysis is an engineering approximation approach to allow satisfactory interface with the comprehensive chemical interactions in the model.

Additional programs [11] for summarizing the stream water quality program outputs include a statistics program and a graphics program for time series analysis and a second graphics program for stream profile plots as shown in Figures 7 and 8 respectively. The time series statistics program shows minimum and maximum simulated results, errors of reproducing observed data and percent of time the simulated data exceeded the minimum and maximum stream standards.

These programs are readily available for individual distribution with documentation or are available at the Corps' BCS library. These programs have been successfully applied on several projects.

RESERVOIR SYSTEM WATER QUALITY ANALYSIS

The development of the HEC-5Q program has evolved over a three year period with an ultimate objective of evaluating up to ten reservoirs, 30 control points and eight water quality parameters. The eight parameters include water temperature, three conservative and three nonconservative (two of which can be oxygen demanding constituents) parameters, and dissolved oxygen. The model is capable of simulating a comprehensive multipurpose reservoir system for evaluation of a "best operation" for each individual reservoir discharge to meet desired water quantity and quality target objectives at user specified control points throughout the drainage basin [12].

The currently available model will perform as described above for two reservoirs only. The complete capability discussed above will be available in 1983. The HEC-5Q model is presently a research tool undergoing extensive testing and the user should carefully evaluate the model output.

APPLICATIONS

The Hydrologic Engineering Center and others have used the models described above on numerous applications. These models have been used for river and/or reservoir water quality analysis at the various locations and types of jobs described in Table 1.

SUMMARY

All of the models described above are available from the HEC. These models are maintained at state-of-the-art status. Users should be in contact with HEC at the initiation of any new project and routinely during the

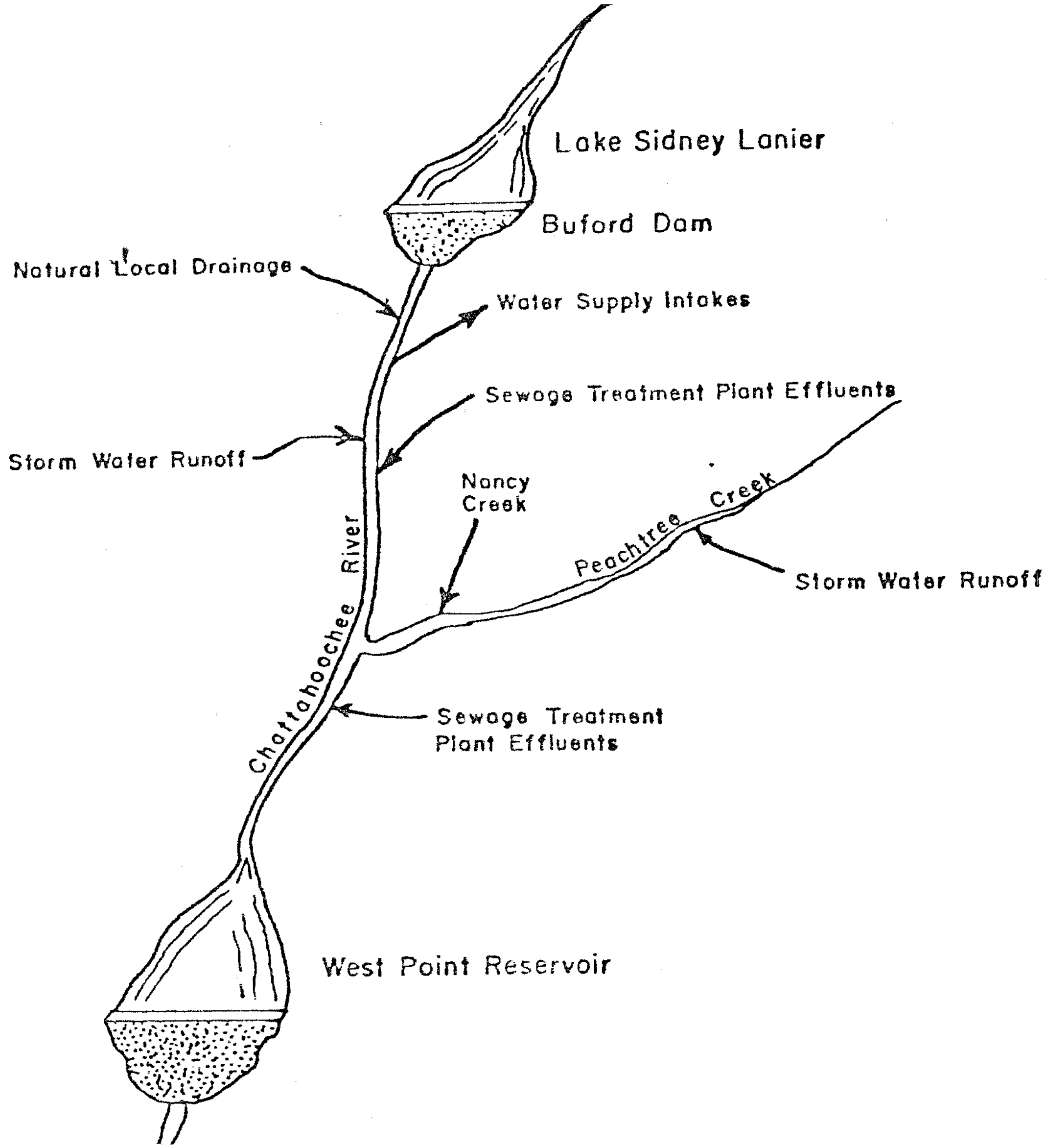

Figure 3
TYPICAL RIVER-RESERVOIR SYSTEM

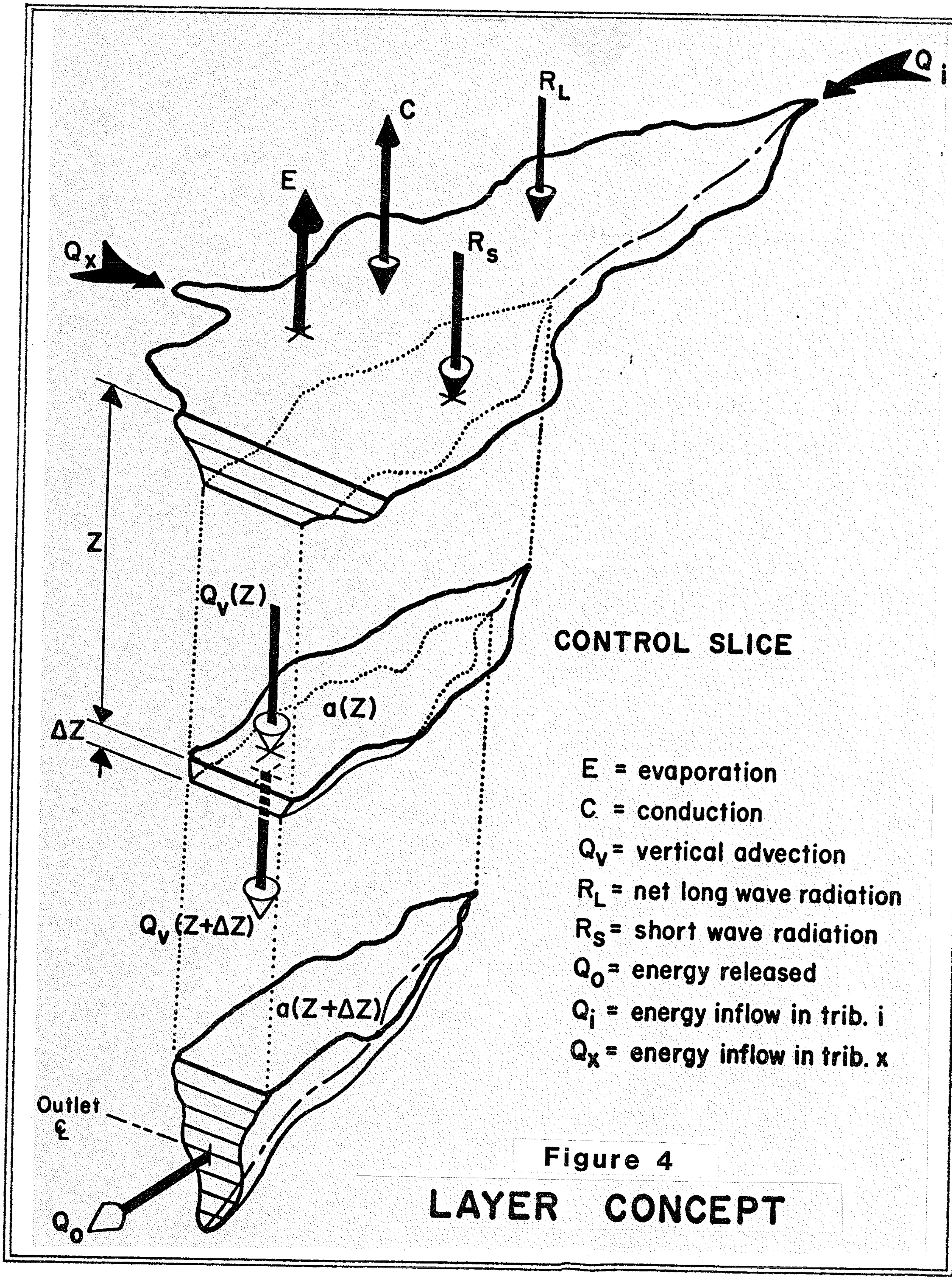

Figure 4

LAYER CONCEPT

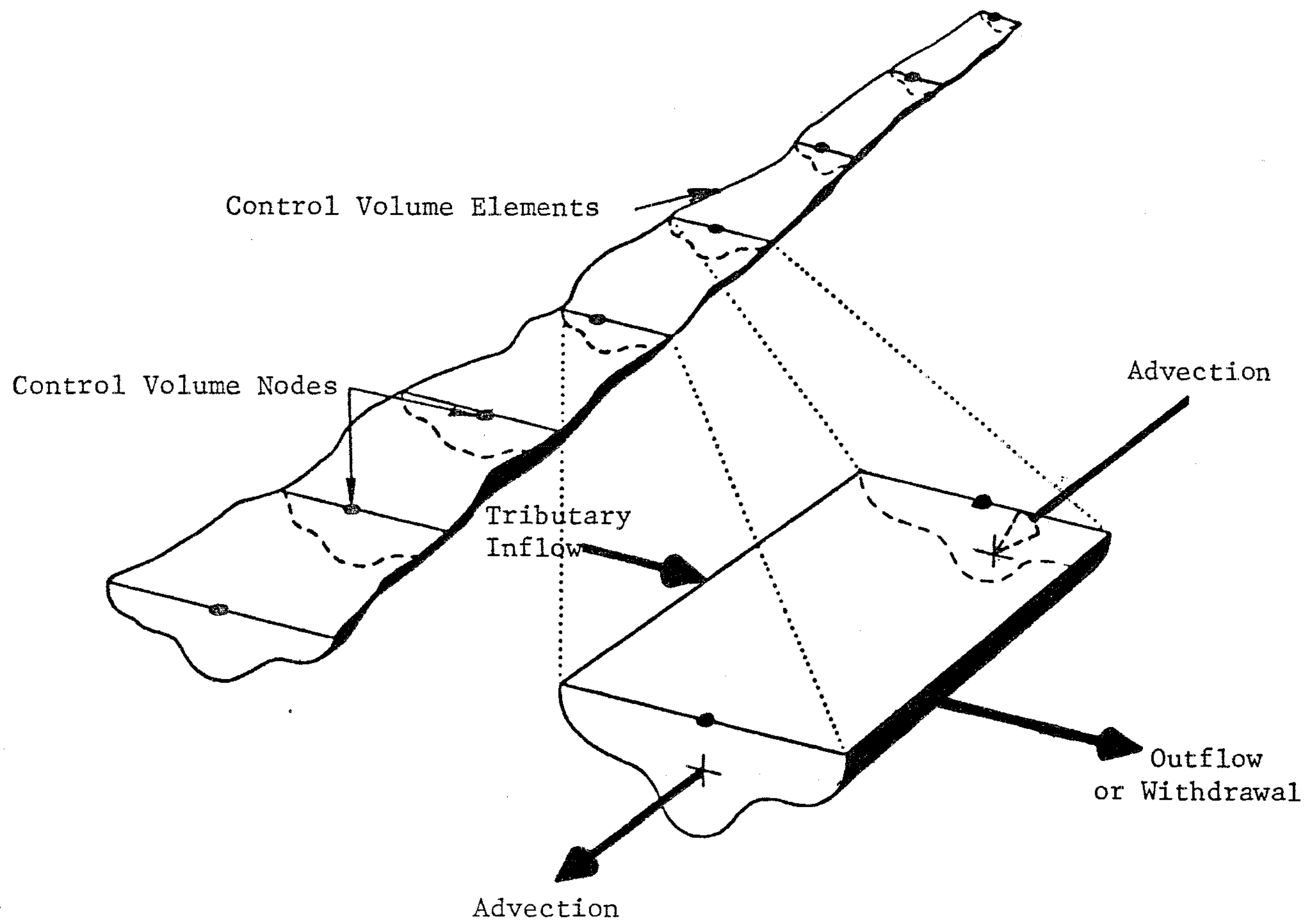

Figure 5

DISCRETIZED STREAM SYSTEM

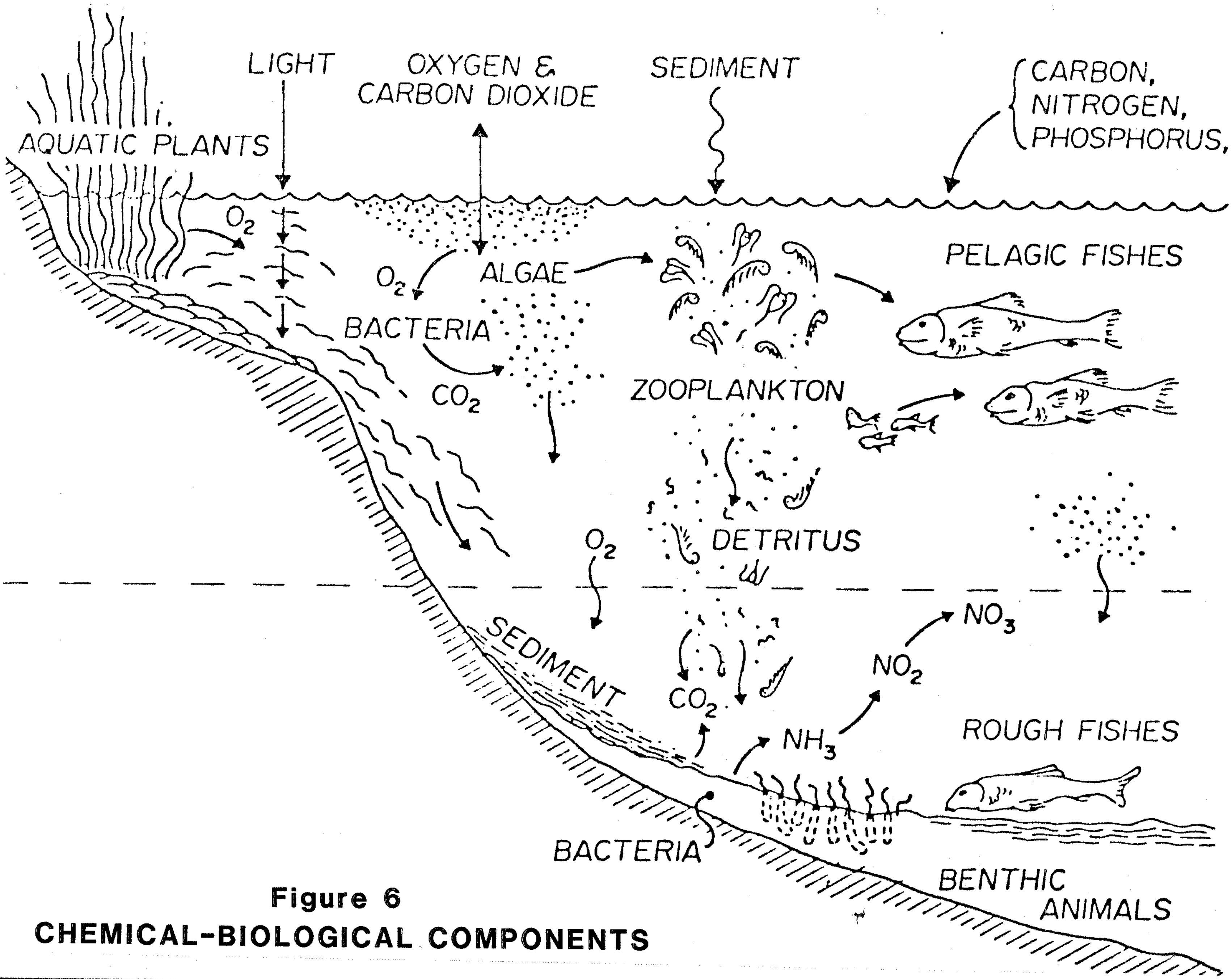

Figure 6
CHEMICAL-BIOLOGICAL COMPONENTS

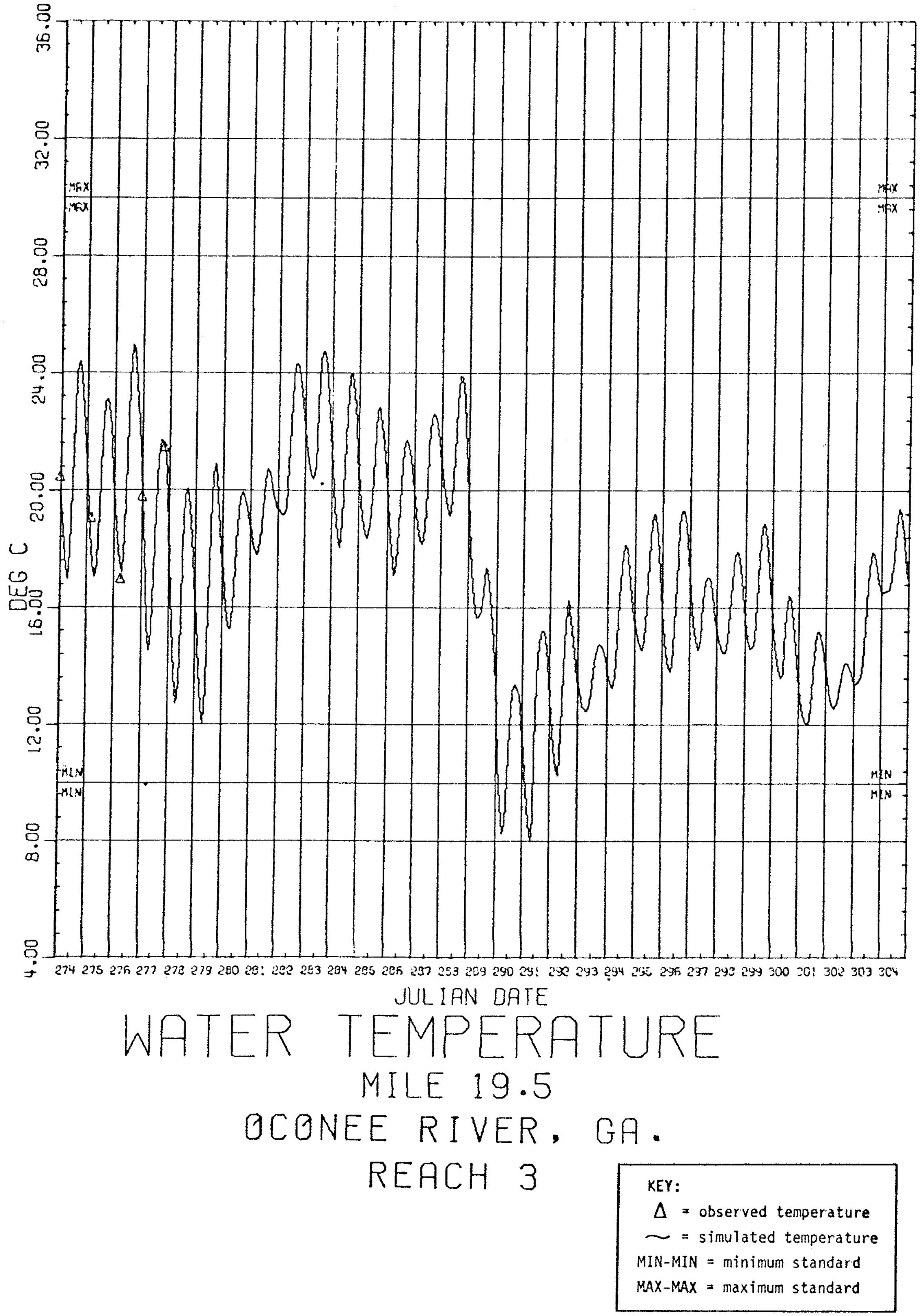

Figure 7 TIME SERIES OUTPUT

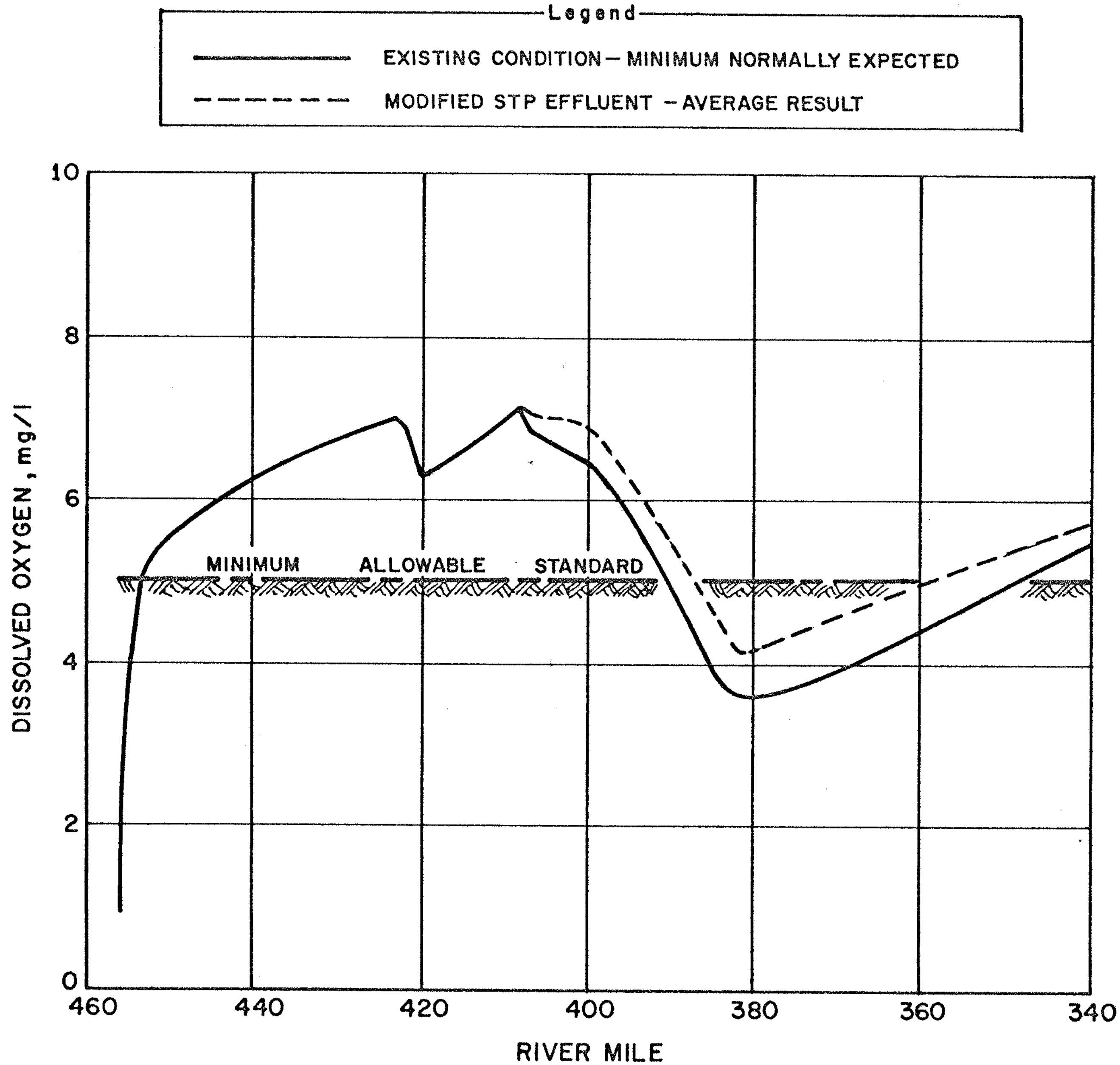

Figure 8 IMPACT ON D O DUE TO MODIFIED STP EFFLUENT

TABLE 1

EXAMPLE MODEL APPLICATIONS

Model	Parameters Used	Reservoir Analysis	River Analysis	Corps Office*
THERM	Temperature	X	–	Ohio River Division
WQRRS	Temp, DO, BOD	X	–	Tulsa District
WQRRS	Temp, pH, TDS, DO, BOD	–	X	Pittsburg District
WQRRS	Ecologic	–	X	Savannah District
WQRRS	Ecologic	X	X	Ft. Worth District
WQRRS	Temperature	X	X	Sacramento District
WQRRS	Temperature	X	–	Bureau of Reclamation
RWQM	Temp, DO, Nitrogen, Phosphorous, Coliform	–	X	Philadelphia District
HEC-5Q	Temp, DO, BOD, EC, Nitrogen	X	–	Savannah District
HEC-5Q	Temp, DO, BOD, EC, Ammonia	X	X	HEC Research

*except as noted

project to identify the latest version of the model and to be aware of any recent updates planned or in progress. The models limitations are documented in the users manuals and should be fully understood as to their effect on the specific project. The HEC is always willing to provide technical assistance in the use of any of these models.

The models discussed above provide an excellent package of programs to meet many of the normal needs for one dimensional modeling capability. Models of more dimensions are available and are discussed by other participants in this seminar but the user must remember that they require a more extensive data base and involve more complexity. When two-dimensional models are absolutely necessary, use the more complex model but always try to use the simplest model available to meet your objectives.

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ONE AND TWO DIMENSIONAL WATER QUALITY MODELING

by

Donald L. Robey[1] and Aaron B. Stein[2]

Introduction

A major objective within the Corps of Engineers' (CE) Environmental and Water Quality Operational Studies (EWQOS) research program is the development of water quality models specifically for use by CE Division and District engineers and scientists. Emphasis has been placed on obtaining the required field and laboratory data to form a better understanding of water quality processes and also provide information for verification of models. This paper will discuss only those water quality models being developed within EWQOS in the reservoir and riverine areas.

Background

The CE became involved in water quality modeling of reservoirs in the mid- to late 1960's. At that time, water quality in the CE was mainly considered to be the vertical temperature distribution within the reservoir and the temperature of release waters. There was a large emphasis on the design of selective withdrawal structures to provide a specified release temperature objective. In the early 1970's, procedures were developed to estimate the annual inflow stream temperature regime at a reservoir site and to estimate daily average stream temperatures from meteorological conditions, streamflow, and site characteristics (1). In addition, procedures were developed for selection of study years for reservoir temperature simulation and the overall development of design criteria for selective withdrawal structures (2). This work formed the basis for the design of selective withdrawal structures within the CE using mathematical temperature simulation models.

In the mid-1970's, the CE Hydrologic Engineering Center, through a series of contract efforts, developed the model known as the Water Quality for River and Reservoir Systems (WQRRS) (3). This model was the first attempt within the CE to consider water quality in its broadest sense. The model has been used extensively by the consulting engineering community, and to a lesser extent within the CE's. The WQRRS model has not been verified, and the biological and chemical algorithms are approximately 12 to 15 years old, indicating that present state-of-the-art techniques are not included.

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[2]Supervisory Civil Engineer, Acting Chief, Water Quality Modeling Group, Environmental Laboratory, USAE Waterways Experiment Station, Vicksburg, MS.

The WQRRS model was the basis for a reservoir one-dimensional water quality model (CE-QUAL-R1) that has been developed within the EWQOS research program (4). The original WQRRS model contained numerous coding errors, was coded in a cumbersome manner, contained algorithms that were coded for specific project studies, and was not consistent with latest research results both within the CE and elsewhere.

Water quality model
development within the EWQOS program

The major emphasis within the EWQOS program has been the development of CE water quality models that have been verified using data that were collected specifically for water quality models. In addition, it was planned to develop these models so that they could be applied by CE District and Division personnel and the models recognized as having overall acceptance by other Federal agencies, and state and local governments. In effect, they would be the basis for a CE "family" of models which would reduce documentation problems and training of personnel; increase CE credibility in responding to water quality concerns; and contain results of the latest applied research in the water quality area. The water quality models receiving emphasis in the EWQOS program include a one-dimensional reservoir water quality model (CE-QUAL-R1), a two-dimensional reservoir water quality model (CE-QUAL-R2), and a two-dimensional riverine water quality model (CE-QUAL-RV2). These models are briefly described below.

CE-QUAL-R1: This model is the culmination of approximately 8 years of research at the Waterways Experiment Station. The model predicts the vertical distribution of thermal energy and over twenty biological and chemical constituents in a reservoir. Computations are usually made with the model on a daily average basis. Model output includes graphical and tabular reservoir and discharge concentrations. The model can be used to address many types of water quality questions, including:

* 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.

* The addition of hydropower units.

CE-QUAL-R1 has been used during its developmental phase to evaluate water quality in both proposed and existing impoundments (5, 6, 7). The model is currently recommended by the U. S. Environmental Protection Agency's Center for Water Quality Modeling, Athens, Georgia, as the State-of-the-art in one-dimensional reservoir water quality modeling.

The thermal portion of CE-QUAL-R1 is a stand-along model that can be used for predicting the temperature characteristics of reservoirs under various project operational schemes and release structure characteristics. This one-dimensional reservoir temperature model is named CE-THERM-R1 (8). If thermal simulations are made for a specific reservoir, and if later water quality modeling studies are planned to be conducted, it is important that the CE-THERM-R1 model be used for the thermal simulations. This will reduce the effort required in later water quality modeling studies and avoid problems with explaining the use of two different temperature models.

CE-QUAL-R2: This model is presently under development with an initial version scheduled to be completed in 1983. The water quality constituents will be somewhat similar to those in CE-QUAL-R1. The major use of the model will be evaluating water quality problems during and following large inflow events and under dynamic project operation. CE-QUAL-R2, with LARM (Laterally Averaged Reservoir Model) as a submodel, will have the capability to predict reservoir water quality constituents in the longitudinal and vertical direction.

LARM has been systematically developed for the CE beginning in the mid-1970's (9, 10, 11). Emphasis was placed on the development of an efficient hydrodynamic computational code. Within the EWQOS program, a two-dimensional water quality data set was collected at DeGray Lake, Arkansas, for use in model verification. The water quality questions that CE-QUAL-R2 will be capable of addressing includes those that can be evaluated by CE-QUAL-R1, with the additional capability to predict longitudinal gradients (12).

CE-QUAL-RV2: A vertically averaged, two-dimensional, dynamic riverine water quality model is currently under development. This model, CE-QUAL-RV2, will be of great use for the analysis of potential and existing water quality problems in large rivers. CE-QUAL-RV2 makes use of a curvilinear coordinate modeling technique developed by Thompson (13). This technique numerically transforms the river into a rectilinear evenly spaced numerical grid, and the boundaries of the numerical grid are exactly coincident with the river boundaries. Also, the computational grid is automatically generated. The advantages of using this technique are simple boundary conditions with no costly interpolations and rapid grid generation.

The water quality model will be linked to a hydraulic model, VAHM (14). The initial version of CE-QUAL-RV2 will predict temperature, dissolved oxygen, nutrients, and algae as well as selected conservative materials. Initial phases of this work will be completed in 1983.

Because collection of two-dimensional riverine data sets is costly, a survey is in progress to locate existing field studies which may be used to test CE-QUAL-RV2 as its development proceeds. A preliminary data set has been collected on the Susquehauna River, Pennsylvania, as part of the EWQOS program.

Summary

Within the CE EWQOS research program, water quality modeling techniques are being developed specifically for use by CE District and Division personnel. Emphasis has been placed on obtaining data for verification to assure that models are capable of predicting water quality under a variety of conditions. These models, CE-QUAL-R1, CE-THERM-R1, CE-QUAL-R2, and CE-QUAL-RV2, are the basis for a CE "family" of water quality models in reservoirs and rivers. The use of these models will improve CE credibility in the area of water quality modeling and increase the acceptability of results.

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DISTRICT CONSIDERATIONS IN MATH MODELING

by

Richard E. Punnett[1]

INTRODUCTION

In two previous papers, math models being developed by HEC and WES for Water Quality were discussed. The models are extensive, rigorous, and complex but not difficult to apply. The primary purpose of this paper is to provide some guidance for proper selection of a math model for application at the District level. The secondary purpose of this paper is to assure those interested in math modeling that the task is not formidable. This paper was selected for presentation so that recipients can identify with the obscure, District-level employee who is newly confronted with math modeling - such as the author of this paper. From this working level the good news has been proclaimed, "It can be done!"

MATH MODELING AT THE DISTRICT LEVEL

From an individual standpoint, math modeling is an excellent opportunity for career development. The math modeling field is relatively new and the need for modeling is rapidly growing. Modeling expertise requires a willingness to continually grow with the state of the art. The intrinsic benefits to the District to be able accomplish inhouse modeling are great in terms of money, time, and gained expertise.

Once developed, a math model is easily updated and reused; this is a major benefit. The following two observations, although somewhat tongue-in-cheek, underscore this benefit:

Observation No. 1 - New studies never die; they simply become old studies.

Observation No. 2 - Old studies never die; they simply become restudies.

There are economic and political justifications for those two observations. With the increased benefits of hydropower and the expanding need for energy, the impetus for review of project purposes is substantial. A math model may be the only accurate prediction tool available to assess the effects, both in a lake and downstream, of various kinds of withdrawal schemes. If the expertise to run a math model is available within the district, various operational schemes can be easily evaluated at little expense.

[1] Hydraulic Engineer, Water Quality Section, Huntington District.

Because math models are easily modified, a change in project purposes or desired objectives is easily accomodated. During a restudy of Summersville Lake in West Virginia, a math model was employed to demonstrate that a withdrawal scheme for hydropower was possible which would allow the release water temperatures to enhance the downstream warm water fishery. Political interests then shifted the attention from downstream effects to inlake effects. The math model was used to locate a penstock elevation which would allow the lake thermal profile to remain essentially unchanged. Because of the flexibility of the project proposal (as demonstrated by the math model), State support was given for the proposed installation of hydropower.

Use of the math model naturally develops the insight of the modeler. A better understanding of reservoir hydrodynamics and interactions lead to improved management practices for water quality objectives.

MODEL SELECTION

ALIAS: EENIE, MEENIE . . .

To the neophyte in math modeling, this golden observation is humorously offered:

Observation No. 3 - Always select the math model least familiar to your supervisor.

In sincerity, do not select a model just because it has "stood the test of time." Math modeling is in a constant state of development and improvement. Old models - while still good for some uses - cannot accomplish the scope of the newer models. In this section, four major considerations in model selection are discussed.

Model Limitations

Understanding model limitations is a prerequisite to matching a math model to the study objectives. For example, many hydrologic models are available; however, no model should be considered universal. Some models account for momentum and tidal affects, but would be inappropriate to use where these affects are not significant. Some math models include routines for predicting dissolved oxygen (DO) concentrations. The accounting method for DO may or may not include biological and chemical interactions. DO in a river can be modeled effectively by accounting only for reaeration for several miles below many reservoirs; whereas modeling DO in longer, eutrophic rivers would require routines to account for biological and chemical interactions.

A list of examples of "selection by limitations" would be lengthy and confusing. The best way to use this method is to rely upon the expertise and knowledge of the staff of either the HEC or WES. By providing study objectives (keeping in mind the two observations in the third paragraph), a manageable list of models may be obtained from the HEC and/or WES. This process of selection naturally leads to the next major consideration.

Help Availability

Gilb's Third Law: Undetectable errors are infinite in variety in contrast to detectable errors which are by definition limited.

O'Toole's Commentary on Murphy's Laws: Murphy was an optimist.

A critical factor in the use of a math model is how much aid would be available if (when) problems are encountered. Next to data acquisition, debugging the initial model may be the most time consuming aspect. Without good documentation or help from the program developers, debugging may lead to frustration ad infinitum. A poorly documented model requires the user to consult the program developers too often. "Black box" programs should be avoided.

To labor further the point of the need for help, the following observation is offered:

Observation No. 4 - Most math modeling errors are not original; however, you will engender at least one error that is both unique and persistant.

System Availability

The selection of a model may ultimately depend upon which computer system is available. Where possible, use a computer system common to a source of help so that input and/or output files can be quickly transferred. Boeing Computer Services, Inc., for example, offers a high degree of commonality; however more cost effective systems (including District-owned computers) are available.

The math models available to an individual for use will depend upon which computer system is available. Because most models are relatively new and are being improved, different versions of the same model may exist simultaneously on different computer systems. Some computer systems offer special plot packages and statistical analysis in conjunction with the output from some math models. This is particularly desireable for reports and presentations.

Data acquisition and preparation usually involve the use of several computer systems and require the most amount of time. The computer system used for modeling should provide utility in the handling, modification, and merging of data files.

Data Availability

Perhaps nothing else is as important to the success of a modeling attempt as the gathering and preparation of input data. Data availability may determine the kind of math model that may be used. There is little or no reason to develop a two dimensional model where data do not exist for calibration or verification. Without a proper data base, the modeling attempt is, at best, the best guess.

Weather data can be purchased on magnetic tape from the National Weather Service. Conversions from the tape to input format for many math models are available at the HEC and WES. Data retrieved from the USGS (WATSTORE) and EPA (STORET) require modification before entry into an input data base.

University studies and special reports are also excellent sources of data. A thorough data search is worth the effort.

USE AND MODIFICATION

The time required to develop a math model depends upon the number of parameters to be modeled. As a rule of thumb, data collection and preparation requires 70 percent, debugging requires 20 percent, and calibration requires 10 percent of the modeling effort. If a model requires data input for dissolved oxygen and the associated parameters for interactions, the data collection and preparation could take up to about 3 months (for a first time effort).

A calibrated model can be easily altered to predict inlake and release water changes due to various operational schemes. Schemes could include multilevel withdrawals, hydropower installations, and increasing pool levels. The model can be used as an operational tool or as a means of predicting environmental impacts for reallocation studies.

Observation No. 5 - The desired study objective always lies just beyond the state of the art.

Math modeling is a very dynamic method of analysis. Many operational models are periodically revised, improved, and expanded. Quite often the available program documentation lags the actual state of development. Even though math modeling programs are generalized for a wide range of applicability, a particular study may involve special operational routines not included in the model program. The need for special routines should be considered in model selection, however the need may arise as a result of a modeling effort. If a special modeling need is identified after the model has been developed, the modeler has possibly three recourses:

1. Model Conversion. Different math model programs which accomplish similar results require essentially the same inputs. Model conversion would require reformatting the existing data set and calibrating a new model. Model conversion may be the easiest and quickest recourse.

2. Source Modification. Because math modeling is a very dynamic field of study, the special need routines may be developed or under development and not yet publicised. Some simple modifications can be accomplished upon request to the program developers, however a realistic expectation for modification should include both time and cost.

3. Personal Modification. Obviously this would require the most amount of District programming expertise. Familiarity with the source program, routine logic, programming ability, and coordination with the original program developer(s) are required.

Observation No. 6 - Any given computer program, once working and well documented, is obsolete.

PRESS ON

Nothing in the world can take the place of persistance.
Talent will not; nothing is more common than unsuccessful men with talent.
Genius will not; unrewarded genius is almost proverbial.
Education alone will not; the world is full of educated derelicts.
Peristance and determination alone are omnipotent.

Perhaps the most important message to emphasize is: Math modeling can and should be performed at the District level. Messers. Jerry Willey (HEC) and Don Robey (WES) have extended invitations to contact them and discuss your math modeling needs. Let this be your first step in math modeling.

WATER CONTROL STRATEGIES

BY

R. TERRY COOMES[1]

The Corps of Engineers is responsible for operating and maintaining large multipurpose reservoirs throughout the United States. Included in this responsibility is the determination of how the water itself will be managed.

This water management process varies in complexity from isolated flood control projects in humid areas to complex, multipurpose systems of reservoirs in highly developed, water deficient areas. Irregardless of the complexity of the project the common denominator is that the water control plan will change with time. Some projects have been operating for 50 years and many more for 25 years or more. The problems that a 50-year old reservoir was expected to solve are not necessarily today's problems. Water control plans are based upon conditions which are expected to change over time, and Corps of Engineers field offices are responsible for updating plans through continuing and progressive study.

The most common changed condition the Corps finds is reduced channel capacity, but there are many others, including changes in water quality. When water quality at a Corps' project is found to be damaging a project use, we frequently lack:

a. Authority to reallocate storage.

b. Money for a structural solution.

c. Time to wait for legislation or future budget cycles.

A change in the water control plan must be considered a potential solution to a temperature, dissolved oxygen or other water quality problem. We have responsibility and authority to review the water control plan and look for these solutions. The review can frequently be done at a low enough cost and within a short enough time frame to be responsive to the urgency of the problem. It is to be expected that where there are water quality problems there will be evaluations of water control strategies taking place.

The water control strategy depends first upon the latitude given the Corps of Engineers to make changes in the projects' water control plan. The public laws and project documents relating to specific projects usually contain provisions for development of water control plans and appropriate revisions under the authority of the Chief of Engineers. In those cases where water quality was not mentioned in the project documents, a change in water control criteria for a water quality benefit must be found to not have a significant detrimental impact on the authorized project purposes. The process leading to this

[1]Chief, Water Management Branch, Southwestern Division, Corps of Engineers

finding has become more complex and formal during the past few years. In the past the Corps of Engineers had a much larger degree of flexibility to unilaterally change a rule curve, or change a flood control evacuation target or the criteria for hydropower scheduling. These and other adjustments were used to resolve instream flow or water quality problems.

The flexibility the Corps has used in the past is rapidly being restricted by increasing demands upon the reservoir storage. We are experiencing only the beginning of this growing demand as population shifts, groundwater depletion and energy development--all add to the historical increase in the demand for water. The demand for water is accelerating and the development of new supplies has been slowed down by the environmental concerns, and currently, the economic concerns. Meeting the demands with our existing system of reservoirs will require tighter control and more efficiency in the management of reservoir storage.

Our water supply customers have some very real needs. We are writing dozens of new water supply contracts each year to meet these needs. These are mostly contracts for reallocation of storage under authority given to the Secretary of the Army in the 1958 Water Supply Act. The reallocations are usually from the flood control or power pool to water supply. Each reallocation is a reduction in Corps' flexibility as we retain no operational control over contracted, current use water supply storage.

The recreation customer continues to express needs for controlled pool elevations, instream flows, and water quality. The sportsman also has needs for managed pool fluctuations for fish propagation and waterfowl.

The Federal power customer is also becoming more vocal as the value of energy increases. Future development of hydropower by nonfederal entities will likely surface another highly demanding customer.

These customers are all presenting well intentioned, deserving but conflicting demands. Customers expect new demands to be met, but at the same time all past project benefits are to be retained. No tradeoffs are offered. While competing demands are increasing, each new demand that is met reduces the flexibility to meet the next new demand. The restrictions on water control criteria are becoming very specific. They include the following:

Water supply contracts
State water rights for reservoir storage and streamflow
Power marketing contracts
Environmental impact statements (EIS)
Project master plans
Interagency agreements

The demands of the future cannot be met with the flexibility of the past. The strategy for the future is to learn to use the above documents as multipurpose tools instead of single purpose restrictions. The water supply contracts can include provisions for special operations and restrictions on the user. The States are more frequently requiring minimum releases in their newly issued water storage permits. We can become more active in insuring that power marketing contracts consider the overall project in defining operating parameters. The EIS can be a very powerful document in maintaining a particular mode of operation at a project. Master Plans and interagency agreements are a means of formally coordinating and documenting water control procedures for a particular objective. The improvements in project effectiveness that have come through past water control flexibility may be lost unless procedures are formalized in Master Plans and water control plans; institutionalized in water rights, marketing contracts and water supply contracts; and documented in interagency agreements. These are the means for protecting gains as they are made.

The strategy for developing water control plans for a new project is well defined in Corps' guidance and regulations. One very important issue in design is to make the dividing line between the conservation and flood storage zones as wide and grey as possible. It is very important to avoid the perception of a normal pool elevation in order to retain flexibility into the future.

The resolution of growing and conflicting demands at existing reservoir projects is not as well established as for new projects. The most formal and comprehensive way to review a project operation is under authority of Section 216 of Public Law 91-611. This has been done with varying degrees of success and is most appropriate in those cases where a new Federal investment or a new authorized purpose is recommended. Otherwise, the best procedure is a review of the water control plan as part of the operations and maintenance program.

There are some realities that must be accepted prior to restudy of a water control plan to consider new or changed conditions. First, this is not a vehicle for adopting a new project purpose or doing away with an old one. Also, you cannot reallocate storage between project purposes. You <u>can</u> blend project purposes by modifying operation criteria to serve more than one objective, even one for an unauthorized purpose.

The first step in today's environment is to define the limits of your authority. This may not be an easy task. There are legal limits in authorizing documents and other Federal laws, State water rights, and river basin compacts. There are policy limits defined in Presidential executive orders, Corps' regulations and other guidance and local division or district taboos. The authority limits also depend to a degree on how controversial the project is and how many entities are affected by a change in operation. The definition of the limits of authority in changing the water control plan is site specific and must not be neglected.

The next step is to study the overlap documents--the Master Plan, O&M Manual, EIS and any others. This is necessary for early identification of constraints and areas of needed coordination. These steps lead to the definition and evaluation of alternative water control plans. The modeling techniques for simulating these alternatives and their impacts are described in various Corps' publications and other sources of technical literature. The selection of impacts to be evaluated and the measurements to be applied is a critical decision. The measurements must be simple enough to apply and complete enough to be credible. In addition, there must be a definition of the threshold of significant adverse impact on the authorized purposes.

The flexibility the Corps has in adoptng water control plans is constrained by the degree of impact on the authorized purposes. A plan cannot be adopted to benefit an unauthorized purpose if it has a significant adverse impact on an authorized purpose. The level at which significant impact is reached must be resolved through coordination and negotiation with the impacted customers. This resolution should take place early in the water control plan's development process.

The completion of the simulations, the measurements of impacts, the identification of constraints and authority are not likely to point out one ideal solution. There will be an array of options from which one must be chosen. Negotiation and compromise will complete the process. The "good old days" of hydraulic engineers making the final decision are gone. In some instances public participation may be desired before an alternative is selected. Always the impacted customers are contacted. The responsibility for the final decision rests with the Corps.

Once this final decision has been made, it should be given all the status possible. Certainly document it in the water control manual but also update the Master Plan, the EIS, permits, coordination agreements, and all related documents.

A successful plan will not have to be renegotiated annually. It will be implementable. It will be understood and accepted by the impacted entities.

WATER CONTROL OPERATING CONSTRAINTS[1]

by

C. E. Abraham[2]

INTRODUCTION

In recent years the Corps of Engineers has been experiencing a shift in its workload away from design and construction of water resource projects. New projects have been coming on line adding new water control management requirements. Yet this discipline of engineering continues to lag in terms of research and development. Only in recent years has the Corps concentrated its efforts on state-of-the-art data communications and hydrologic engineering applications to water control.

The Corps of Engineers as well as other agencies engaged in the management of water resources are faced with an array of serious limits concerning trade-offs between alternate uses of water resources and alternate means of obtaining particular objectives. Most reservoirs are operated to meet several objectives: (1) to protect the downstream river valley areas from flooding; (2) to generate hydroelectric power; (3) to augment the natural flow; (4) to provide commercial navigation; (5) to provide lakes for water based recreation; (boating, fishing, waterfowl, and hunting); and (6) to store the waters generated during flood events to insure continued reliable water supply through the lean drought years or seasons for irrigation and municipal water supply.

Water control strategies and procedures used to attain an overall best water control plan were discussed in this seminar. My objective is to cover the constraints water control managers must work within. For purposes of this discussion, I have divided these water control constraints into four categories: (1) Structual, (2) Physical, (3) Environmental, and (4) Legal.

STRUCTURAL

Structural constraints include all matters concerned with operating the facilities in dams and channel capabilities. The water control plan must

/1 Presented at the Seminar on Attaining Water Quality Goals Through Water Management Procedures, 17-18 Feb 82; Dallas, Texas

/2 Chief, Reservoir Control Center, Missouri River Division recognize the limits and the particular idiosyncrasies of the facilities. The most desired release from a dam at a particular time may be inconsistent with outlet or power facilities. Further, structural facilities located in the reservoir area such as recreation areas within the flood control zone can cause a variation from the most desired water control plan.

Generally, outlet conduits can be operated efficiently within their hydraulic limits. But spillway gates often operate at particular openings thereby providing finite character for discharges rather than continuous. This can impact on gas supersaturation problems whereby spillway releases may be desired to be spread accross several gates but particular gate openings would not allow the most desired pattern. Most dams designed and built prior to 1960 do not include multiple level outlets for water quality considerations. Without this flexibility, downstream water quality standards may not be met at certain discharges thereby impacting on a water control plan.

Where authorized hydro power facilities exist, the water control plan must provide flexibility both in release patterns and reservoir fluctuation patterns. Here the hydraulic and generating capability are of primary concerns in that the water plan and generation schedule must be coordinated. For example, if a dam having a hydraulic limit of 40,000 cfs must pass an average daily discharge of 30,000 cfs in order to keep the reservoir within limits, the turbines would be required to pass a minimum of 10,000 cfs for no more than eight hours or zero cfs for no more than six hours. Power Unit outages for maintenance are generally scheduled to coincide with low power load and peaking seasons which may not be compatible with water supplies thereby requiring consideration in the water control plan.

Power unit loadings may have a relatively narrow efficiency range, depending on the type of turbine. If units are operated outside of this range for long periods, damage may occur to the generator and/or turbine, damage may occur to the penstock and damage to any fish being passed through the turbine may be more severe. Therefore, where a limited number of units are installed, the water control plan must recognize such operating restrictions.

Transmission facilities and their maintenance needs can impact on the water control plan. Sometimes the transmission system experiences high reactive loads and certain power plants must temporarily generate larger amounts of energy than planned in order to maintain stability in the system.

The water control manager must maintain very close coordination with the power marketing agency to meet both power and water rquiements.

Recreation facilities sometimes are placed in the flood control storage zone. During flood control operations, the water control manager may be faced with the consideration of damaging the recreation facilities or modification of the water control plan. On the other hand, drought conditions create a conflict between the downstream user and/or irrigators and the recreationists who cannot launch boats and lose usable beaches. Such conflicts can cause modifications to the water control plan.

Downstream channel capability can change drastically with profound impacts on the water control plan. Channel deterioration due to vegetation, sedimentation and/or human encroachment are common problems. These are usually remedied through modification of the water control plan which impacts on reservoir fluctuations. Where downstream navigation is authorized, the shifting of the channel and changes in downstream tributary flow routinely cause modiciations to water control plans. These actions require modifications to other functions such as generation schedules and flood control operation.

PHYSICAL

When water control managers devise a reservoir operating plan that tries to meet multiple objectives, they are faced with the reality that these objectives are not necessarily mutually compatible. Good flood control calls for catching the flood and then releasing it as soon as possible to empty storage for the next flood. Irrigation and water supply call for keeping water in storage to be ready for a drought year. Ideal power generation calls for short term high releases patterned during the day and during certain months of the year to coincide with the hourly, daily, and annual periods of maximum power demand. But releases for downstream navigation must be steady in discharge and concentrated in the proper seasons. Irrigation calls for keeping and using water where the reservoirs are located. But navigation calls for running water downstream to float barges. Recreationists, fishermen, campers, and boaters want a steady pool level with little fluctuation but the other water resource objectives call for operating the reservoir system and using the water which means fluctuating the pools. All of the rest of the multiple objectives can be at odds with the natural environment for it is an inescapable fact that river systems cannot be dammed up and its water supply utilized to suit human purposes without supplanting the old natural river environment with the new river and lake system environment.

The water control managers work with a particular physical system that is subjected to random natural hydrologic events. This requires a varied background in hydrologic engineering, meteorology and power marketing to: (1) Evaluate impacts of potential regulation alternatives; (2) Develop a plan covering potential hydrologic events; (3) Coordinate and obtain input from organizations and individuals concerned with the water resource; and (4) Carry out the plan. Compromises are frequently necessary in recognition of and in reconciliation of the diverse viewpoints, interests, and responsibilities of the states and other agencies involved. Local individuals and groups must be encouraged to present their desires or problems.

Flexibility in regulation criteria is important in order to be sensitive to the dynamics of the water resource system. Like time, once the water has been released, it cannot be recalled. Therefore, regulation must be based on reliable information. State of the art procedures and equipment including computers and satellite communication systems to maintain surveillance on river and project conditions must be used. Streamflow data including the stage, discharge measurements, and other related information such as ice cover are logged and analyzed each day. The collection network may be greatly expanded during flood periods. Weather data not only in the form of weather maps but in the form of precipitation, snow and temperature information are also analyzed.

Long term effects of weather and basin conditions must be continually reviewed and updated for determining current reservoir regulation actions. These long term effects to power production, navigation, fish and wildlife, recreation and other concerns are evaluated for coordination.

ENVIRONMENTAL

Environmental constraints to water control is common and such constraints can have severe economic impacts. Just how should a water control organization that is faced with a wide range of alternatives go about deciding on the optimum plan? To list a set of priorities or identify economics and devise hard and fast rules to be followed would certainly do an injustice to the process and the mission because so many functions are dependent on not only physical but social and environmental elements. These elements often readily change. Endangered species and flyway concerns can have a profound effect on the water control plan, regardless of economics.

Water control plans commonly consider fish enhancement. Often power and fish considerations conflict. For example, ideal power generation calls for short term high releases patterned to meet daily and weekly loads. When coupled with a thermal system, desired night time hydro loads would be near zero, but during spawning seasons, fish eggs would be damaged by zero flow. High night time releases are made to maintain spawning habitat at the cost of lower than desired daytime releases.

Water quality concerns downstream of dams are commonly corrected by providing adequate mixing water. This action can conflict with water supply and other upstream uses whereas it may be compatible with fish enhancement.

LEGAL

Water rights is a common legal consideration in the water control plan. Downstream water rights often requires passing certain inflows up to the required amount. Water use rights cover storage of water for irrigation, water supply, power production, flood control, etc. It has not been the Corps' policy to obtain such water rights but the Corps must recognize the water rights of others in the water control plan.

The Corps commonly enters into operating agreements with other organizations who impact or are impacted on by our regulation. These agreements become part of the water control plan. Additionally, agreements made between second and third parties affect the water control plan. This type of action is commonly an agreement made between the power marketing agency and a utility.

SUMMARY

Given the system of reservoirs, it has been and will be the job of the water control manager to insure that the authorized net payoff from the overall tradeoffs will be achieved. In order to insure this, the manager must try to identify the interaction of impacts from actions taken, reveal and display those impacts, identify the tradeoffs involved, formulate institutional engineering and economic alternatives and consult with appropriate representatives of the public before adoping a plan of action. The water control manager values this consultation but in the end the ultimate decision on operating projects is up to the manager and these decisions within authorized purposes are made on a day-by-day basis.

WATER CONTROL AND ENVIRONMENTAL OBJECTIVES

BY

DR. MARK ANTHONY[1]

All reservoir and reservoir system regulation strategies induce multiple environmental impacts. These impacts range from subtle to dramatic, vary from short-range to long-range in both time and space, and may be positive or negative. All habitats and all water uses, reservoir and downstream, are affected. The criteria for evaluating each impact may be unique, may overlap with other criteria, may be site specific, and often change in relation to other factors such as time or season.

Thus, water control elements make hundreds of decisions each year that enhance or degrade reservoir and stream habitats to some degree and tend to promote or diminish the value of water for different water uses. Such decisions may be based on sophisticated risk analysis and thorough knowledge of the consequences or some lesser degree of knowledge, or perhaps, the convenience factor. My definition of environment is synonymous with ecosystem and all inclusive in terms of man's activities and needs.

Reservoir regulation objectives are legally defined by authorized project purposes. In practice, structural integrity, threat to human life, and economic loss, or property damage, are prevailing concerns. Obviously, multipurpose reservoirs increase the number of regulation targets, constraints, and criteria, as well as conflicts between users, the degree of coordination and the amount of data and information required for risk analysis. It is appropriate to stress that these factors tend to change. New interests evolve, old interests modify criteria, priorities change and even authorized project purposes are subject to modification.

The quantitative side of water control is inherently unique and complicated. The fact that this is not well understood by other than water control elements within our agency is a further complication. Reservoir regulation personnel are totally dependent on the acquisition of varying arrays of real time data which must be evaluated and analyzed in a timely fashion on a day-to-day basis. The phenomena they must account for vary so significantly in several dimensions that the data are often suspect in terms of adequacy and reliability. Mother Nature does not work 8-hour days or 5-day weeks, is remarkably unconcerned about producing average or normal conditions, and is less than precise in duplicating past events. The uncertainty of hydromet predictions, compounded by the possibility of further extremes, provides the water control expert with interesting challenges in risk analysis. "Risk analysis" is a game of "what if" played according to

[1]Chief, Water Quality Section, Ohio River Division, Corps of Engineers,

different sets of rules that is used to evaluate ever-changing data arrays to understand varying cause-effect relationships in order to predict events and conditions and identify actions which meet changing objectives and avoid unnecessary consequences. While this procedure may be considered a mysterious "black box" by other elements, the day-to-day product is very obvious, vulnerable to hindsight review, criticism and speculation.

The quantitative side of water control is fundamental in considering environmental objectives. Each day the reservoir regulation element must verify what actually happened yesterday, try to determine what is happening today, and attempt to predict what will happen tomorrow. Simultaneously, risk analysis is performed in terms of operating objectives, criteria, impacts, constraints, alternatives, and long-term trends prior to scheduling of releases. It is within this framework that environmental objectives must be identified, evaluated, considered, and accommodated. In other words, the hydrologic considerations in water control dictate what, where, when, and how the environmental data are collected, evaluated, interpreted, and applied.

This means that biologists or chemists (or whatever) must depend on a sophisticated understanding of hydrodynamics, velocities, travel time, flows, frequencies, elevations, volumes, as well as the knowledge regarding other physical, chemical, and biological parameters in order to communicate or help make effective water control decisions. The data on which most biologists are trained to rely are seldom available and often not very useful in water control. The concept of representative chemical and biological data is largely futile and, in many ways, infeasible. This being the case, such factors as controls, key controls, indicators, key indicators, long-term indicators, transition zones, mixing zones, plunge points, overflows, and underflows are critical. Data collection must be site specific and limited to the fewest possible because of logistic and budget constraints and to facilitate quick interpretation. It is the unusual and extreme ranges that are most important to understand and most frustrating to learn about. Figuratively speaking, one must learn to use a few real time data to select and transpose snapshots into a movie that best describes what is probably happening.

The capability to consider the broad gamut of environmental interests impacted by water control requires: 1) recognition that it's a full time job; 2) ability to evaluate these interests in day-to-day risk analysis; 3) adequate knowledge of real time conditions; and, 4) strong tolerance for extensive coordination. It amounts to fine tuning the scheduling of reservoir releases in accordance with many sets of criteria. An example of this is our muskrat fiasco. In parts of our basin, trapping has responded to supply side economics to a degree we were unaware of prior to complaints about winter releases from some projects. It is routine, convenient, and often essential to release winter storm inflows as soon as downstream conditions permit. The trappers have learned to accept Mother Nature and can usually set their traps effectively by anticipating natural changes in flow. However, they could not anticipate either the timing of our releases (often several days after the rain) or the abrupt, extreme changes in flow. A solution requires scheduling stepped releases, coordination, and overtime by reservoir personnel. This is technically simple but bureaucratically complex and very inconvenient.

The Ohio River Basin suffered such extensive and intensive water pollution that the planning of the federal reservoir system in the 1930s recognized needs for water quality control in addition to flood control. This plan assumed that drawdown of the system would respond primarily to downstream needs throughout the low flow period. However, the actual process of authorization and legislation incorporated additional project purposes including recreation, fish and wildlife, etc. In practice, it has been extremely difficult to protect the degree of operating flexibility that is critical to downstream interests. Nevertheless, day-to-day operating policy in ORD emphasizes a full recognition of all water uses including those downstream.

Currently, we are extensively involved in continuous coordination, evaluation, and manipulation of reservoir releases in order to meet multiple environmental objectives. These actions are significant to some degree at most of our 75 storage reservoirs in terms of enhancing habitats, fisheries, recreation, and other uses. The impacts on downstream habitats, including navigation pools, are especially critical during the annual low flow period and drought events. These efforts have been rated successful by many of our critics and have certainly helped our credibility and reduced the potential for litigation. For example, this is a quote from an editorial by Franc White in a recent issue of The Southern Sportsman Magazine.

> "Here I must approach the point of eating crow, just a little bit. I refer to the Corps of Engineers, which I have taken to task many, many times before. In West Virginia on recent trips, I have seen several instances where the Corps is working in very close cooperation with DNR where recreational values are at stake when industrial changes are involved.
>
> Whether it is simply just that so much is at stake and everybody knows it, or whether it is a friendly yielding on both sides, nothing is beyond discussing in West Virginia between the two groups.
>
> Until now most of my experience with the Corps has been projects originating from the Wilmington District, and perhaps Huntington District personnel are pleased with the aggressively progressive attitude of DNR in Charleston (WV). At least, folks in that area are not jumping all over the Corps' case all the time and I find that refreshing.
>
> Public relations aimed at friendly cooperation is the best kind. They are the same thing. I have seen a different side of the Corps of Engineers than that to which I am accustomed-in the Huntington District."

Water control elements must cope with one major problem that seriously inhibits communication, coordination and getting the job done. This is the universal over-simplification augmented by erroneous concepts that persist in regard to hydro-meteorological phenomena and the analysis thereof and real time water control. It is especially frustrating to water control elements that over-simplification is as prevalent among professionals in our agency and other water resource agencies as it is among laymen. Part of this is a failure to recognize the fact that the period of record is extremely short and thus, is limited in relation to the total scope of cause-effect factors. Also, the way that averages based on this short period of record are actually used in water control is poorly understood and their limited reliability as a predictive tool is disregarded. This over-simplification inspires other misconceptions including the faucet concept (each reservoir has infinite yield and thus infinite storage); the bathtub concept (run of the river projects have flat pools and are equipped with faucets and drains); the controlled rain concept (all rain always occurs on controlled watersheds); and the plumbers concept (when water is impounded, it acquires a tendency to run uphill and to violate other natural law). All of this adds to the general confusion and helps to create unreasonable expectations followed by impossible requests or irrational conclusions and may snowball into unnecessary conflicts.

There are other factors which have helped to conceal the full potential of reservoir systems for meeting basin-wide or national needs. To at least some degree, this potential has been obscured by national problems, priorities, and controversy. For example, the thrust to treat all sources of pollution has ignored alternatives including reservoir storage which, in many cases, would be most cost effective and more sound in terms of the total environment. One might also inquire how we can expect public support when only a handful of taxpayers is likely to know of more than one or two Corps reservoirs, much less comprehend the overall significance of reservoir systems, even for flood control purposes. I'm sure that our image and the effectiveness of our activities would be enhanced if the public understood that water control is far more compatible with environmental concerns than what is popular to believe.

The concept of controlling water for both quantitative and qualitative purposes is certainly not new. However, bridging the gap between concept and implementation is exceedingly difficult. This requires a mixed team of scientists and engineers together with the use of both conventional and novel techniques. It poses a challenge in which all concerned scientists and engineers have a special and responsible part to play -- not just within the water control element but also in interaction with other engineering and planning elements. These elements should be much better informed than is the case as to both the needs of water control and the possible effects which reservoir and reservoir systems regulation might engender. If the right questions had been asked, a number of past and existing studies would be more adequate in terms of meshing water control with changing needs without undue penalty to other users. Studies regarding add-on hydropower, for example, must include thorough analysis of hydrologic, hydraulic, and environmental factors. Hydropower can be and should be fully compatible with other water uses.

While I accept responsibility for this paper and especially enjoyed preparing it, much of the enjoyment and credit is due to input and review provided by J. T. Mitchell, Jr., Ron Yates, Mike Koryak, George Kincaid, George McKee, Jeremiah Parsons, and Dick Enrione, as well as extra effort by Marcia Schimpf.

OHIO RIVER DIVISION WATER CONTROL
OBJECTIVES AND ACTIONS

1. Existing storage reservoirs and authorized purposes:

Total number:	75
with authorized flood control	75
with authorized recreation	73
with authorized water quality	38
with authorized fish and wildlife	34
with authorized water supply	16
with authorized power	6
with authorized navigation	1

2. The following categorization is aimed at display of the different sets of criteria associated with specific objectives. There is overlap and redundancy but, in many cases, the criteria require a different approach even though the objective appears similar. For example, early fill and late drawdown is used to accommodate recreation and drought contingency, but the priorities are drastically different as is the risk analysis involved.

3. Flood Control Objectives and Actions:

Objectives: Store and release runoff on controlled watersheds so as to minimize the degree and extent of flooding in terms of space and time in immediate reaches, lower tributary, and main stem Ohio: coordinate actions involving Cumberland River, Tennessee River (TVA), lower Ohio and Mississippi River to minimize impacts of flooding on lower Ohio and lower Mississippi River reaches.

Actions: Daily evaluation of data arrays, such as: soil moisture, snow pack, groundwater, vegetation status, streamflows, status of storage, rainfall-runoff; anticipate and predict these conditions for subsequent days; evaluate constraints, such as: structural, downstream channel capacity, etc.; perform risk analysis; schedule releases; conduct post event analysis.

4. Water Quality Objectives and Actions:

Objectives: Meet downstream water quality standards and/or tailwater fish habitat needs; maintain reservoir water quality, fish habitats and recreation use standards; mitigate downstream pollution; maintain best possible quality conditions in lower tributaries and mainstem Ohio; mitigate low flow impacts of navigation structures.

Appendix 1

Actions: Daily risk analysis and scheduling; control existing selective withdrawal structures; monitor reservoirs and downstream water quality conditions; coordinate mainstem flow to achieve maximum reaeration during low flow; investigate emergency situations; special studies including pre-impoundment conditions in regard to problems and control needs; modify structures to enhance selective withdrawal capability; maintain coordination with states and local agencies.

5. Fish and Wildlife Objectives and Actions:

Objectives: Enhance fish and wildlife habitats in reservoirs and downstream reaches; meet needs and desires of state agencies and public.

Actions: Coordination; stabilize pools during spawning and other special events; schedule drawdown or modify normal drawdown for special studies; fish eradication, fish and game management, fishing and hunting access; modify pool elevation; schedule special releases.

6. Recreation Objectives and Actions:

Objectives: Extend recreation season; maintain optimal pool levels and minimize pool fluctuation; meet downstream needs and requests.

Actions: Coordination; schedule early fill and late drawdown, if necessary, and/or possible; schedule releases from least used reservoirs in system; schedule releases to accommodate maintenance and construction of facilities; schedule releases for whitewater rafting or canoe interests, etc.

7. Drought Contingency Objectives and Actions:

Objectives: Anticipate, coordinate, and schedule operation of the reservoir system to mitigate the effects of short-term and long-term drought events. Avoid or postpone possible depletion of storage with special concern for domestic water supplies.

Actions: Evaluate appropriate data for detecting local and basin-wide trends; coordinate and schedule early fill and additional storage; schedule releases with strong bias toward conservation of storage; pray for rain.

8. Hydropower Objectives and Actions:

Objectives: Meet generation schedules established by utilities to fullest extent possible within the criteria imposed by other project purposes.

Actions: Evaluate overall project and reservoir system situations in regard to conditions and water needs; coordinate with utilities and other water users; respond to emergency events or requests and veto generation if necessary. Such actions often involve awkward, uncertain coordination because of vague language in the license or permit and the universal over-simplification concerning hydromet phenomena.

9. Miscellaneous Objectives and Actions:

Objectives: Support other Corps' elements and other agencies in regard to routine and non-routine requirements and requests including emergencies, studies, etc.

Actions: Analyze, coordinate, schedule, in regard to barge accidents, spills, inspections, ice formation, special studies, etc.; analyze dredge material for toxic materials.

10. Navigation Objectives and Actions:

Only one storage reservoir in ORD contains authorized storage for navigation. Of course all the locks and dams and the navigation pools have navigation benefits. It was assumed that the original plan to initiate drawdown as soon as necessary, corresponding to seasonal cycles and the low flow period, would meet navigation needs along with the other downstream requirements. In other words, all lower tributary and mainstem flow requirements during the low flow period are incidental to routine systems operation. The fact that this includes navigation is often a sticky factor in coordination with state representatives who often assume that our desire to meet low flow needs is based entirely on navigation concerns.

AN UPDATE ON DREDGING ACTIVITIES IN THE PACIFIC NORTHWEST

BY

ROBERT J. HOPMAN*

INTRODUCTION

Since the last seminar on water quality for which I prepared a paper on a riverine case study for the Columbia River, much has occurred in way of dredging related activities in the Pacific Northwest. We have had a violent volcanic eruption and blast that disgorged an estimated four billion cubic yards of material from the top and center of Mt. St. Helens, lowering its height by more than 1,200 feet and producing an estimated but potentially astronomical 1/2 billion cubic yards of materials that could require rehandling by artificial means and primarily through dredging techniques. Of course, this massive change in nature's plans has a tremendous impact on the water quality of the affected areas. We have constructed jetty systems along the Oregon coast and on the North and South Forks of the Toutle River to help lessen huge dredging requirements. We have built new dredging plant and related equipment to undertake the dredging needs that are left when other solutions aren't adequate. And finally, we have tried to lessen the impacts of dredging activities on water quality by monitoring these activities and studying means to accomplish this feat.

MT. ST. HELENS

ERUPTION. On 18 May 1980, a massive and explosive eruption devastated Mt. St. Helens which had been a dormant volcano for over 120 years. The upper and north flank of the mountain, which for a few days previously had bulged outward as much as five feet per day, gave way in an immense landslide, instantaneously releasing the pressure of a plug of gas-chared magma that had risen within the crust below the volcano. The blast and resultant mud and pyroclastic flows from the mountain's north side impacted the river basins of the Toutle, Cowlitz and Columbia Rivers. It is estimated that three billion cubic yards of material settled in the upper 14 miles of the North Fork of the Toutle River, with a smaller but still staggering 60 million cubic yards settling in the upper reaches of the South Fork of the Toutle River. Mudflows in the following 24 hours, buoyed by melting mountain ice and waters displaced from the upper Toutle River channels, carried more than 50 million C.Y. of material into 21 miles of the Cowlitz River from the mouth of the Toutle downstream, and deposited an additional 45 M.C.Y. into the Columbia River upstream and downstream of the mouth of the Cowlitz River near Longview. These flows and volumes occurred in less than a 24-hour period after the eruption. All this activity had a great water quality impact.

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WATER QUALITY IMPACT. On the day of the eruption, the massive mudflow into the North Fork and South Fork of the Toutle River not only resulted in enormous sediment transport, but also because of the pyroclastic nature of much of the mudflow material, water temperatures in the river raised drastically. On 19 May, it has been established that at the mouth of the Toutle River where it enters the Cowlitz River approximately 50 miles from the base of the mountain, temperatures were in the neighborhood of 90°F. Turbidity levels were nearly immeasurable. Measured suspended sediments peaked at between 1-1/2 and 2 million milligrams per liter for a peak river flow of approximately 1,700 cubic meters per second. On the following day after the eruption, temperatures and suspended sediment loads tapered off, but nonetheless, suspended sediment loads were well above 1 million milligrams per liter with corresponding river flows of only 60 to 90 cubic meters per second. For those two days, there was more than 150 million tons of sediment passing from the Toutle River into the Cowlitz River. Turbidity levels 15 miles downstream from the mouth of the Toutle River, on 19 May, were above 50,000 JTU's (almost immeasurable). Water temperatures in the Cowlitz River at that location were also above 90°F. Water temperatures for the next few days quickly reduced to near normal levels of 50°F to 55°F, while suspended sediment loads reduced from 10 to 20 thousand milligrams per liter for the first week and gradually continued at fairly significant rates of from 6 to 15 thousand milligrams per liter with isolated peaks of 30 or more thousand milligrams per liter in following months. During infrequent rain storms over the winter of 1980-1981, suspended sediment concentrations would increase significantly for several days and turbidity readings would often approach 7 to 8 thousand JTU's. During the summer of 1981, one year after the eruption, suspended sediment readings reached low points of 15 to 20 milligrams per liter with corresponding turbidity readings of near normal 5 to 7 JTU's. With the exception of the first few days after the eruption in May of 1980, dissolved oxygen readings were generally near the normal in a range of 8 to 12 milligrams per liter. There are no readings recorded for the first few days after the eruption for dissolved oxygen levels.[1]

FISHERIES IMPACT. The initial high temperatures caused in the Toutle and Lower Cowlitz Rivers by the eruption of 18 May, immediately resulted in the killing of essentially all fisheries resources in those portions of the Toutle and Cowlitz Rivers impacted. Temperature readings of above 90°F were recorded the day after the eruption in the Lower Toutle River and near that figure in the Lower Cowlitz River. Although those temperatures subsided rapidly in following days, damage had already been done and fishery resources were essentially eliminated. Because of the continued high levels of sediment transport and turbidity readings experienced throughout the summer of 1980 and the fall of 1981, we were fearful about the survival of fish attempting to return up these tributaries from the ocean and the Columbia River. However, in July of 1980, only six weeks after the eruption, Washington State Game Department officials used electroshocking techniques in the Green River, a tributary of the North Fork of the Toutle River, to ascertain the existence of fishery stocks. To their pleasant surprise, they encountered significant numbers of steelhead that could only have originated from Columbia River waters in the intervening period. This is especially significant because turbidity levels were still in the neighborhood of many thousand JTU's and up until this time, those levels had been reported as fatal to anadromous fish species. Late in the summer and early fall of 1980, the fall chinook and coho run from the ocean up the Columbia River also proved to be near record proportions and the runs entered the Cowlitz and moved upstream to the Toutle River in large numbers. So many of these fish returned to upstream hatchery sites that the Game Department opened a special season for gill netters at the mouth of the Cowlitz in the fall of 1980 to harvest the excess numbers of those fish. Again, turbidity levels were at significant levels in the Lower Cowlitz and Toutle River Basins, but appeared to have no impact on the returning trends for these anadromous fish.[2]

In the late fall of 1980 and early winter of 1981, the traditional smelt run was observed in the Columbia River. Since smelt, although being an anadromous type species are not prone to return to their exact place of birth, but rather will often enter into any suitable stream to their liking, it was not anticipated that they would return in large numbers to the Cowlitz River as experienced normally on an annual basis. However, in 1981, the smelt run was near record proportions and a substantial portion of the entire run spawned in the Cowlitz River. Commercial and recreational dipping was allowed at high levels for many weeks in the Lower Cowlitz River in the presence of the large number of dredge plant working in these rivers.

The apparent lack of impacts on the anadromous fish species in the Toutle and Cowlitz Rivers was a pleasant surprise for nearly all concerned. It demonstrated that those species generally could cope with the high suspended sediment and turbidity levels and the large number of dredging plant working in the stream 24 hours a day, 7 days a week, without significant impairment.

DEBRIS RETAINING STRUCTURES. In the aftermath of the Mount St. Helens eruption on 18 May 1980, as already mentioned, the North and South Forks of the Toutle River soon became torrents of slurried mud, volcanic ash and forest debris. Reportedly, the river also contained a variety of potentially hazardous chemical substances produced by phenomena associated with the St. Helens event. Thus, the placement of debris retention structures was viewed with some apprehension by some agencies concerned about the condition of the river downstream of the projects, especially the quality of water drawn by municipalities for drinking and other domestic purposes. Nonetheless, because of a concern over devastating downstream flooding, debris retaining structures were constructed on the North and South Forks of the Toutle River to impede the flow of mud and forest debris generated by the eruption. An additional purpose was to create a settling basin for large quantities of sediment and ash being carried downstream. The basins filled up rapidly and dredging was initiated to remove the sediment where disposal areas were available in an effort to extend the usefulness of the structures.

The 6,100-foot long north structure is approximately 43 feet high and constructed of rock from a nearby quarry. The 500-foot south structure is of similar construction but to a 20-foot height. Spillways were provided in both dams by using gabion wire baskets filled with rock and covered with several inches of concrete mortar.

A fish trap facility at the South Fork debris retaining structure, completed in May 1981, is operated by the Washington State Game Department. It is designed primarily to trap steelhead trout for transfer to upper tributaries or other suitable undamaged streams. The facility includes a wooden fish ladder, attraction pond, approach channel and collecting pond.

Speculation about the projects' effects on water quality was based generally on the beliefs that (1) high degraded water could worsen in quality while pooled temporarily behind the structures, and (2) the disturbance of accumulated sediments by maintenance dredging could release additional water contaminants. These concerns prompted the Corps of Engineers to make a water quality assessment, including monitoring, of the Toutle River projects. This response was appropriate, too, inasmuch as it is incumbent upon the Corps to comply with (1) the spirit of the National Environmental Policy Act of 1969, (2) the goals of Executive Order 11752 concerning the prevention, control and abatement of environmental pollution at Federal installations, and (3) other directives issued by the Office of the Chief of Engineers.

Although monitoring was restricted to periodic grab-sampling and to parameters specified in drinking water standards, the data collected revealed no evidence of hazardous chemical contamination as had been originally feared. Indeed, at least initially while the projects were functioning as sediment traps, there appeared to be some improvement in downstream water quality (i.e., as opposed to the condition of project inflows) due to the uptake of metals by particulate matter (sorption) and the settling of some portion of the suspended load in shallow water behind the structures. Moreover, of the nearly 40 constituents tested, including those in sediment eluates, most were either near or below minimum detection limits or were well within guidelines recommended by the Environmental Protection Agency. Concentrations of iron and manganese were markedly higher than levels normally encountered in surface waters, but this was typical, perhaps, for water from a volcanically disturbed watershed. Neither iron nor manganese posed a serious water quality problem; both elements, in fact, are regulated for the purpose of aesthetics rather than health.[3]

Concern about the projects becoming pools of contaminated water lessened considerably in late November 1980, when the North Fork impoundment filled with sediment. At that time, monitoring was discontinued because it was found that the projects were having little or no effect on water quality in the Toutle River.

SEEDING. Seeding of mudflow materials and disposal areas was accomplished at varying intervals during the recovery effort. A small seeding contract was awarded in the summer of 1980 to seed approximately 1,400 acres at the toe of the mudfill on the North Fork of the Toutle River. The purpose was to stabilize the mudfill immediately upstream of the North Fork debris retaining structure. Seeding was accomplished by helicopter dropping grass seed incased in an adhesive-like mixture of fertilizer which allowed the seed to germinate and grow a certain amount until it could find root in the surrounding material. This seeding program was highly successful and in the fall of 1980, grass several inches high existed in most of the areas seeded. An additional fertilizer application was applied in the spring of 1981.[4]

JETTY SYSTEMS

For the usual purposes of providing greater channel dimensions for longer periods of time without the utilization of costly hopper dredges and to reduce inner channel wave action, the training jetty was extended at the mouth of the Umpqua River on the Oregon coast, approximately 22 miles north of Coos Bay. The Umpqua River has the largest drainage basin and average discharge of coastal rivers in Oregon. The mouth of the Umpqua River is centrally located on the longest sand beach and dune complex in Oregon, stretching over 50 miles from Coos Bay north to Florence.

Prior to impoundment, the area created by the near one-half mile extension of jetty construction was a high energy sand beach, fully exposed to wave action and both river and tidal currents. Now, the area is biologically important in having a diversity of marine habitats including rocky substrate and sand beach adjacent to a large river channel. At present, approximately 57 acres are inclosed on both ocean and river sides by stone jetties. Due to expressed concerns for circulation, the jetty extension was designed with a 200-foot porous section. Four culverts, each 4 feet in diameter, were implaced at mean lower low water. Wave action is negligible within the study area and circulation is limited to tidal exchange through the jetty and culverts on the river side. The area now provides locally unique marine habitats of protected sandy beach and rocky substrate.

An extensive monitoring study of the affected area was cooperatively conducted by the Portland District and University of Oregon to determine if there were any harmful effects on existing biologic environment and water quality.[5] Based on observations of water quality in the study area, as compared with ocean and river water quality, several conclusions were made.

(1) Temperature increases may be expected because of less circulation of normally cooler marine water. The magnitude of this increase will depend upon the efficiency of the jetty-culvert system. There will be a greater vertical range in temperature during summer months, the magnitude and timing depending upon such factors as winds and upwelling.

(2) Salinity extremes during winter and early spring may be lessened as most riverflow is diverted past the jetty-culvert system. Expected higher surface temperatures may promote slightly higher overall salinity. Depending upon the depth of circulation through the jetty, bottom salinity may gradually increase.

(3) Any expected "problems" in water quality would most likely occur in the deeper areas. Tidal circulation will probably keep the surface and mid-depths well aerated, mixing dissolved oxygen and dissolved nutrients. Particulates, either inorganic sediments or organic detritus will probably collect in deeper pockets.

(4) Overall water quality as it affects plankton and fish will probably not be significantly changed.

DREDGING PLANT AND RELATED EQUIPMENT

Just recently, new hopper dredges and a new hydrographic surveyboat have been specifically constructed for West Coast use.

HOPPER DREDGE. The new 825 cubic yard small class hopper dredge YAQUINA was recently constructed for work along the West Coast at exposed ocean entrances such as might be found at the Umpqua River entrance. The seagoing hopper dredge operates on the same principle as the pipeline dredge in bringing the excavated material to the surface, but here the similarity ends. The seagoing hopper dredge is a self-propelled and sturdily built seagoing vessel with a ship-form hull. It is a self-contained and self-sufficient dredging plant that operates underway, requiring no anchors or mooring devices while dredging and requiring no tug assistance. It is designed for ocean service and for work in coastal waters and is utilized principally for the improvement and maintenance of navigation channels in locations where wave action or heavy traffic does not permit the employment of stationary dredges. In its normal mode of operation, the hopper dredge pumps bottom materials, such as mud and sand, into its hoppers through trailing suction pipes (dragarms) and, when loaded, proceeds under its own power to a deepwater disposal area where the dredged material is disposed of by gravity-dumping through gates or doors in the bottom of the hoppers. In recent years, some hopper dredges of the split-hull type have been built in order to facilitate the dumping operation. The 5,500 cubic yard EAGLE I, owned by C. F. Bean Co., is one such split-hull hopper dredge. Also, some hopper dredges are equipped with self-unloading facilities that permit the hopper load to be pumped ashore through long discharge pipelines. In some cases, rather than loading the hoppers, the dredged material is pumped overboard (often through the overflow system) with the objective that a major portion will be transported and deposited outside channel limits by tidal, river or littoral currents. This method of dredging is called "agitation dredging" and is used by the Corps of Engineers in certain entrance channels along the Gulf Coast, such as the Mississippi River passes. In the interest of developing more effective high capacity agitation dredging tools, a few hopper dredges have been equipped with boom-supported discharge pipes that permit the discharge of the dredged material at a point some distance from the ship's side. This type of agitation dredging is known as "side-casting."

Regardless of the method used for disposal, the hopper dredge invariably operates while underway with its dragarms in a trailing position on the channel bottom during the dredging or pumping phase. It provides a temporary depository (the hoppers) for the dredged material until it can be transported to a disposal area. It must be highly maneuverable and, most important, its construction and dredging equipment must be suitable to permit dredging operations under adverse conditions (waves and swells).

HYDROGRAPHIC SURVEY VESSEL. Recently, the 48-foot high speed Surveyboat RODOLF was constructed for use in the Portland District. This vessel, capable of attaining speeds greater than 35 MPH, is an example of surface-effect ship (SES) technology - the concept of an air-cushion supported vessel with rigid sidewalls. With air-cushion assist, up to 80 percent of the vessel weight is supported by air pressure. Equipped with the latest in modern hydrographic surveying acquisition systems, the RODOLF compares quite favorably to slower speed vessels in accurately performing survey missions. However, because it has attained an improved level of speed performance it, accordingly is capable of providing greater survey coverage of West Coast waters even at a less cost per survey mile based on fuel consumption.[6]

STUDIES

In addition to the water quality studies already mentioned in reference to the debris retaining structures on the Toutle River and Umpqua River training jetty extension, we have conducted numerous other studies in connection with dredging operations in the Pacific Northwest. One such study of particular importance, is a 3-year effort at Coos Bay, Oregon with five objectives:

(1) Determine the best possible location for a permanent ocean disposal site.

(2) Determine the feasibility of ocean disposal of moderately polluted material dredged from miles 12 to 15, Coos Bay channels.

(3) Determine the fate of dredged material deposited in the established disposal site.

(4) Establish regional testing requirements and verify existing testing and modeling procedures required by the Marine Protection Research and Sanctuaries Act.

(5) Compare results with those obtained during earlier research at Columbia River disposal sites to hopefully utilize the findings to establish other disposal sites without the need of other expensive investigations.

Dredging and associated disposal of dredged material at Coos Bay has been the subject of increasing environmental concern. This concern manifests itself in the reduction of acceptable disposal areas available to the Corps and the port for deposition of dredged materials.[7]

An analysis undertaken in 1975 was used to determine remaining acceptable disposal sites in Coos Bay. As a result of that analysis, it was determined that in several years, currently acceptable upland disposal areas will be filled to capacity. This is particularly true of upper bay materials. Some of this material can be used for small demonstration projects, but if dredging is to continue, the majority of it will require removal to approved ocean disposal sites.

CONCLUSIONS

The above provides a brief update on some of the major dredging-related activities in the Pacific Northwest. Four items were briefly discussed--Mt. St. Helens, Jetties, Dredging Plant and Studies. I hopefully exposed a view that traditional fears of water quality degradation resulting from dredging-related activities are, for the most part, unfounded.

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THE EXPERIENCE OF THE ST. PAUL DISTRICT, CORPS OF ENGINEERS, WITH STATE COORDINATION OF DREDGING ACTIVITIES

By

Robert J. Whiting[1]

INTRODUCTION

Of the 860 miles of navigable channel in the Upper Mississippi River maintained by the Corps of Engineers, the St. Paul District is responsible for the 242.5-mile stretch from Minneapolis-St. Paul to Guttenberg, Iowa. The Rock Island and St. Louis Districts are responsible for the remainder of the Upper Mississippi. The St. Paul District also maintains 14.7 miles of congressionally-authorized 9-foot channel in the Minnesota River and 24.5 miles in the St. Croix River, both tributaries of the Mississippi.

Sand is the predominant sediment type in the St. Paul District portion of the Upper Mississippi. We annually remove an average of approximately 1.4 million cubic yards of sediment from the navigation channel with three dredges: a 20-inch hydraulic pipeline dredge, the WILLIAM A. THOMPSON; a 12-inch hydraulic pipeline dredge, the DUBUQUE; and a 4-cubic yard clamshell dredge, the HAUSER. The two hydraulic dredges pump dredged material through floating pipelines, usually to an on-land disposal site. The clamshell dredge loads into barges and usually unloads directly from the barges into an on-land disposal site.

In the late 1960's, environmental interests expressed concern that placement of dredged material was severely affecting the environment of the Upper Mississippi River. At that time, the St. Paul District's primary concern in the placement of dredged material was cost. However, we provided material to private or public landowners within normal operating limits of the dredging and disposal equipment.

In 1969, the Upper Mississippi River Conservation Committee (UMRCC) developed a survey identifying critical areas to avoid and areas of least impact. The St. Paul District agreed to follow these recommendations, even with increased costs, if the placement was within equipment capability.

In 1971, we initiated an annual meeting to discuss disposal in the following navigation season. Site-specific disposal review supplemented the UMRCC recommendations.

In response to the 1972 Federal Water Pollution Control Act (FWPCA) Amendments, the Corps of Engineers began publishing an annual notice of proposed channel maintenance. Individual dredging requirements were published as the dredging need developed, and on-site meetings were scheduled upon request to receive information on proposed disposal sites of concern. Eventually this basic on-site review developed into the more formal on-site inspection team approach developed by GREAT (Great River Environmental Action Team).

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THE 1973 WISCONSIN LAWSUIT (WISCONSIN VS. CALLAWAY)

The original issue in this suit was the lack of a completed Environmental Impact Statement (EIS) for the 9-foot channel. The court issued an injunction because channel maintenance was not in compliance with the National Environmental Policy Act (NEPA). During the term of the injunction, we conducted dredging on an emergency basis under guidelines established by the court. When the EIS was filed, the injunction was lifted. The State of Wisconsin then added issues to its suit relating to the adequacy of the EIS, the authorized depth of the 9-foot channel project, and the necessity for the Corps to obtain State permits for dredging under Section 313 of the FWPCA Amendments of 1972. The court never ruled on the issue of the adequacy of the EIS because Wisconsin chose not to pursue this point. The issue relating to the requirement for Federal agencies to obtain State permits was dropped because enactment of the Clean Water Act of 1977 made it clear that State permits were necessary for dredged material disposal.

This litigation lasted from 1973 to 1981. After January 1976, the only issue before the court was the authorized depth of dredging for the 9-foot channel. When the court ruled on this remaining issue in July 1981, it disagreed with the State, ruling that the Corps does have the authority to dredge deeper than 9 feet.

1975 MINNESOTA LAWSUIT (MINNESOTA VS. CALLAWAY)

In 1974, the St. Paul District, Corps of Engineers, completed a draft EIS on the 9-foot navigation channel on the Mississippi, St. Croix, and Minnesota Rivers. In that same year, the District began negotiations with the Minnesota Pollution Control Agency (MPCA) over a stipulation agreement which would serve in lieu of a State water quality permit.

A number of issues were discussed in these negotiations. One of these was the monitoring plan. The State of Minnesota advocated extensive sampling of sediments in dredge cuts and monitoring of water quality during dredging operations. The testing package for the Mississippi River and Duluth Harbor, Lake Superior, would have exceeded one million dollars. These negotiations extended over the summer and into the fall but were never concluded. The Office of the Chief of Engineers refused to sign the stipulation agreement and would not delegate authority for the District to sign.

In April 1975, the State filed a complaint in Federal District Court in Minnesota seeking a declaratory judgment, stating that the Corps of Engineers must obtain State permits during its dredging activities.

Essentially, the conflict between the Corps of Engineers and the State of Minnesota revolved around the interpretation of Sections 313 and 404 of the Federal Water Pollution Control Act Amendments of 1972. The State position was that Section 313, which set forth a general obligation for Federal agencies to comply with State water quality standards, was applicable to the Corps of Engineers. The Corps position was that our dredging activities were regulated exclusively by Section 404 of the FWPCA and that Section 404 did not require the Corps to obtain State water quality permits. In October 1975, the Federal District Court for the State of Minnesota issued a declaratory judgment in favor of the Minnesota Pollution Control Agency, which ruled that the Corps must comply with State water quality standards. We appealed this decision to the 8th Circuit Court of Appeals, which reversed the judgment of the District Court in October 1976. The 8th Circuit Court relied heavily on a number of statements in the legislative history and decided that, if the Congress intended the Corps to be subject to State water quality standards, it would have to explicitly so state.

The State appealed to the United States Supreme Court, but the Supreme Court denied the request for review.

The Minnesota Pollution Control Agency then contacted the Minnesota congressional delegation in an effort to amend applicable laws which would require the Corps of Engineers to comply with State water quality standards. The MPCA assisted the congressional delegation in drafting various changes to Sections 313 and 404 of the FWPCA Amendments of 1972. The most substantive change was the addition of part (t) to Section 404. The redrafted legislation, when passed by Congress and signed by President Carter, became part of the Clean Water Act (CWA) of 1977.

THE CLEAN WATER ACT OF 1977

Section 404(t) of the CWA allows the States to regulate the discharge of dredged or fill material into the navigable waters of the State "Including any activity of any Federal agency." Federal agencies are to comply with State requirements, both substantive and procedural, to the same extent as any person. The last sentence of this section, "This section shall not be construed as affecting or impairing the authority of the Secretary to maintain navigation," is the so-called emergency dredging provision. The official position of the Corps on emergency dredging is that the Districts are free to work out definitions of "emergency" with the respective States and that emergency dredging can be performed in accordance with such definitions. If such agreements cannot be reached, emergency dredging can only be authorized by the Secretary of Army, because the authority set out in 404(t) will not be delegated.

With the CWA of 1977 as legislative authority, the Corps of Engineers issued implementing guidance in a letter of 25 July 1978, signed by Major General Charles I. McGinnis, Director of Civil Works. This guidance letter, which became the so-called "McGinnis Policy," outlined the steps that the Corps was to follow in complying with the CWA of 1977.

A. Prior to commencing maintenance dredging, District Engineers shall obtain State water quality certification, unless the State elects to waive its right to certify. Such certification is required by Section 401(a) of the Federal Water Pollution Control Act, as a part of a Section 404 evaluation still prescribed by 33 CFR 209.145.

B. The excavation phase of dredging is not subject to State authority unless a discharge of dredged material, such as re-entry into the water, occurs during the operation itself. Nonetheless, District Engineers should cooperate with any State that desires special controls on the excavation phase of Corps of Engineers maintenance dredging activities. Expenses for employing such additional special controls should, however, be assumed by the State if not required by application of the EPA guidelines prescribed in 40 CFR 230.

C. District Engineers should develop a dredged material disposal plan that meets the requirements of Section 404(b) Guidelines, State dredged material permit conditions, and State water quality certification. When a State requires on-land disposal, but a Section 404(b) determination, through application of the EPA guidelines prescribed in 40 CFR 230 using the EPA "red book" (Quality Criteria for Water), does not require on-land disposal, District Engineers should proceed as follows. In those cases where the project authorization requires a local sponsor to provide suitable disposal areas, the local sponsor should be advised of the need for disposal areas; disposal areas must be made available by a sponsor before dredging proceeds. In other cases where there are no local sponsor requirements to provide disposal areas, the State or a prospective local sponsor should be advised that unless the State or the sponsor provides suitable disposal areas, including necessary containment, the added Federal cost of providing these disposal areas will affect the priority of performing dredging on that project. In either case, States should be made aware that additional costs to meet State standards may cause the project to become economically unjustified.

The official Corps position is that Section 404(t) applies only to maintenance dredging; other Corps activities do not require permits but could require a Section 401 water quality certification. It is the District position that 404(t) gives the States authority to regulate only when there is placement in waters of the United States (which includes adjacent wetlands). Thus, confined upland disposal is not under Section 404(t). It is unclear whether an effluent discharge from such disposal is a 404 or a 402 activity.

MINNESOTA CONTESTED HEARING OF 1978

Pursuant to Section 404(t), the St. Paul District applied for a permit for maintenance dredging; we sought one permit for the entire season based on historical data. The District negotiated many specifics of the permit satisfactorily but was unable to resolve others. A contested hearing before a State examiner took 10 days. Among the issues were:

How to treat exceptions and variances.

Whether a permit could be granted without site-specific requirements.

Water quality and other impacts of the operation.

Ability to comply with State standards.

Wisconsin participated in the hearing as an intervenor because they objected to some of the permit provisions which had been agreed to by the Corps and the State of Minnesota.

The proposed permit contained an effluent standard of "best effort." The State of Wisconsin challenged that standard but it was upheld.

The St. Paul District attempted to show that the water quality impacts from those operations were not significant, that the important impacts were physical (and best evaluated by the 404 process), that there were economic and operational barriers to complete compliance, and that the permits should be granted without any need for further MPCA approval because scheduling difficulties would arise. The State of Minnesota essentially contested all of those positions.

Minnesota took the position that variances from the standards could not be granted without a showing of economic impossibility and that, if we did not provide all of our funding requests, such a showing could not be made. Based upon Corps policy, we refused to provide that information even when ordered to do so by the hearing examiner. Minnesota went to Federal Court and obtained an order directing us to release the information. Although we gave this information to the State, they never seemed to use it.

Wisconsin contested the inclusion of an imminent closure section. Both the State of Minnesota and the St. Paul District had agreed to it; the hearing examiner upheld it.

The final decision by the hearing examiner did not completely favor either side. Some of the hearing examiner's findings agreed with the State; some agreed with us. We did not succeed in securing a blanket permit without the need for further approvals when variances were involved. However, the actual workings of the permit issued proved satisfactory.

Since the hearing, dealings with MPCA have been easier; we now have a five-year permit.

WISCONSIN HEARING

Pursuant to the requirements of Section 404(t) of the CWA, the Corps applied in November 1980 to the State of Wisconsin for permits for dredged material disposal during the 1981 navigation season. Construction of the disposal sites and placement of dredged material therein did not require permits because the disposal sites were upland (i.e., not in a "water of the U.S."). However, the return water discharges from the disposal sites were into waters of the U.S. and did require permits. Wisconsin treated those discharges as Section 402 activities and processed the applications accordingly. We did not dispute that interpretation, but went on record that we reserved the right to contest the issue because there was a basis for treating the discharges as 404 activities.

Wisconsin Pollution Discharge Elimination System (WPDES) permits were granted but contained limitations with which we could not agree. The effluent limitations must reflect application of Best Practicable Technology (BPT). Because Wisconsin had not formally developed effluent limitations for this activity, they developed them through the use of transfer technology and arrived at a limitation of 50 mg/l for total suspended solids (TSS). We appealed based upon our belief that 50 mg/l does not represent BPT. A contested case hearing was held. We introduced evidence that our present operation removes 99.98 percent TSS, that it is not operationally possible using these disposal sites and a large hydraulic dredge to achieve 50 mg/l TSS, and that the disposal sites cannot be expanded. The State's position was that none of these factors make any difference, that the 50 mg/l limitation is achievable, and that we must do whatever it takes to comply with that limitation. It is interesting to note that when we attempted to introduce bioassay data which would demonstrate that there was no potential toxicity from the effluent to indigenous organisms, the State objected, claiming such information was not part of BPT. When pressed by our counsel and the hearing examiner, the State said that it was not an issue but that, just to expedite the hearing, they would stipulate that the effluent from our proposed disposal sites would not result in any harm to the aquatic organisms in the Mississippi River.

The Wisconsin Hearing Examiner's Findings of Fact, dated 10 February 1982, made the following statement regarding the November 1980 WPDES permits issued by the Wisconsin Department of Natural Resources:

> The effluent limitation of 50 mg/l of total suspended solids in carriage return water from dredge spoil disposal sites as found in Special Conditions, Part II, p. 1 of 4 of the WPDES Permits issued to the Corps by the Department is unreasonable. The effluent limitation imposed is unreasonable, incapable of being attained and incompatible with normal dredging operations and procedures considering the disposal site limitations.
>
> There is no necessity for an effluent limitation of 50 mg/l for total suspended solids as found in Special Conditions, Part II, p. 1 of 4 in the WPDES Permits issued to the Corps by the Department. A higher level than 50 mg/l of suspended solids discharge to the Mississippi River will not in any way deleteriously affect the navigational capability of the river.
>
> An effluent limitation of 80 mg/l of total suspended solids in the carriage return water from the dredge spoil disposal sites of the petitioner is attainable and achievable by the petitioner by application of best practicable technology and is reasonable and necessary.

The hearing examiner amended the permits by substituting 80 mg/l for 50 mg/l as the daily effluent limitation for suspended solids.

The State of Wisconsin takes the position that the discharge from a confined disposal facility is a Section 402 activity and as such requires a National Pollution Discharge Elimination System (NPDES) permit. The State also takes the position that upland disposal of dredged material should be regulated as a solid waste under the Resource Conservation and Recovery Act (RCRA). We disagree with both positions.

Future litigation is probable on several other issues.

COORDINATION WITH IOWA

Recent discussions with Iowa indicate that they disagree with our position that Section 404(t) does not regulate confined upland disposal. They believe that we need State permits no matter where we place the material. They may be willing to litigate the issue; we will know the next time the question arises.

ARE DISCHARGES FROM CONFINED DISPOSAL FACILITIES REGULATED UNDER SECTION 402 OR SECTION 404 OF THE CLEAN WATER ACT?

Section 402 is the basis for the NPDES permit program and essentially regulates point source discharges into waters of the United States; Section 404 regulates the discharge of dredged or fill material into waters of the United States. The question of whether discharges from confined disposal facilities are regulated by Section 402 or Section 404 of the Clean Water Act can be argued either way.

The basic arguments for Section 402 coverage follow. The discharge from a pipe through a berm from a confined disposal area is a point source. In a strict sense, the discharge is made subsequent to the application of treatment because the settling out of the solids and other materials in the containment area is considered primary treatment. The discharge is liquid and nearly completely free from any solid material, including dredged material. It can also be argued that the discharge from the disposal area is a separate step or action apart from the actual disposal of the dredged material into the containment area.

As previously stated, there are also arguments in favor of considering these discharges to be under the purview of Section 404 as discharges of dredged material. This is the position taken by the North Central Division after discussions with the Office of the Chief Counsel. Basic arguments in support of this position follow.

The discharge from the containment area is a continuation and therefore part of the disposal of dredged material. Impacts related to the discharge and the regulatory mechanism for controlling the operation are not well suited to the procedures set up in NPDES permit programs. The EPA combined regulations favor consideration of these discharges as 404 activities. Those regulations (40 CFR 122.3) set out certain definitions. Among these is the definition of effluent, which states that effluents under Section 404 mean dredged material or fill material, including return flow from confined sites. Another definition in the same section relates to the discharge of dredged material and says that the term discharge of dredged material includes the addition of dredged material into waters of the United States and includes the runoff or overflow from a contained on-land or in-water dredged material disposal area.

Further support for this position is found in the Corps regulations. The definition of discharge of dredged material set out at 33 CFR 323.2(k)(1) states that dredged material includes the addition of dredged material to a specified disposal site and the runoff or overflow from a contained land or water disposal area. The definition somewhat confuses the issue, however, by stating that Section 402 covers the discharge of pollutants from the on-shore subsequent processing of dredged material extracted from any commercial use other than fill.

The preceding analysis explains generally the relationship of Section 402 and Section 404 to the discharge from a confined on-land disposal site. As stated, it is the Corps position that such discharges are considered to be 404 activities. No case law has addressed this issue.

DISPOSAL OF HIGHLY CONTAMINATED DREDGED MATERIAL

By

Robert J. Pierce[1]

INTRODUCTION

The disposal of highly contaminated dredged material requires many complex management decisions. First and foremost is the establishment of a reference point: "highly" contaminated has no meaning without comparison to a reference. As an example consider dredged material originating from any of the highly industrialized ports in the United States. Comparison of these sediments with those from a relatively pristine area (e.g. Chincoteague Bay) results in a conclusion that the former are "highly" contaminated.

Sediments from New York Harbor would fit this scenario: polychlorinated biphenyl (PCB) concentrations (usually in the 0.5 mg/kg wet range and generally no higher than 10 mg/kg wet) in the lower estuary are probably two to four orders of magnitude greater than sediment concentrations from Chincoteague Bay. Yet these "highly" contaminated New York Harbor sediments (when compared to Chincoteague Bay sediments) are two to five orders of magnitude lower than sediments in the upper Hudson River ("hot spots" as high as 100 mg/kg, Hetling et al. 1979). Fifty mg/kg has been adopted as a cut-off between hign and low concentration areas for PCB clean-up studies in the Hudson River (Horn et al. 1979).

Dredged material, when considered itself as a pollutant, differs considerably from other types of discharges. First it is often 50 percent or more solids in composition and the bulk of the mass is composed of a naturally derived, inorganic matrix. Secondly, sediments often serve as a major sink for dissolved and particulate sorbed inorganic and hydrophobic organic contaminants resulting in a complex mix of contaminants. Furthermore, the contaminants that are present have undergone photolytic degradation, selective vaporization, biotranformations, chemical complexing and the other processes which are characteristic of chemicals in the aquatic environment. Thus, we start with a potpouri of contaminants bearing only accidental resemblence to the technical-grade chemicals that first entered the environment and must assess whether the dredging and relocation of the material will increase their availability to organisms and cause an unacceptable adverse impact.

Realizing that industrialized ports are polluted and accepting the fact that dredging must continue to maintain economic viability, the regulator who is considering the open water discharge of contaminated sediments must make two decisions: 1) how much contamination is too much for uncontained, open water discharge (establish the reference point); and 2) what to do with the sediments in the "too much" category.

In this paper, I will discuss the approach that we have developed to address the question of how much is too much for the ocean discharge of New York Harbor dredged material. In addition, I will present a synopsis of our ongoing efforts to manage the "too much" category.

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THE CRITERIA

The potential for undesirable impacts of dredged material disposal and determinations of trace contaminants are assessed in the Ocean Dumping Criteria by means of bioassays of the liquid, suspended-particulate, and solid phases along with chemical analyses of the liquid phase (Figure 1). The impact of chemical constituents released into the solution can be addressed by comparing their elutriate concentrations with appropriate water quality criteria after taking initial mixing into account or through use of a liquid-phase bioassay.

Generally, the liquid and suspended particulate phase bioassays are conducted with one phyloplankton or zooplankton species, one crustacean or mollusc and one fish species. At the end of the 96-hour bioasssays, the lethal/effective concentration for fifty percent of the test organisms (LC_{50}/EC_{50} for phytoplankton) is calculated. A mixing zone is calculated to determine if water column effects will be diluted within four hours to a level below the limiting permissable concentration (LPC) calculated as 0.01 of the 96-hour LC_{50}/EC_{50}.

It is generally felt that if a dredged material is going to have an environmental impact, the greatest potential for impact lies in the solid phase. This is because it is not mixed and dispersed as rapidly or to such an extent as the liquid and suspended-particulate phases and because bottom-dwelling animals live and fed in and on the deposited solid phase for extended periods. Therefore, unless there is a specific reason to do otherwise, the major evaluative effort is placed on the solid phase. Ten-day bioassays are required for evaluation of the potential impact of the solid phase. Generally, this test is conducted with one filter-feeding, one deposit-feeding and one burrowing species.

Biological evaluations of the suspended-particulate and solid phase are required to include an assessment of the potential for contaminants from dredged material to be bioaccumulated in the tissues of marine organisms. This is intended to assess the potential for the long-term accumulation of toxic substances in the food web to levels that might be harmful to the ultimate consumer, often man, without killing the intermediate organisms. Since concern about bioaccumulation is focused on the possibility of gradual uptake over long exposure times, primary attention is usually given to the solid phase that is deposited on the bottom. Bio- accumulation from the suspended-particulate phase is considered to be of secondary concern due to the short exposure time resulting from rapid dispersion of the suspended particulates by mixing. Thus, for N.Y. Harbor sediments, those organisms which survive the 10-day solid-phase bioassay are held for gut clearance and then analyzed for Cd, Hg, PCB, DDT and petroleum hydrocarbons.

THE PROBLEM

Although the NY District routinely has been conducting bioassays and observing very little statistically significant mortality, shortly after implementation of the solid phase bioaccumulation test, statistically significant increases in PCB uptake above control organism levels were measured. This finding led to a need to determine if the test organism concentrations were ecologically important.

Philosophically, organism tissue concentration data can be interpreted from two perspectives: the traditional, human health concern; and/or the effect that the body burden has on the organism itself, on the species population dynamics and on the viability of the aquatic community. From a dredged material regulatory standpoint, the first concern can be evaluated relatively easily if FDA standards have been established for the contaminants. It is the latter perspective which is the problem.

Bioaccumulation in and of itself is a necessary physiological process. Unfortunately, organisms accumulate non-essential as well as essential chemicals. The mere presence in the organism can not be considered harmful. Only when these non-essential chemicals (e.g. PCB) have some adverse impact on the species, population or community or on the health of man are they degrading to the environment. Thus, it becomes essential to evaluate the ecological significance of concentrations of contaminants in the test organisms.

Two additional factors increase the complexity of the problem. First, is our lack of understanding of the relationship between 10-day laboratory test results and equilibrium concentration in organisms living in the field. Recent data (Rubinstein, personnel communication), however, suggest that 10-day concentration values may be 40 to 50 percent of the equilibrium concentrations (100-day test).

Secondly, research data on tissue concentrations in marine invertebrates from the New York Bight Apex are from a variety of published and unpublished research sources. It is recognized that the data may not be completely comparable. Unfortunately, the paucity of data, the lack of a routine monitoring program, and the immediacy of need forced the assumptions that the data were derived in a consistent manner with similar concerns for quality control and that temporal differences were insignificant.

The interpretive guidance for bioaccumulation discussed in this paper is a first generation approach. We continue to evaluate its usefulness and to seek other methods for determining ecological significance. While the methodology may be applicable to other regions of the country, the values developed are only applicable to NY Harbor and the NY Bight Apex.

STUDY AREA

The New York Bight in the Atlantic Ocean is a valuable, natural resource which has been, and continues to be, subjected to multiple human uses and environmental stresses. The waters of the bight are important for commercial and recreational fishing, swimming, recreational boating, and waterborne commerce as well as for the support of a diverse and productive natural community. Because New York City has historically been a population center, enrichment of the Bight with human wastes has occurred for more than two hundred years. In addition, industrial and technological development in the first six decades of this century without the proper concern for environmental protection has resulted in the introduction of many chemical contaminants into the Bight. Today, the Bight exists as a stressed but viable ecosystem. Although in many respects the ecosystem appears to be holding its own, it cannot be expected to indefinitely withstand a continually increasing level of stress.

The New York Bight Apex as defined for this evaluation is bounded on the north and west by Long Island and New Jersey, respectively, on the east by longitude 73°30'W and on the south by latitude 40°10'N. This area (approximately 2100 square kilometers) encompasses all of the principal ocean disposal sites for the New York metropolitan area (Figure 2).

New York Harbor is normally divided into upper and lower bays (Figure 3). The seaward extent of the Harbor is defined by a transect drawn between Sandy Hook and Rockaway Point. Within the Hudson-Raritan estuary, there are approximately 400km of federal channels and numerous private boat slips which are maintained for commercial navigation. Annually these maintenance operations generate between 4 and 8 million cubic meters of dredged material, most of which is discharged into the New York Bight.

Because of the urban and industrial activities in and about the harbor, dredged sediment are often contaminated to varying degrees with heavy metal and hydrophobic organic compounds. Recognizing the reality of the existing conditions, the Corps' short-term goal is the management of dredged material discharges so that they will not cause a further reduction in the viability of the New York Bight. This action will prevent unreasonable degradation of existing environmental conditions. There is a further commitment within a realistic time frame for taking significant action to reduce any environmental stresses on the New York Bight which may be occurring today due to dredged material discharges.

TOXICITY EVALUATION

Applications were made by two private corporations to perform maintenance dredging of boat slips utilizing mechanical dredging equipment and to transport the material in bottom-dumping scows to the New York Bight disposal site. Application A was located in the Arthur Kill and the sample consisted of 71% silt and 21.5% clay fractions. Application B was located in the Hudson River near New Windsor, N.Y. and consisted of 48% silt and 47% clay.

Bioassays were conducted on the liquid, suspended-particulate and solid phases of samples from each project in accordance with the 1977 Regulations and Critieria and utilizing the procedures described in the EPA/CE Manual.

The liquid and suspended-particulate phases were assayed using _Menidia menidia_ (fish), _Mysidopsis_ sp., _Acartia tonsa_ (crustacean), and _Skelotonema costatum_ (algae). Interpretation was based on calculation of an LC_{50} for the animals and an EC_{50} for the phytoplankton. Based on these concentrations, a limiting permissible concentration (LPC) was calculated by applying a safety factor of 100 (e.g., $LC_{50}/100$).

The mixing zone in this case was the volume of water bounded on the surface by the relaese zone (locus of points constantly 100 metres from the perimeter of the conveyance engaged in dumping at the moment of dump, ending at the last moment of dump) and exending to a depth of no more than 20 metres. Because of the almost instantaneous release feature of scow dumping, this calculation of the mixing zone offered an environmentally conservative level of protection from potential harmful effects due to disposal.

Sediment samples from project A (Table 1) resulted in considerably lower LC_{50}/EC_{50} values than those from project B (Table 2). Yet when dilution within the mixing zone was considered, the liquid and suspended-particulate phases from both projects met the LPC and presumptively would be rendered harmless when the discharge occurred.

The solid phase was assayed using _Palaemonetes_ sp. (crustacean), _Mercenaria mercenaria_ (mollusc) and _Nereis virens_ (polychaete) (Table 3). Interpretation was based on differences in survival rate and any indication of sublethal effects. Test and control data were subjected to analyses of variance by species and then blocked on species and tested for community effects. No statistically significant differences in survival were observed for individual species or community tests from either project. In addition, no sublethal effects were noted.

Table 1. Liquid and suspended particulate phase bioassay test result for water extracts from dredged material discharge Project A. LC_{50}/EC_{50}, limiting permissible concentration (LPC) and 4-hour dilution concentration as a percentage of the undiluted extract are presented by species.

SPECIES	LC_{50}/EC_{50}	4-HOUR LPC	4-HOUR DILUTION
LIQUID PHASE			
Skeletonema Costatum	25%	0.25%	0.17%
Mysidopsis sp.	70%	0.70%	0.17%
Menidia Menidia	>100%	1.00%	0.17%
SUSPENDED PARTICULATE PHASE			
Acartia Tonsa	44%	0.44%	0.002%
Mysidopsis sp.	64%	0.64%	0.002%
Menidia Menidia	>100%	1.00%	0.002%

These data generally are characteristic of the vast majority of the hundreds of ocean dumping bioassay tests that have been conducted on sediments from around the country: vis. the liquid and suspended-particulate phases can always be diluted below the LPC within a relatively small volume, and solid phase rarely causes statistically significant mortality and even less frequently suggests that substantive ecological effects will occur after the discharge. Thus, interpretation of the test results is simple and straight-forward although the importance of the test must be questioned.

BIOACCUMULATION EVALUATION

Based on the concept of no further degradation and the lack of field data on tissue concentrations for N. virens, M. mercenaria and P. pugio, the initial endeavor for PCB was to calculate a grand mean of tissue concentrations in all species of invertebrates from the Bight for which data were available. It was the concensus of opinion of those working on the problem that a grand mean tissue concentration utilizing organisms from both impacted and undisturbed areas might reasonably characterize the status quo of the Bight faunal community. Not exceeding the grand mean value should then result in no further degradation. After compiling existing data, however, it was apparent that a grand mean approach was not viable for several reasons. Data were available on five species, but there was only one data point for one of the species (Nereis). Data for two other species (Homarus americanus and Cancer irroratus) had only been collected on edible muscle, not whole body as in the other three species. Finally, one species, the surf clam (Spisula solidissima), did not appear to have the same propensity for accumulating PCB as that of the other four species; values for the surf clam were an order of magnitude lower than those of other species from the same location.

As an alternative to the grand mean concept, an interim limit for evaluating laboratory bioaccumulation of PCB in Nereis was formulated based on levels of PCB in the water column and on the potential for bioconcentration that can be expected in the Bight. This approach was based on the concept that the organisms realize a certain portion of their body tissue concentrations from direct partioning between the soluable fraction in the water column and their lipid pool.

A review of BCFs that have been published in the literature revealed that many organisms have the ability to concentrate PCB three to five orders of magnitude greater than concentrations in the water. For the purpose of computing the value to be used in evaluating laboratory data on Nereis tissue concentration, several assumptions were made. First, a BCF of 10,000 is expected to occur in the Bight. This value is below the maximum BCF for many species reported in the literature (Table 4). The use of a low BCF in this context results in a low, and therefore environmentally protective, tissue concentration. Secondly, concentrations of PCB in the Bight can be expected to range between 10 and 44 ng/l (MacLeod et al. 1981, Pequegnat 1980, Interstate Electronics Corp. 1979, Lee and Jones 1977, O'Brien and Gere 1979). Finally, the concentration which can be expected from direct uptake from the aqueous medium is defined by the equation: (Water Concentration) (BCF) = Tissue Concentration. For PCB this results in a concentration of: (40 ng/l) (10,000) = 0.40 ug/g.

Since uptake by M. mercenaria or P. pugio suggests that PCB might be leaving the sediments and entering the water column, a more conservative approach was adopted. Guidance levels for these two species were intentionally set at 0.1 ug/g which is the value recommended for fish by the Water Quality Section of the American Fisheries Society (1979).

A comparison of PCB concentrations from invertebrates (Table 5) demonstrates that the interpretative guidance values are lower than existing averages for organisms collected from areas that are minimally influenced to those that are heavily impacted by man. The values for lobster were from edible flesh. While edible flesh values are important from a human health standpoint, ecologically, whole body concentrations are more meaningful. Estimates of whole body concentrations were made based on the relative tussue partitioning of contaminants and the weight of each tissue.

It appears that PCB maybe concentrated in the lobster's hepatopancreas and roe (both of which are consumed by humans) to 16-45 times the muscle values (Bend et al. 1975). Data collected by MacLeod et al. (1981) support the concentrating ability of the hepatopancreas (24-43 times). Based on an average increase in PCB levels in hepatopancreas and roe of 28 times the tissue concentration and a tissue weight make-up per 456 g live lobster of 218 g shell weight, 152 g muscle weight, 20 g hepatopancreas weight, 30 g roe weight and 36 g miscellaneous soft tissue, we estimate the whole body concentration to be approximately 0.24 and 0.50 ug/g wet weight for males and females respectively. On a soft tissue basis, the corresponding values are 0.47 and 0.96 ug/g wet weight. A similar exercise probably is applicable to rock crab. The data on polychaetes is based on a follow-up study conducted after establishing the 0.400 ug/g guidance level for Nereis.

As with PCB, no data are available from the NY Bight on DDT concentration for the three test species and few values exist for any invertebrates collected in the Bight. Therefore, a similiar approach was adopted. Reported BCFs for DDT range from 10^3 to 10^6 (Kneip & Laner 1973, Hansen and Wilson 1970, Macek et at. 1979, Quality Criteria for Water 1976) a BCF of 20,000 was assumed for this study and a water column concentration of 2 ng/l (MacLeod et al. 1981). The resulting interpretive value is : (2 ng/l) (20,000) = 0.04 ug/g and was adopted for Nereis, Mercenaria and Palaemonetes.

Data on edible flesh from organisms collected in the Bight Apex (MacLeod et at. 1981) generally are of the same magnitude as the guidance value (Table 6). As in the case of PCB, the hepatopancreatic value of DDT for lobster suggests that whole body concentration are probably three to four times greater than the edible flesh. Similar projections for rock crab are reasonable.

More data are available for Cd and Hg invertebrate tissue concentrations from the Bight than for the organic compounds. Grand mean tissue concentrations were calculated from the data for Cd (Table 7) and Hg (Table 8) in invertebrates from the Bight. The grand mean for Cd was 0.3 (range 0.02 to 0.8) ug/g wet weight. In some cases concentrations in lobster, crab and fish were on an edible flesh basis. Whole body tissue concentrations should be higher than edible flesh levels since Cd and Hg generally are more highly concentrated in the gills and digestive glands of these organisms (Greig et al. 1977, SHL, 1972).

Cadmium and Hg concentrations in demersal fish are presented where available, but were not used in developing decision guidelines limits since contaminant levels in such biota usually do not provide clear evidence for the source of contamination (Pararas-Carayannis 1973). Oyster data were not used in arriving at decision guidelines limits because oysters can selectively accumulate greater amounts of metals than other bivalve species (Hall et al. 1978a). No data were available on Cd or Hg concentrations in shrimp or polychaetes in the New York Bight although data for polychaetes has been collected and is presented from a subsequent study.

As a second check on the acceptability of the values for Cd and Hg, we back-calculated the BCF using the grand means and reported water-column contaminant concentrations. Mean Cd concentrations in the NY Bight have been reported to be 0.17 ± 0.06 (EIS, 1980) to 0.63 ± 0.13 ug/l (Segar and Cantillo 1976) with an overall range of 0.09 to 0.8 ug/l). Mercury concentrations ranging from 0.04 to 0.23 ($\bar{x}=0.08 \pm 0.08$ ug/l have been measured in the Bight (EIS, L980). Utilizing the range of water concentrations, BCFs were calculated (Table 9) utilizing the equation:

(Tissue Concentration)/(Water Concentration) = BCF.

Bioconcentration factors of 10^2 to 10^3 realistically compare with values reported in the literature (Zaroogian 1979, Kopfler and Mayer 1973, Pringle, et al. 1968). Thus, the interpretive guidance values derived using the grand mean approach should prevent further degradation from dredged material since organisms in the Bight may be expected to accumulate similar tissue concentrations directly from the water column.

Returning to a consideration of the two case studies, Table 10 reveals for project A that statistically significant bioaccumulation which exceeded the guidance limit (0.20) occurred for Hg in both Palaemonetes and Mercenaria. PCB was bioaccumulated by Nereis but the concentration did not exceed the limit. In project B (Table 11) PCB accumulated in Palaemonetes but at a low level only slightly above the level of detection. In both projects low-level accumulation of petroleum hydrocarbons was observed. Because of the complex nature of the family of petroleum compounds, we have been unable to date to derive even a first-generation interpretive guidance package that we are satisfied with. We are continuing our efforts at this time.

The final disposition of the two permit applications was strongly influenced by the outcome of the bioaccumualtion analyses. After determining that there was a definite need for each project and that the ocean was the most reasonable discharge alternative, approval was granted for uncontained discharge of Project B material at the designated ocean site. To reduce the availability of the contaminants in the project A material, the applicant was required to coordinate his dredging operation such that the material would be discharged at a specified location and would be covered within fourteen days with cleaner, acceptable material.

GENERAL CONCLUSION

As stated earlier, the bioaccumulation interpretive methodology is a working straw-man; it is not as objective as we would prefer, yet we consider it to be a reasonable approach. We believe that in the end analysis interpretation must rely on field data, not laboratory research. We point as an example to the fact that in many aquatic ecosystems, natural populations of species continue to carry on their normal functions (e.g., swimming, eating, growing and reproducing) despite the fact that contaminant concentrations exceed water quality standards and their tissue concentrations might cause adverse effects under laboratory conditions. The Hudson River is a prime example: sediment concentration of PCB are in the hundreds of parts per million in some areas, water concentrations exceed EPA standards and tissue concentrations in eels for example, may exceed 100 parts per million, yet white perch, striped bass, eels and sturgeon all have viable populations. The size of the strugeon population in fact has increased during the same period as the greatest releases of PCB into the River.

This should not be construed, however, as a suggestion that we should relax our efforts to reduce contaminant inputs to the aquatic environment. On the contrary, we, as the keepers of the ultimate sink for most of the worst contaminants, believe that our problems can be solved ultimately only through a reduction of inputs.

MANAGEMENT

Finally, a few thoughts on management of contaminated sediments. Upland containment of contaminated sediments is technologically feasible and may be practicable in some instances, however, it is not free from problems. Paramount is the consideration of loss to the surrounding environment: both surface and subsurface. Thus, complete long-term isolation or encapsulation appears to be required. This by necessity would require control of direct uptake by flora and fauna, and of overland runoff and most importantly prevention of ground water contamination, as well as long-term monitoring and site maintenance programs. Obviously, to do the job correctly is a costly endeavor. Furthermore, and especially in the case of low and mid-level contaminated sediments, we must ask whether these funds could be spent more effectively on control programs for high level hazardous substances (e.g. toxic waste sites) where the environmental benefits will be more tangible.

As mentioned earlier in this presentation, currently we are managing N.Y. Harbor sediments that exceed the interpretive values through a program of controlled covering in the N.Y. Bight Apex. At the same time we are studying a method which in the long-term may provide a valuable method for reducing the bioavailability of contaminats from dredged sediments: subaqueous burial. The method involves the discharge of the contaminated sediments in existing (or intentionally excavated) depressions, and covering with uncontaminated material sedimentalogically similar to the surrounding substrate.

We have begun field testing the feasibility of discharging fine-grain sediments into existing sand-mining borrow pits in the lower bay. Of primary concern in this phase of the operation will be the ability to precision dump and to control the loss of fine-grain material after impact with the bottom. During the second phase of the operation, the critical factor which is being studied is the ability to place and maintain a layer of sand over the fine-grain material. Along with the field testing of these physical and logistic factors, an extensive program of biological and chemical monitoring is planned. Nothing runs smoothly, however. Even this experimental program which is scientifically appealing is frought with social, political and legal problems.

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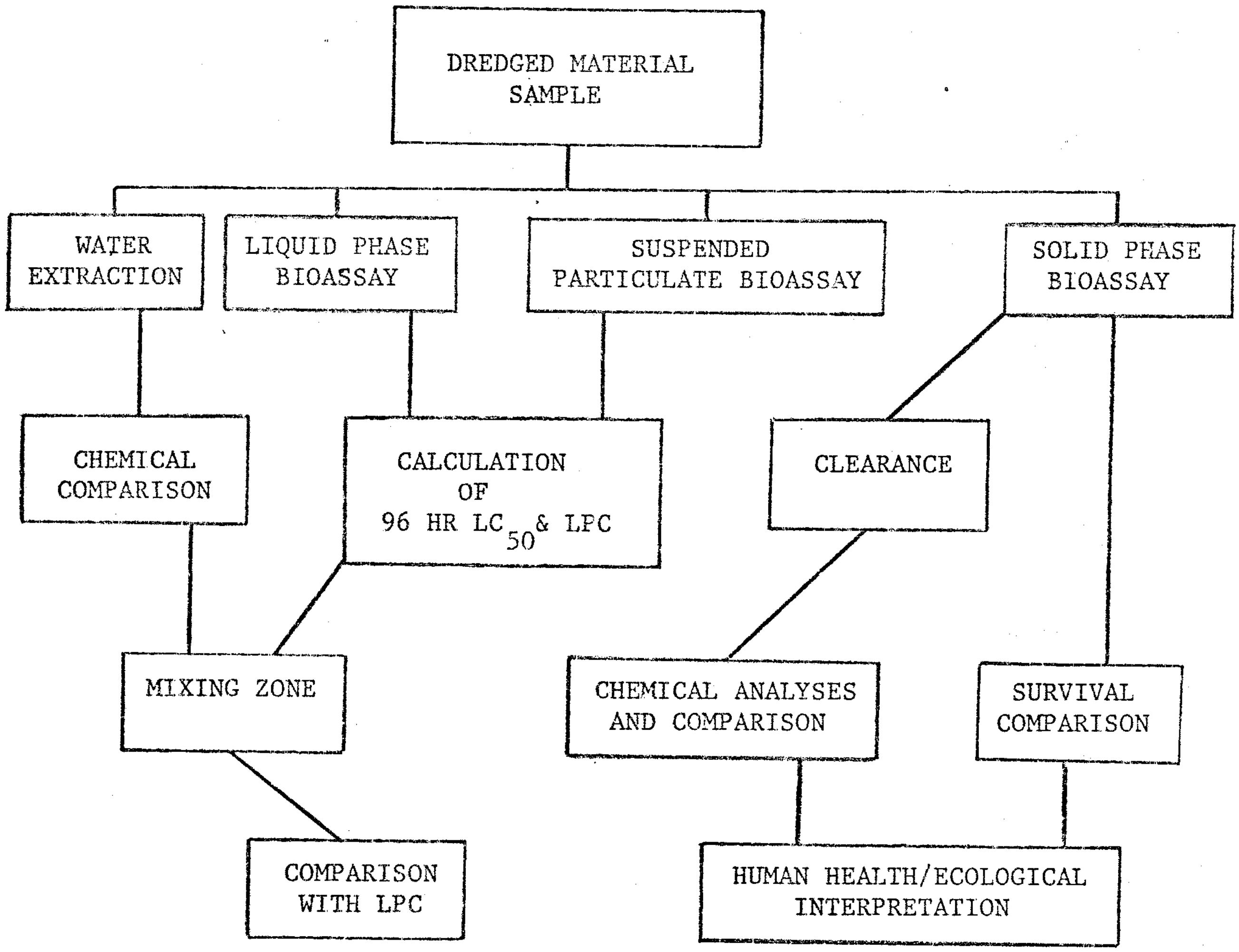

Fig. 1. Schematic diagram of testing protocol required for the evlauation of dredged material prior to discharge into the ocean.

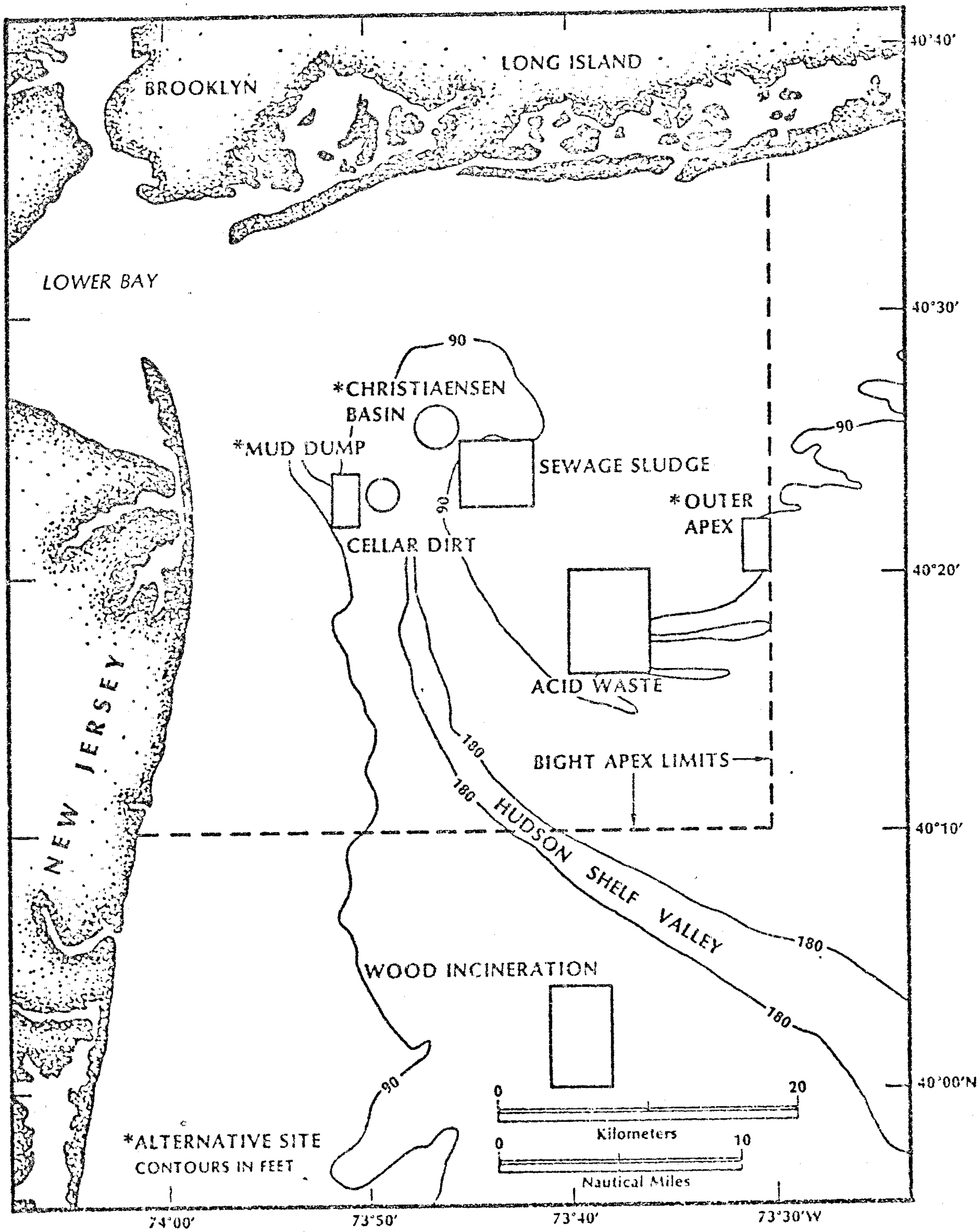

Fig. 2. New York Bight Apex and primary waste disposal sites. Christiaensen Basin and Outer Apex sites are being considered as potential alternatives to the current dredged material site (Mud Dump). All other sites are active.

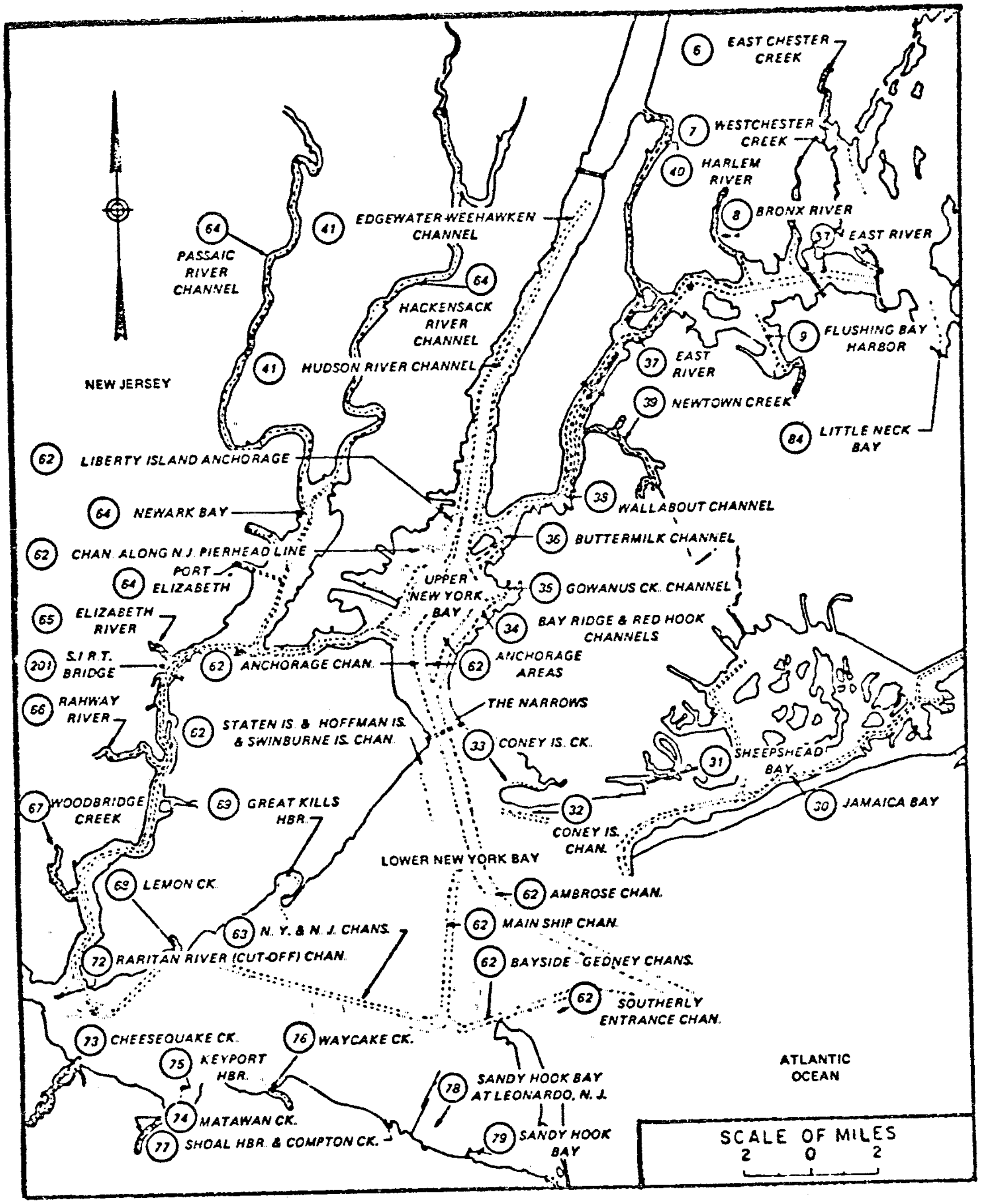

Fig. 3. Upper and Lower Bays of the New York Harbor Complex. Federally authorized navigation Projects are identified by dotted lines. New York District project numbers are circled.

Table 1. Liquid and suspended particulate phase bioassay test result for water extracts from dredged material discharge Project A. LC_{50}/EC_{50}, limiting permissible concentration (LPC) and 4-hour dilution concentration as a percentage of the undiluted extract are presented by species.

SPECIES	LC_{50}/EC_{50}	4-HOUR LPC	4-HOUR DILUTION
LIQUID PHASE			
Skeletonema Costatum	25%	0.25%	0.17%
Mysidopsis sp.	70%	0.70%	0.17%
Menidia Menidia	>100%	1.00%	0.17%
SUSPENDED PARTICULATE PHASE			
Acartia Tonsa	44%	0.44%	0.002%
Mysidopsis sp.	64%	0.64%	0.002%
Menidia Menidia	>100%	1.00%	0.002%

Table 2. Liquid and suspended particulate phase bioassay test results for water extracts from dredged material discharge Project B. LC_{50}/EC_{50} , limiting permissible concentration (LPC) and 4-hour dilution concentration as a percentage of the undiluted extract are presented by species.

SPECIES	LC_{50}/EC_{50}	4-HOUR LPC	4-HOUR DILUTION
LIQUID PHASE			
Skeletonema Costatum	100%	1.0%	0.17%
Mysidopsis sp.	100%	1.0%	0.17%
Menidia Menidia	100%	1.0%	0.17%
SUSPENDED PARTICULATE PHASE			
Acartia Tonsa	100%	1.0%	0.004%
Mysidopsis sp.	100%	1.0%	0.004%
Menidia Menidia	100%	1.0%	0.004%

Table 3. Solid phase bioassay survival results of three species exposed for 10 days to sediments from projects A and B and compared to the same species in an uncontaminated control sediment. Values expressed as percent survival (Standard Deviation).

	SURVIVAL			
	PROJECT "A"		PROJECT "B"	
SPECIES	Control (%, S.D)	Test (%,S.D.)	Control (%,S.D.)	Test (%, S.D.)
Palaemonetes	100(0)	100(0)	93.0(6.71)	93.0(6.70)
Mercenaria	100(0)	100(0)	93.0(2.74)	90.0(3.54)
Nereis	100(0)	99.0(2.24)	97.0(4.47)	100(0)
Total Community	100(0)	99.7(1.29)	94.3(4.95)	94.3(5.63)

Table 4. Bioconcentration Factors (BCF) of Aroclor 1254 for a variety of marine species as determined through field and laboratory studies conducted by the referenced authors. BCF based on wet weight values.

Species	Study Type	Length of Study (days)	Water Conc. (μg/L)	BCF	Reference
Penaeus setiferus	Field	Resident	0.1	25,000	1
Callinectes sapidus	"	"	0.1	70,000	1
Cynoscion nebulosus	"	"	0.1	20,000	1
Invertebrate	"	"	$\bar{x}$=0.6	1,350[1]	2
"	"	"	0.03	230,000[2]	2
Fishes	"	"	$\bar{x}$=0.6	6,650[1]	2
"	"	"	0.03	70,000[2]	2
Palaemonetes pugio	Lab	35	0.04	5,250	3
" "	"	35	0.09	8,330	3
" "	"	35	0.62	26,580	3
Lagodon rhomboides	"	42	3.00	55,000[3]	4
Brachionus plicatilis	"	45	0.009	9,556[4]	5
Engraulis mordax	"	25	0.002	207,000[4]	5
" "	"	3	0.0025	195,200[4]	5
" "	"	2	0.0045	194,222	5
Crossostrea virginica	"	168	5.00	85,000	6
" "	"	56	0.01	165,000	7
Leiostomus xanthurus	"	33	1.0	17,000	8
" "	"	56	1.0	27,000	8
" "	"	20	5.0	9,200	8
" "	"	26	5.0	24,000	8
" "	"	45	5.0	30,400	8
Lagodon rhomboides	"	14	5.0	2,800	8
" "	"	35	5.0	21,800	8
Cyprinodon variegatus (fry)	"	21	10.0	32,000	9
" " (adult)	"	21	10.0	32,000	9
" " (adult)	"	28	0.14	68,000	10

1. Average value
2. Maximum value
3. Value for Aroclor 1016
4. Converted from dry weight values assuming 80% water content

References: 1) Duke et al 1970; 2) Nimmo et al 1975; 3) Nimmo et al 1974; 4) Hansen et al 1974; 5) Scura and Theilacker 1977; 6) Lowe et al 1972; 7) Parrish 1974; 8) Hansen et al 1971; 9) Shimmel et al 1974; and 10) Hansen et al 1973.

Table 5. Mean PCB concentration (±SD) from edible flesh or whole body analyses of invertebrates and fish collected in the N.Y. Bight Apex. See text for discussion of male (M) and female (F) estimate of whole body concentration for lobster.

	PCB CONCENTRATIONS (ug/g wet weight)		
SPECIES	FLESH	SOFT TISSUE WHOLE BODY	References
Lobster	0.144(0.075)	0.47(M) 0.96(F) ESTIMATED	1,2
Rock Crab	0.314(0.495)		1,2,3
Blue Mussel		0.247(0.217)	1
Surf Clam		0.037(0.18)	1,3
Mixed Polychaetes		0.83(0.54)	4
Mackeral	0.204(0.086)		1
Windowpane flounder	0.196(0.127)		1
Ling	0.075(0.033)		5
Whiting	0.273(0.163)		5
Winter flounder	0.127(0.056)		1,5

References: 1) MacLeod et al. 1981; 2) Pequegnat 1980; 3) Interstate Electronics Corp. 1979; 4) Raltech 1981; 5) Lee and Jones 1977.

Table 6. Mean total DDT concentration (±S.D.) from selected tissues of invertebrates and fish collected in the N.Y. Bight Apex. Data from MacLeod et al. 1981

	TOTAL DDT CONCENTRATIONS (ug/g wet weight)			
SPECIES	FLESH	LIVER	ROE	HEPATOPANCREAS
Mackerel	0.089(0.034)	0.010	0.099	
Winter flounder	0.010(0.009)	0.494		
Windowpane flounder	0.035(0.040)			
Striped Bass	0.946(0.077)			
Lobster	0.011(0.011)			0.405
Rock Crab	0.011(0.004)			
Blue Mussel	0.037(0.027)			
Surf Clam	0.006(0.005)			
Scallop	0.007(0.009)			

Table 7. Cadmium concentrations (± S.D., wet weight) from selected tissues of invertebrates and fish collected in the N.Y. Bight Apex.

SPECIES	Cd (ug/g)	Reference
Lobster flesh (*Homarus americanus*)	*0.02	O'Brien and Gere (1979)
Lobster flesh	*0.18	Hall et al. (1978a)
Lobster flesh	*0.14	IEC (1979)
Lobsters flesh (in dump site)	1.08 ± 0.2	SHL (1972)
Ocean quahog (*Artica islandica*)	*0.54	EIS (1980)
Ocean quahog	*0.42 ± 0.034	Wensloff et al.(1979)
Ocean quahog	*0.42	Hall et al.(1978a)
Hard clam *Mercenaria mercenaria*	*0.27	Hall et al. (1978a)
Hard clam	*0.57 ± 0.13	Hall et al. (1978b)
Hard clam (inner Bight margins	*0.8	Atwood et al. (1979)
Surf clam (*Spisula solidissima*)	*0.13 ± 0.008	Wenzloff et al. (1979)
Surf clam	*0.16	Hall et al. (1978a)
Surf clams (inner Bight margins)	*0.1 - 0.2	Atwood et al (1979)
Surf clams	*0.13 ± 0.02	SHL (1972)
Rock crab flesh in dumpsite (*Cancer erroratus*)	0.1	Greig et al. (1977)
Rock crab flesh	*0.29	Hall et al. (1978a)
Rock crab flesh (unspecified)	*0.64	IEC (1979)
Rock crab flesh	*0.29 ± 0.18	Hall et al. (1978b)
Oysters	2.9	Atwood et al. (1979)
Yellowtail (*Limonda ferruginea*)	0.3 ± 0.02	SHL (1972)
Winter flounder (*Pseudopleuronectes americanus*	0.3	SHL (1972)
Windowpane flounder flesh (*Scophthalmus aquosus*)	<0.1	Greig et al. (1977)

* Used in calculating decision guideline limit.

Table 8. Mercury concentrations (± S.D., wet weight) from selected tissues of invertebrates and fish collected in the N.Y. Bight Apex.

SPECIES	Hg (ug/g)	Reference
Lobster flesh (*Homarus americanus*)	*0.23 ± 0.08	O'Brien and Gere (1979)
Lobster flesh	*0.49	Hall et al (1978a)
Lobster flesh	*0.034	IEC (1979)
Lobster flesh (in and around dump site)	*0.32 ± 0.2	SHL (1972)
Ocean quahog (*Artica islandica*)	<0.06	Wenzloff et al.(1979)
Ocean quahog	*0.07	Hall et al. (1978a)
Hard clam *Mercenaria mercenaria*	*0.052 ± 0.04	Hall et al. (1978b)
Surf clam (*Spisula solidissima*)	<0.07	Wenzloff et al. (1979)
Surf clam	*0.07	Hall et al (1978a)
Rock crab flesh in dumpsite (Cancer *erroratus*)	*0.19	Greig et al. (1977)
Rock crab flesh	*0.11	Hall et al. (1978a)
Rock crab flesh	*0.03	IEC (1979)
Rock crab flesh	*0.23 ± 0.08	Hall et al. (1978b)
Windowpane flounder flesh (*Scophthalmus aquosus*)	0.21	Greig et al. (1977)
Windowpane flounder flesh	0.15 + 0.04	SHL (1972)
Weakfish (*Cynoscion regalis*)	0.62	EIS (1980)

* Used in calculating decision guidance limit.

Table 9. Back calculation of bioconcentration factors (BCF) for Cd and Hg based on grand mean tissue concentrations (wet weight) from invertebrates and on reported water concentrations from the New York Bight Apex.

CONTAMINANT	GRAND MEAN TISSUE CONC. (ug/g)	WATER CONC. (ug/L)	BCF
Cd	0.30	0.09-0.80	$3.8 \times 10^2 - 3.3 \times 10^3$
Hg	0.20	0.04-0.23	$8.7 \times 10^2 - 5 \times 10^3$

Table 10. Concentrations of petroleum hydrocarbons, PCB, total DDT, Cd and Hg in test and control organisms surviving a 10-day, solid phase bioassay for project A. Organisms were maintained in clean water for a 24-hour clearance period prior to chemical analyses.

CONTAMINANT	PALAEMONETES		MERCENARIA		NEREIS	
	Control (ug/g)	Test (ug/g)	Control (ug/g)	Test (ug/g)	Control (ug/g)	Test (ug/g)
Petro Hydro	<.10	7.77	<.10	.99*	0.21	20.07*
PCB	<.04	<.04	<.04	<.04	<.04	.28*
DDT	-	-	-	-	-	-
Hg	<.20	.28*	<.20	.26*	.26	<.20
Cd	<.25	.27	<.25	.29	.39	.32

*Statistically significant, $\alpha = 0.05$

Table 11. Concentration (wet weight) of petroleum hydrocarbons, PCB, total DDT, Cd and Hg in test and control organisms surviving a 10-day solid phase bioassay for project B. Organisms were maintained in clean water for a 24-hour clearance period prior to chemical analyses.

CONTAMINANT	PALAEMONETES		MERCENARIA		NEREIS	
	Control (ug/g)	Test (ug/g)	Control (ug/g)	Test (ug/g)	Control (ug/g)	Test (ug/g)
Petro Hydro	<.10	.18*	<.10	<.10	<.10	<.10
PCB	<.04	.06*	<.04	<.04	<.04	<.04
DDT	<.02	<.02	<.02	<.02	<.02	<.02
Hg	<.20	<.20	<.20	<.20	<.20	<.20
Cd	<.25	<.25	<.25	<.25	<.25	<.25

* Statistically significant, $\alpha = 0.05$

OCEAN DUMPING OF DREDGED MATERIAL OFF THE LOUISIANA COAST

by

Rixie J. Hardy[1]

On 23 October 1972, Congress passed the Marine Protection, Research, and Sanctuaries Act, commonly known as the Ocean Dumping Act. The Environmental Protection Agency (EPA) published the final revision to the Ocean Dumping Regulation on 11 January 1977. Ocean waters, as far as Louisiana is concerned, are those waters which lie beyond the Louisiana coastline.

Transportation of dredged material has been defined by the Chief of Engineers Office as material which is carried through a cutterhead discharge line in addition to that which is transported by a hopper dredge or barge. Therefore, all dredging performed in the Gulf of Mexico off the Louisiana coast must meet the requirements of the Ocean Dumping Act. The Ocean Dumping Regulation requires that bioassay and bioaccumulation tests be performed unless disposal operations can be excluded under section 227.13.

After reviewing the regulation in early 1977, the US Army Engineer District, New Orleans, took the position that all of our open water bar dredging in the Gulf of Mexico could be excluded from testing. In May 1977, representatives from EPA met in New Orleans with representatives of the New Orleans District and WES to discuss testing exclusions under Section 227.13 of the Ocean Dumping Regulation. We at the New Orleans District assumed that, if one places like on like, or two substantially the same materials on each other, that no degradation of the marine environment would occur.

Material dredged from our bar channels in the Gulf of Mexico is dumped along either side of the channels. We are not introducing new material in the gulf, but simply relocating existing material.

EPA representatives, however, felt that dredged material must be free from contaminates to be excluded from testing under the substantially the same category as specified in the regulation. They suggested that we select a project and run bioassays to show that the material was, in fact, substantially the same. We then ran bioassay and bioaccumulation tests on material in the Calcasieu River bar channel and furnished the results of these tests to EPA, Region VI, in Dallas, Texas.

Based on the test results, EPA denied our request to perform maintenance dredging on this project and suggested that we seek a waiver from the Administrator of EPA. Going through the waiver process, it took a little over 3 years from our initial request for us to obtain EPA approval to perform maintenance dredging on this project.

We have since run bioassay and bioaccumulation tests on all of our bar channel projects in the Gulf of Mexico. To date, the New Orleans District has expended $2.6 million on tests required by the Ocean Dumping Regulation. In addition, we have used O&M funds totaling over $2.5 million to fund the Ocean Site Designation Studies.

[1]Chief, Navigation Branch, Operations Division, New Orleans District

We have encountered problems with meeting the criteria on most of the tests run on dredged material dumped in the Gulf of Mexico which are governed by the Ocean Dumping Regulation. Some of these problems are:

a. Difficulty in obtaining less than 10 percent mortality in the control, reference, and channel sediments.

b. Selection of Appropriate species.

c. The selection of appropriate control sediment.

d. Statistical significant difference in mortality.

e. Statistical significant difference in tissue concentrations.

In general, bioassay and bioaccumulation test results for projects in the New Orleans District did not meet the less than 10 percent mortality criteria in the control sediment, or there was a statistically significant difference in mortality and tissue concentration of organisms in the reference sediment and channel sediment.

We are now using either clean sand or beach sand supposedly free of contaminants. We feel that the biggest problem is in trying to approximate field conditions in the laboratory and obtain consistent results. One of the reasons why we do not obtain consistent results is that there is too much room for error when trying to approximate field conditions in the laboratory.

We mailed the test results to EPA without environmental assessments and requested EPA to approve dredging based on raw data. EPA did not approve five of our requests to perform maintenance dredging in the bar channels in the Gulf of Mexico. This meant that we would be required to seek a waiver from the Administrator of EPA prior to being allowed to perform maintenance dredging on these projects. It was then the desire of the New Orleans District to meet with EPA to try to reach some agreement or come to some understanding as to what was required to comply with their regulation on ocean dumping without going through the waiver process. We therefore requested WES to conduct a technical meeting on the potential environmental effect of bar dredging off the Louisiana coast in the Gulf of Mexico.

The meeting was held in March 1980 between representatives from EPA, Region VI, EPA Headquarters, WES, and the New Orleans District to discuss the ocean disposal of dredged material in relation to bioassay and bioaccumulation testing required by ocean dumping criteria, and to place laboratory test results in prespective with the dump site environment and natural conditions in the Gulf of Mexico.

At the meeting, Corps of Engineers personnel stressed the fact that the results of bioassay data should be used as one of several tools in decision making rather than using bioassay results as the sole criteria for determining unreasonable or undesirable degradation. Corps of Engineers personnel also mentioned the fact that bioassay and bioaccumulation data provides only a measure of the potential for harm rather than an ultimate determinate of harm to man and the environment.

WES suggested that the New Orleans District use existing data to make a determination rather than sending raw data reports to EPA, Region VI, for their interpretation and assessment. In addition, WES further suggested that the final determination on the need for ocean dumping, using any existing relevant data to formulate an assessment and determination, should be made by the New Orleans District and presented to EPA, Region VI, for their review and concurrence. EPA agreed that this procedure would be preferable to going through a reviewing process of all raw data presented. Representatives from EPA, Region VI, indicated that they would reconsider their decision relative to projects mentioned earlier in this talk, if the New Orleans District would utilize additional existing data and present such data in a statement of findings. We are presently in the process of preparing statements of findings for projects which have been tentatively disapproved by EPA, Region VI. All future requests to EPA for approval to dump dredged material in ocean waters will be provided with a statement of findings. At the New Orleans District, we have established an Environmental Resources Specialist position in our Dredging Planning Section of Operations Division.

We, in Operations Division, are also presently preparing contract specifications for bioassay and bioaccumulation tests on material removed from the disposal sites in the Gulf of Mexico. The established position in conjunction with the preparation of contract plans and specifications affords us much better control during testing and allows us an early evaluation of test results. We are hopeful that this will also generate acceptable tests and evaluations. We will provide EPA with the data it requires to reach a decision concerning the dumping of dredged material in ocean waters.

We have reservations on the appropriateness of using bioassay and bioaccumulation test results in determining unreasonable or undesirable degradation of the marine environment. Results of tests conducted by the New Orleans District seem to indicate that such tests are not easily reproduced with any degree of certainty.

We are hopeful that the revision to the Ocean Dumping Criteria will allow exclusion from the testing of dredged material which is substantially the same in physical and chemical properties as the sedimentary materials at the dump site.

In May 1981, the New Orleans District advertised for bids to perform ocean dumping bioassay/bioaccumulation tests on sediments to be dredged from the Barataria Bay Waterway gulf approach channel. Work to be bid on in the solicitation included:

a. Liquid and suspended particulate phase bioassays.

b. Solid phase bioassay.

c. Bioaccumulation study.

d. Chemical analyses.

e. Report preparation.

In the past, the New Orleans District accomplished bioassay testing through Architect-Engineer type contracts which were time consuming and more expensive than the competitive bidding procedure presently being used.

The contractor was required to collect, preserve, and transport disposal site water, channel, reference, and control sediments. Test sediments were obtained from three separate locations within the length of the channel. Reference sediments were collected from three separate locations parallel to the channel test sites, approximately 1,000 feet west of the disposal site and later composited to form one homogeneous reference sediment. Control sand was taken from the inter-tidal zone approximately 2 miles west of Barataria Pass. Water samples were collected near the surface, middle, and bottom of the water column and combined to represent general water conditions at the site.

For logistical purposes and convenience of inspection, the contract specified that all work be performed within a 300-mile radius of New Orleans, Louisiana. Because the solid phase bioassay test was a continuous flow through bioassay instead of the standard "static" type, the contract also specified that natural seawater obtained from an uncontaminated source in the Gulf of Mexico would be used in the test. The water had to approximate the salinity and pH conditions at the disposal area. Chemical analysis of water, sediment, and tissue samples of organisms to be tested were performed prior to the actual tests to determine pretesting levels of the constituents of concern.

The contractor made arrangements with the US Coast Guard to locate their mobile testing laboratory at the base in Grand Isle, Louisiana, because of its proximity to the project site. This allowed the contractor to utilize large amounts of channel site water required to run a flow through bioassay and better approximated the actual field conditions at the test site.

TABLE A.2: Results of liquid phase concentrations compared against disposal site water controls at site C-1, using sheepshead minnows showing no statistically significant difference.

TABLE A.1: Similar results of the suspended particulate phase.

TABLE A.19: Survival summary of the culture water controls for all three species used in liquid and suspended particulate phases of the bioassay.

TABLE C.5: Parameter summary of the liquid and suspended particulate phases using grass shrimp for all test sites and controls. The contract specified that the water temperature would be maintained at 25°C $\pm$ 1°C to represent summer conditions, and that DO concentrations not fall below 4.0 ppm.

TABLE B.1: Sites C-2 and C-3 show survival higher than the reference sediment. Although survival at site C-1 was lower than the reference, the difference was small enough where it was not statistically significant.

TABLE B.2: Same data as Table B.1, above.

TABLE B.3: Same type data as stated in Table B.1, above.

TABLE E.1: Time 0 shows that clams were contaminated with cadmium prior to testing, and actually depurated during the test. All test clams had lower levels of cadmium than the reference clams.

TABLE E.2: Although clams at sites C-1 and C-2 had higher tissue concentrations of mercury than the reference clams, the concentrations were not statistically different as shown by the calculations.

TABLE E.6: Same type data as stated in Table E.2, above.

In summary, the extensive bioassay/bioaccumulation testing of the Barataria Bay Waterway gulf approach channel sediment revealed that the disposal of such sediment would not result in any chronic sublethal or acute toxicity effect on organisms living adjacent to the disposal site.

The 100 percent suspended particulate phase or liquid phase did not approach the 96-hour LC_{50} for sheepshead minnows, grass shrimp, or brine shrimp.

Survival of clams, polychaete worms, or commercial shrimp in the channel sediment during the solid phase was not statistically significantly different from their survival rate in the reference sediment.

Clams and shrimp exposed to channel sediment during the solid phase did not accumulate any statistically significant levels of constituents of concern.

Channel sediment contained higher levels of contaminants than reference sediment. However, elutriates from both the channel and reference sediments were chemically indistinguishable.

Table A.2. Results of Sediment C-1 Liquid Phase Bioassay Using *Cyprinodon variegatus*

Exposure Condition	Replicate	Time of Observation - Number of Survivors 0 hr	4 hr	8 hr	24 hr	48 hr	72 hr	96 hr
Control, water from Disposal site	1	10	10	10	10	10	10	9
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Total	30	30	30	30	30	30	29
100% LP made from Sediment C-1	1	10	10	10	10	10	10	9
	2	10	10	10	10	10	10	10
	3	10	10	10	10	9	9	9
	Total	30	30	30	30	29	29	28
50% LP made from Sediment C-1	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	9	9
	3	10	10	10	10	10	10	10
	Total	30	30	30	30	30	29	29
10% LP made from Sediment C-1	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	9	9	9
	Total	30	30	30	30	29	29	29

Notes:

Sheepshead minnows were laboratory cultured and less than one month old. Tests were run October 28 to November 1, 1981.

Table A.1. Results of Sediment C-1 Suspended Particulate Phase Bioassay Using *Cyprinodon variegatus*

		Time of Observation - Number of Survivors						
Exposure Condition	Replicate	0 hr	4 hr	8 hr	24 hr	48 hr	72 hr	96 hr
Control, water from Disposal site	1	10	10	10	10	10	10	9
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Total	30	30	30	30	30	30	29
100% SPP made from Sediment C-1	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Total	30	30	30	30	30	30	30
50% SPP made from Sediment C-1	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	9	9	9
	Total	30	30	30	30	29	29	29
10% SPP made from Sediment C-1	1	10	10	10	10	10	9	9
	2	10	10	10	10	10	9	9
	3	10	10	10	10	10	10	10
	Total	30	30	30	30	30	28	28

Notes:

Sheepshead minnows were laboratory cultured and less than one month old. Tests were run October 28 to November 1, 1981.

Table A.19. Survival of Controls in Culture Water From Barataria Bay, Louisiana

Species	Replicate	Time of Observation - Number of Survivors 0 hr	4 hr	8 hr	24 hr	48 hr	72 hr	96 hr
Artemia salina	1	10	10	10	10	10	10	10
Brine shrimp	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Total	30	30	30	30	30	30	30
Palaemonetes pugio	1	10	10	10	10	10	10	10
Grass shrimp	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Total	30	30	30	30	30	30	30
Cyprinodon variegatus	1	10	10	10	10	10	10	9
Sheepshead minnows	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Total	30	30	30	30	30	30	29

Note:

Each control was run identically to and concurrently with the suspended particulate and liquid phase bioassay for the respective species.

Table C.5. Dissolved Oxygen (mg/l), Temperature, Salinity, and pH Measured During Suspended Particulate Phase (SPP) and Liquid Phase (LP) Bioassays Using Grass Shrimp

Parameters		Day 1			Day 2			Day 3			Day 4		
Dissolved* Oxygen	SPP C-1 100%	6.7	6.0	6.8*	7.0	6.9	7.0	4.6	5.0	5.4	6.5	6.4	6.7
	50%	5.5	5.1	4.4	5.8	6.2	6.4	4.1	4.8	4.4	5.9	6.1	6.1
	10%	4.7	4.6	4.6	7.0	7.5	7.3	5.7	6.2	6.1	6.1	6.3	6.0
	SPP C-2 100%	5.5	6.0	5.8	7.3	7.6	8.5	6.3	6.5	7.1	6.7	6.4	6.2
	50%	5.1	5.2	5.4	6.0	6.5	6.4	4.2	5.0	4.8	6.0	6.4	6.1
	10%	5.9	5.6	5.3	6.2	6.3	6.0	4.2	4.7	4.2	6.3	6.5	6.1
	SPP C-3 100%	5.1	5.5	5.3	5.8	6.6	7.2	4.0	4.8	5.4	6.6	5.9	6.1
	50%	5.7	4.9	5.4	6.5	7.1	6.5	5.0	5.7	5.0	6.1	6.1	6.2
	10%	5.3	5.5	5.3	6.8	7.0	7.3	4.9	5.4	5.7	6.3	5.9	6.0
	LP C-1 100%	6.7	6.6	6.7	7.0	7.0	6.7	4.1	4.6	4.1	6.5	6.8	6.2
	50%	6.7	7.0	6.0	6.0	5.0	5.4	4.3	4.0	4.1	5.9	6.1	6.2
	10%	4.9	4.8	4.8	7.8	7.4	7.7	6.1	6.0	6.3	6.1	6.3	6.0
	LP C-2 100%	5.0	5.1	6.7	5.7	6.1	6.4	4.3	4.6	4.8	6.5	6.2	6.7
	50%	4.9	4.5	4.9	5.8	6.3	7.0	4.5	5.2	5.7	6.6	6.2	6.8
	10%	5.5	5.2	5.8	5.2	4.1	4.6	5.3	4.0	5.3	6.3	6.1	6.5
	LP C-3 100%	5.7	5.6	5.9	5.6	6.4	7.1	4.0	4.0	5.4	5.9	6.3	5.7
	50%	4.7	4.5	4.8	5.6	6.7	6.9	4.0	5.1	5.3	6.6	5.8	6.1
	10%	4.2	3.7	4.1	7.3	6.6	5.5	4.5	4.0	4.0	6.0	6.3	5.9
	D.S. Control	5.9	6.2	6.1	6.6	6.2	6.2	6.0	5.7	5.7	6.8	7.1	6.6
	Lab. Control	6.5	6.5	6.7	5.5	4.6	6.2	5.0	5.5	5.6	6.3	6.8	5.9
Temperature	All Tests	26°C			25.5°C			26°C			26°C		
pH	All Tests	7.9			7.9			7.9			7.9		
Salinity o/oo	Lab Control	30			30			30			30		
	All Others	34			34			34			34		

*The three DO values for each treatment each day are values for each of the three replicates.

Table B.1. Results of Solid Phase Dredged Material Bioassays Using *Neanthes arenaceodentata* (Polychaete Worm) as the Test Species

	Number of Survivors in Each Replicate				
Replicate	True Control	Reference Sediment	Sediment C-1 Opposite Buoy #2	Sediment C-2 Opposite Buoy #6	Sediment C-3 Opposite Buoy #10
1	19	18	20	17	18
2	20	15	16	20	18
3	15	20	19	18	20
4	19	18	14	19	17
5	17	18	17	18	19
total survivors of 100	90	89	86	92	92
mean		17.8	17.2	18.4	18.4
sum of squared data		1,592	1,502	1,698	1,698
corrected sum of squares		12.8	22.79	5.198	5.198
variance, s^2		3.2	5.698	1.3	1.3

	sum of squares	mean square	
treatments	4.95	1.65	F = 0.57 ns
error	45.986	2.87	

Note:

Tests were started with 20 animals per replicate and were conducted from November 2 to November 12, 1981.

ns = no significant differences.

Table B.2. Results of Solid Phase Dredged Material Bioassays Using *Mercenaria mercenaria* (Clams) as the Test Species

Replicate	Number of Survivors in Each Replicate				
	True Control	Reference Sediment	Sediment C-1 Opposite Buoy #2	Sediment C-2 Opposite Buoy #6	Sediment C-3 Opposite Buoy #10
1	20	20	20	20	20
2	20	20	20	20	20
3	20	20	20	20	20
4	20	20	20	20	20
5	19	20	20	20	20
total survivors of 100	99	100	100	100	100

Note:

Tests were started with 20 animals per replicate and were conducted from November 2 to November 12, 1981.

Table B.3. Results of Solid Phase Dredged Material Bioassays Using *Penaeus setiferus* (White Shrimp) as the Test Species

Replicate	Number of Survivors in Each Replicate				
	True Control	Reference Sediment	Sediment C-1 Opposite Buoy #2	Sediment C-2 Opposite Buoy #6	Sediment C-3 Opposite Buoy #10
1	19	15	20	17	14
2	17	15	16	18	17
3	17	18	15	18	18
4	20	17	18	18	16
5	20	16	19	16	14
total survivors of 100	93	81	88	87	79
mean, $\overline{x}$		16.2	17.6	17.4	15.8
corrected sum of squares		6.8	17.2	3.2	12.8
variance, s^2		1.7	4.3	0.8	3.2

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Treatments	3	11.75	3.917	1.57 ns
Error	16	40	2.5	

Note:

Tests were started with 20 animals per replicate and were conducted from November 25 to December 5, 1981. Each replicate of 20 shrimp was divided between two aquaria with 10 shrimp apiece.

ns = no significant differences ($F_{.05(3,16)}=3.24$)

Table E.1. Results of Laboratory Assessment of Potential for Bioaccumulation of Cadmium by Clams (*Mercenaria mercenaria*)

	Concentration of Cadmium (ppb, wet weight) for Each Replicate					
Replicate	Time Zero	True Control	Reference Sediment	Sediment C-1 Opposite Buoy #2	Sediment C-2 Opposite Buoy #6	Sediment C-3 Opposite Buoy #10
1	130	31	50	58	39	31
2	270	37	50	32	45	54
3	210	30	60	63	47	30
4	100	33	80	18	38	45
5	20	24	230	52	25	54
mean, $\bar{x}$	146	31	94	45	39	43

Note:

All experimentals lower than reference.

Table E.6. Results of Laboratory Assessment of Potential for Bioaccumulation of Cadmium by White Shrimp (*Penaeus setiferus*)

	Concentration of Cadmium (ppb, wet weight) for Each Replicate					
Replicate	Time Zero	True Control	Reference Sediment	Sediment C-1 Opposite Buoy #2	Sediment C-2 Opposite Buoy #6	Sediment C-3 Opposite Buoy #10
1	1	<1	<1	<1	<1	<1
2	2	<1	<1	4	<1	<1
3	7	<1	<1	2	<1	<1
4	<1	<1	2	<1	<1	<1
5	9	6	<1	<1	<1	<1
mean, $\bar{x}$	4.0	2.0	1.2	1.8	<1	<1
s^2			.2	1.7		

Note:

No differences between reference and test treatments.

Variances homogeneous, t = 0.75, not significant.

Table E.2. Results of Laboratory Assessment of Potential for Bioaccumulation of Mercury by Clams (*Mercenaria mercenaria*)

	Concentrations of Mercury (ppb, wet weight) for Each Replicate					
Replicate	Time Zero	True Control	Reference Sediment	Sediment C-1 Opposite Buoy #2	Sediment C-2 Opposite Buoy #6	Sediment C-3 Opposite Buoy #10
1	30	30	70	40	40	<10
2	<10	80	50	40	40	<10
3	<10	<10	<10	80	20	30
4	70	10	<10	<10	40	<10
5	90	<10	10	80	60	10
mean, $\bar{x}$	42	28	30	50	40	14
sum of squared data			770	16,100	8,800	1,300
corrected sum of squares			3,200	3,600	800	320
variance, s^2			800	900	200	80

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Treatments	3	3,535	1,178	2.38 ns
Error	16	7,920	495	

Note:

ns = no significant differences between treatments
($F_{.05(3,16)}=3.24$)

O&M DREDGING EXPERIENCE AS RELATED TO CHANNEL DEEPENING FOR COAL PORTS

by

R. G. VANN, P.E.[1]

ABSTRACT

The Norfolk District, Corps of Engineers, has been involved in innovative channel design, dredging techniques, disposal operations, and environmental coordination which favorably impact on water quality. Innovative channel design for coal export shipping lanes will minimize dredging. The design will employ a computerized ship maneuvering simulator operated by the U.S. Maritime Association and their Computer Aided Operations Research Facility (CAORF). A dredging demonstration with nationwide application in the removal of contaminated sediments is underway on the James River. The demonstration will document the advantages of dredging in a riverine system with different dredge heads: a cutterhead and a dustpan head. Engineering studies indicate that a dustpan head will dredge at near in-place density and thereby reduce turbidity and disposal problems. The district, with the assistance of Federal and state environmental agencies, has made site specific studies to determine the propriety of seasonal dredging restrictions. In four cases the restrictions were found to be unnecessary. Pre-designation studies of the new ocean disposal area (Norfolk Disposal Area) have also been conducted by the district. In addition, positive steps have been taken to effectively manage the Craney Island Disposal Area, with the ultimate view of significantly extending the site's useful life. Other beneficial usages of dredged material have been undertaken by the district, including: marsh creation, beach nourishment, nesting habitat for waterfowl and improved oyster bed substrate. Beneficial usage is essential to successful environmental coordination prequisite to the actual dredging. To that end, the district has instituted bimonthly environmental coordination meetings with the state and Federal environmental regulatory agencies. The meetings have proven to be the single most important factor in the successful accomplishment of the district's O&M dredging program.

[1]Chief, Dredging Management Branch, Norfolk District

TEXT

My subject is entitled "O & M Dredging Experience as Related to Channel Deepening for Coal Ports". While a major emphasis will be placed on dredging in Hampton Roads and its coal related activities, I will also address other district dredging efforts which I believe relate to water quality and may have applications to the Hampton Roads deepening. Actually, I had some difficulty in limiting the scope of this presentation since dredging and water quality cannot be separated. Those topics which I will briefly discuss are:

- Dredging
  - Hampton Roads
  - James River
  - Seasonal Dredging Studies
- Disposal
  - Craney Island Management Plan
  - Ocean Dumping
  - Beneficial Usage
- Environmental Coordination

The Hampton Roads area is a rapidly expanding region whose economy has historically depended upon port and related activites. The authorized project currently serving Hampton Roads provides for channels 45 feet deep over widths varying from 800 to 1500 feet. Maintenance, including permit dredging, requires the removal of approximately 5.0 million cubic yards of material annually.

One major Hampton Roads port activity--the export coal business--has been receiving world wide attention. The January 1981 issue of the magazine, "Commonwealth", contained an article which stated that "Hampton Roads, because of its fine natural harbor and its proximity to the Appalachian coalfields, is the nation's dominant coal port, handling 80 percent of the country's exports".

The renewed international interest in coal has resulted in a significant increase in coal exports from the NWS coal loading facility (NWS Enterprise, Inc.) in Norfolk and the CSX coal loading facility (Chessie System) in Newport News. In 1977, 26.6 million tons of coal moved through the port, while in 1980, 50.6 million tons of coal were shipped from Hampton Roads. The Virginia Port Authority estimates that 55 million tons of coal were shipped from Hampton Roads in calendar year 1981.

Because the future of coal in U.S. foreign trade has been greatly enhanced, additional coal loading facilities will be constructed at Hampton Roads. The new piers are expected to handle up to 45 million tons of coal a year. Several small facilities are also planned. The combined coal tonnage expected to pass through Hampton Roads will exceed 110 million tons a year.

One problem which faces most major U.S. ports is that the channels are not deep enough to accommodate the increasing vessel sizes. The trend to build large "super" vessels has been overwhelming and has caught the United States ports unprepared.

Currently, East and Gulf coast ports are limited to fully loaded vessels in a range of 40,000 to 80,000 deadweight tons drawing 45 feet. Hampton Roads coal terminals already receive colliers in excess of 100,000 deadweight tons which cannot sail fully loaded due to draft limitations of the existing channels. On 2 February 1981, the Virginia Pilot Association checked the maximum draft of vessels at anchor and found that of the 157 vessels in anchor, 67 could not load coal to maximum capacity.

Also increasing in size are vessels carrying liquid petroleum products, grain, fertilizer, and miscellaneous dry bulk commodities. Many ships carrying petroleum products have to lighter in the port. Just as being unable to fully load the coal ships increases transportation costs, lightering also increases costs. The effect is detrimental to business and to the port. The capacity of a port to receive large coal colliers and turn them around without excessive delays has a major bearing on the competitiveness of coal on overseas markets. Vessel delays, for whatever reason, are costly. These delays translate into increase waterborne transport costs to ship coal overseas. The solution involves a need for deeper channels to accommodate super coal colliers, commensurate docking and berthing facilities to permit quick loading and release of vessels, and critical interfacing between the carriers and coal interests. To answer this need, the Norfolk District has taken steps to increase channel depths to 55 feet to meet the increased demand for U.S. coal.

Many questions must be addressed in full detail to assure safe navigation and, at the same time, minimize cost and environmental impacts. Emphasis is being directed toward minimizing overdredging and maintaining acceptable levels of water quality. To answer these questions, the district will rely on experience gained in the accomplishment of our O & M dredging program and some recently developed concepts. One such concept, not previously used by the district, is the computerized ship-maneuvering simulator operated by the U.S. Maritime Association and their Computer Aided Operations Research Facility - CAORF.

CAORF is a highly sophisticated ship-maneuvering simulator for controlled research into man-ship-environment problems. We believe that through controlled experiments, with several vessels simulated under varied conditions, real world impacts on vessel handling characteristics can be evaluated, using local pilots in the man-in-the-loop concept. The CAORF evaluation will prove an invaluable part of our analysis to achieve an optimum channel design.

CAORF begins where we have always begun - with the dimensions of the ships expected to frequent the harbor. To these dimensions, we apply a multiplicity of concerns to arrive at an optimum channel design. I would like to briefly address these concerns.

The factors we address for channel width design are many. Of these items, CAORF will give us very tangible design results for: vessel response, pilot reaction, weather conditions and navigation aid locations. CAORF will address these items by tracking, under various conditions, the path taken by the simulated vessels.

In addition, other ship-handling phenomena are simulated, such as "Yaw" or drift angles. Trackkeeping performance for all runs are analyzed, from which CAORF generates a "Track Envelop". To this "track envelop" we will super-impose our other considerations to arrive at an optimum channel width. These concerns include: environmental issues, disposal problems, dredge types, shoaling rates, physical and social constraints, military needs, and economic concerns.

We go through a similiar analysis for channel depth. Again, we begin with vessel size. To these dimensions we apply a number of factors that correlate with our width determination. Some of the factors we apply are directly related to vessel size and water characteristics, such as trim, squat, and maneuverability. These factors result in a theoretical "safe" channel depth, but not necessarily the "optimum" channel design depth. Other factors must be applied such as the location of physical structures, shoaling rates, slope stability, and disposal issues. I would like to point out that the optimum depth could vary over the length of a channel since depth parameters can differ significantly at different channel points.

I am convinced that the simulator will enable us to optimize our channel design and thereby eliminate unnecessary overdredging. If a channel of reduced overall dimensions, but suitably widened at critical points, is found satisfactory, it would significantly reduce the quantity dredged, the disposal area concerns, abate environmental issues, reduce dredging costs and impacts on water quality. A channel decrease of only 100 feet in Norfolk Harbor would result in a 400,000 cubic yard reduction in the dredging quantity at a cost savings of almost $2,000,000. Our objective is to provide an optimum channel, at an optimum location, with minimum price. Preliminary results of tests run thus far indicate that we will be able to reduce the dredging required. One additional item of interest is the use of the Chesapeake Bay Model to simulate the deepened channel. The model will help us to assess the environmental impacts of the dredging - specific attention is being given to possible impact of increases in salinity.

Another district dredging project which could have nationwide application is currently in progress on the James River. The purpose of this dredging is to demonstrate improved methods of removing contaminated sediments and a potential method for toxic spill clean-up. One of the unique aspects of this work is that it is being accomplished as a part of our on-going O&M program on a river contaminated with the insecticide Kepone. Briefly, the project will demonstrate the advantages of dredging in a contaminated riverine system with a pipeline dredge equipped with first a cutterhead then a dustpan head. Extensive and sophisticated monitoring will be employed. Engineering studies indicate that by using the dustpan head and appropriate operating equipment and procedures, a dredge could remove a selected layer of silt at near in-place density with a minimum of resuspension. This would greatly reduce disposal problems and turbidity generated by the dredging. We are hopeful that the lessons learned on the James River can be applied to other areas where the resuspension of toxic materials must be minimized.

The Norfolk District, with the assistance of state and Federal environmental agencies, has conducted several site specific studies to determine the propriety of seasonal dredging restrictions. We were concerned that the restrictions were arbitrary and were needlessly complicating the dredging effort and resulting in increased cost while providing no real environmental protection.

To date, we have studied four unique sites, one of which was Hampton Roads. I should emphasize that we selected those areas for study where we suspected the restrictions were inappropriate. In all four cases the restricted dredging period was found to be unnecessary. Some of the analysis tools we have used are physical monitoring, physical and mathematical models, hazardous assessments, bioassay testing, and more. Our experience has taught us:

1. Coordinate early and extensively with all environmental agencies.

2. If there are environmental problems and uncertainities, get the advice of a specialist who has the confidence and respect of all agencies.

3. Try to anticipate problems before they happen and assess their potential impacts.

4. Be sure all testing and sampling conforms strictly to accepted EPA standards and criteria.

Now let us briefly discuss disposal concerns.

The Norfolk District owns and operates a 2500-acre upland disposal area known as Craney Island. It serves the entire port of Hampton Roads with both Federal and private concerns using the area for the disposal of dredged material. Approximately 5 million cubic yards of material are deposited annually from dredging in and around Hampton Roads.

Because of the lack of suitable disposal sites in close proximity to the port, the Norfolk District requested the Waterways Experiment Station (WES) to study the disposal practices at Craney Island and offer suggestions that would extend the useful life of the disposal area.

If present operations continue, the area would reach its redesigned height of +30.0 feet in approximately 18 years.

As a result of the study, WES, in conjunction with the Norfolk District, developed the Craney Island Management Plan. Specific objectives of the Plan are:

1. Maximize storage capacity.

2. Dewater and densify dredged material.

3. Reclaim and use dredged material.

4. Maintain or improve water quality of effluent.

5. Abide by legal and policy requirements.

In order to implement the Management Plan, the district must complete the north and south division levees to subdivide the area into the 3 subcontainment areas recommended.

One sub area will be used for disposal activities, the other two will have the surface water decanted and as soon as a crust forms, trenches will be cut to start consolidation of the material.

Projected increase in project life with the Management Plan fully implemented is an additional 18 years. Once the plan is fully implemented each area will be used for disposal for a one year period and allowed to dry and densify for a two year period.

With a little strategic land-scaping, the area can serve a dual role, one as a much needed disposal area, the other as a beautiful recreation area.

Ocean disposal of dredged material is also being considered to augment the use of Craney Island.

At this time a new site 8 miles in diameter in the Atlantic Ocean is undergoing pre-designation studies. This site will provide for long term ocean disposal in accordance with Section 103 of Public Law 92-532. The expensive and comprehensive studies are nearly complete. Site designation is expected later this year. Included in the pre-designated effort are studies being conducted by Old Dominion University (ODU) in Norfolk to analyze the characteristics of the harbor sediments and determine possible water quality effects of the dredging. Bioassay testing using grass shrimp is on-going to test for lethal and sub-lethal effects of solutions with various concentrations of sediments from the harbor. Most of the testing to date has been related to the disposal of the dredged material. The Corps, along with the National Oceanic & Atmospheric Administration and ODU, has determined that the preponderance of the dredged material will be suitable for ocean disposal.

An interim site in the Atlantic Ocean, known as the Dam Neck Site, has been used since 1967. Approximately 20 million cubic yards of material have been placed in this area. Continued use of the site for the disposal of sandy material is currently under study. The idea being to stock pile the valuable fill for beneficial usage elsewhere as the need arises.

Concerning beneficial usage, we are most anxious to utilize dredged material for positive ends.

We estimate that the deepening of the channels serving Hampton Roads will generate 68 million cubic yards of usable material. We will have an over abundance of this valuable commodity. Some of the positive benefits we will employ are:

1. Promote levee construction at Craney Island, thereby extending its useful life.

2. Nourishment of area beaches.

3. Construction material stockpiled in easily accessible sites.

4. Construct perched beaches to reduce future erosion effects.

5. Cover material for exposed, undesirable bottom areas, such as the Kepone areas on the James River or previously used disposal sites.

In a number of other O&M dredging projects, we have successfully created marsh areas, made habitat for nesting waterfowl, and improved oyster bed elevations. I cannot over emphasize how important beneficial usages are and how necessary they are to the ultimate acceptance of the dredging plan.

The ultimate acceptance of the dredging plan leads me into my final topic, that being environmental coordination. In my opinion, the single most important factor in the success of the Norfolk District's dredging program has been our Environmental Coordination Meetings. Environmental scientists work with engineers on a daily basis. In these meetings we meet every other month with state and Federal regulatory agencies to discuss and often cuss our dredging program. We lay all our cards on the table - no hole cards - everybody is a player and all concerns and issues are openly and frankly explored. One important fact: The Corps always has a recommendation. We have found that the concerns never settle if the target keeps moving. For that reason, we state our position and field the issues as they surface. In most cases we are able to anticipate the issues and have ready answers. Our answers must never appear arbitrary or capricious. We make certain they are based on sound engineering principles and the recommendations of WES. Because of such meetings we are able to generate a "team player" concept. This concept helps immeasurably in the preparation of environmental impact statements, assessments, public notice, and the receipt of permits.

In summary, the water quality aspects associated with the deepening of Hampton Roads have and will be addressed through a wide variety of advanced dredging and disposal techniques. They will include:

Technical Applications

Scientific Research

Development or Modification of Dredging Plant

Beneficial Usage

Environmental Coordination

DENISON MANAGEMENT RELEASES

BY

RICHARD E. PUNNETT[1]

JAN C. CULBERTSON[2]

INTRODUCTION

Generation releases from Denison Dam on the Oklahoma-Texas Border frequently approach anoxia from July to September each year. Fish kills associated with low dissolved oxygen (DO) in the releases have been noted infrequently over the past several years. The worst documented fishkill occurred during early September of 1979 and consisted primarily of striped bass. The estimated value loss of the striped bass was about $44,800. Striped bass were introduced into Lake Texoma in the early 1970's. Solutions have been sought to improve the downstream fishery conditions by increasing the DO concentrations. Tests were conducted to determine what management practices were desirable to provide immediate relief to the downstream fishery during a fish kill and to provide a short-term operation which would support the fishery during a period of high potential for a fish kill.

Denison Dam began operation of two hydropower units in 1949, each unit releases about 5,000 cfs at the top of the power pool. Both penstocks and the six floor conduit inverts are located 85 feet below the top of the power pool. During the stratified period of 1980, generation typically began about noon and continued to late evening on Mondays, Wednesdays, and Fridays. Generation during the weekends, if any, was usually shorter in duration.

Current estimates by the Corps show the area below the dam receives about 257,000 man-days of fishing annually. The fishery was valued at about $2,190,000 using the unit day method and the $8.95 per man-day value set by the Water Resources Council (1979). A value of about $632,000 was calculated using the $2.46 per man-day figure suggested by the U. S. Fish and Wildlife Service (1975) for Oklahoma.

MONITORING PROGRAM

Prior to testing different management practices, a monitoring program was established in 1980 to determine what periods were most stressfull to the fishery immediately below Denison Dam. Temperature, DO, conductivity, and pH data were collected at least bi-weekly during the lake stratification period. Occasional sampling for BOD5, ammonia nitrate, hydrogen sulfide, total iron, and manganese was accomplished.

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Data Analysis

Most parameters indicated a poor water quality condition typical of anoxic hypolimnetic releases. The temperature ranged from 19.0 to 24.5° C. Conductivity ranged from 1,800 to 2,540 umhos/cm. The range for pH was 7.2 to 7.9. BOD5 varied from 1 to 4 mg/l. NH4 varied from 0.11 or 0.64 mg/l. Hydrogen sulfide, total iron, and manganese were investigated by Oklahoma State University and ranged from 0.040 to 0.45, 0.12 to 0.14, and 0.60 to 0.80 mg/l, respectively. DO was found to vary diurnally without generation from 1.4 to 6.8 mg/l in shallow areas. In generation releases, DO varied from 1.6 to 3.0 mg/l; the greater values occurred toward the end of the stratification period in September.

Other Observations

During periods of no generation, the fish catch rate was poor. Shortly after generation began, the catch rate for striped bass increased dramatically. Striped bass predation on shad was visually evident during generation periods. Although the DO ranged from 1.6 to 3.0 mg/l for this period, feeding activity was high.

In early July, a grey-colored substance formed in solution downstream. The substance disappeared about 200 yards downstream. The substance was not evident during periods of generation, but was observed in releases up to at least 600 cfs. Coincident with the appearance of the substance was the strong odor of hydrogen sulfide. By mid-September both the substance and odor disappeared.

1980 RELEASE TEST DESCRIPTIONS AND RESULTS

General

Releases made through the generators have little opportunity for aeration. Releases made through the flood conduits go through a hydraulic jump, a series of baffle blocks, and either over a weir or through orifices in the weir. Thus the flood releases have a higher potential for aeration than do the generation releases. Two tests were conducted to determine the DO improvement using the flood conduits. The first test release was a high flow rate, short duration release and the second test was a low flow rate, continuous (24 hours or greater) release.

A third test was conducted to determine what improvements in the water quality were possible by making partial epilimnetic releases through the conduits. Since the epilimnion of Lake Texoma can provide good quality water, surface water was pumped downward to displace the hypolimnion at the conduit intakes. This test was conducted jointly with the Agricultural Engineering Department of Oklahoma State University. The general results of the tests are presented in this report, however a more complete report (see ref. 1) was accepted for publication by The American Society of Civil Engineers in the Journal of Environmental Engineering Division.

High Flow Rate, Short Duration Release

A test release of 10,000 cfs for 30 minutes was made through the flood conduits to determine if the anoxic release would become sufficiently aerated to immediately improve the downstream DO. The test release was made with and without generation.

DO concentrations below the stilling basin were increased from anoxia to near saturation values as a result of the turbulent aeration. DO increases were immediate in the stream just below the basin; however, DO increases about 2 miles downstream did not occur until about 1 hour later (increasing from 3.3 to 5.8 mg/l) during a nongeneration period. During a generation release of about 9,200 cfs, DO increases were not noted until about 4 hours later at the 2 mile downstream station (an increase of about 1.5 mg/l).

Low Rate, Continuous Release

A continuous test release of 50 to 100 cfs was made through the flood conduits to determine if at least one area of sufficient DO could be maintained in the reach immediately downstream of the dam. Although the instream affects would be negligible during generation periods, it was hoped that the downstream reach could be improved during critical nongeneration periods.

DO concentrations at the end of the stilling basin were 82% saturated; 200 yards downstream from the basin, DO concentrations were 47% saturated; 2 miles downstream, the DO was saturated. These values were measured early morning after a 36-hour period of nongeneration. DO concentrations immediately below the stilling basin were maintained at near saturation values even during generation. Although stilling basin DO values remained constant, downstream values decreased rapidly with the onset of generation.

Partial Epilimnetic Releases

Using a 8-foot diameter Garton pump (1982), 150 cfs was pumped downward immediately upstream of the conduit intake. Releases of 50, 150, 300, 450, and 600 cfs were made through the conduit. The pump impellor was about 6 feet below the surface.

The maximum improvement (decrease) in turbidity, hydrogen sulfide, phosphorus, manganese, ammonia nitrate, and total iron was 83, 68, 53, 49, 37, and 21 percent respectively. The release temperature was increased a maximum of $2^{o}C$. Because release samples were taken after the hydraulic jump had occurred, DO increases were slight (less than 1 mg/l); however the reduction in manganese, total iron, and ammonia nitrate levels decreased the DO demand in the stream. The best release rate to pumping rate ratio was between 2.0 and 3.0.

1981 RELEASE TEST DESCRIPTIONS AND RESULTS

General

During 1981 the low flow rate, continuous release management practice was tested at Denison, Keystone, and Tenkiller Ferry Dams. Some additional monitoring programs were initated to establish the DO characteristics below each of these projects. A continuous release made through the flood conduit has an associated loss of revenue for power projects. Estimates of the current market value of the loss of revenue for the conduit releases are about $900 per day at Denison and Keystone Dams, and about $1100 per day at Tenkiller Ferry Dam for a 50 CFS release.

Denison Dam

By early July, 1981, the DO concentrations in power releases had dropped below 1.5 mg/l, however no fish mortalities were noted. The presence of the grey-colored substance was observed in the tailwater by mid-July. Some test releases of 50 to 100 cfs were made through the conduit during several weekends. Readings taken on Monday mornings showed DO concentrations to be near saturation in the tailwater prior to the onset of generation. Striped bass fishing was reported to be good during the periods when the low flow rate releases were made.

On the morning of September 4, a large number of striped bass were reported in the tailwater near the surface and showing signs of stress and loss of equilibrium. DO levels of less than 1.9 mg/l were measured. A generation release was initiated which averted the potential for a fish kill. To relieve the stress on the fish during nongeneration periods, a 50 cfs release was initiated through the conduits. The 50 cfs release was discontinued on September 22, 1981, when the grey-colored substance disappeared and the DO concentrations during generation had increased to 6.5 mg/l. By September 22, the lake was near total destratification.

Keystone Dam

Keystone Dam began generation in 1968, and exhibits the same water quality problems as Denison Dam. Both penstocks and the nine sluice gate inverts are located about 67 feet below the top of the power pool. There are 18 tainter gates; the weir crests are located less than 6 feet below the top of the power pool. Current estimates show the area below the dam to receive about 267,800 man-days of fishing annually. Using the unit day method, the fishery is worth about $2,284,000 according to the Water Resources Council (1979) values. The U. S. Fish and Wildlife Service values (1975) set the worth at about $659,000.

In May of 1981, a fishkill consisting almost entirely of shad occurred in the basin area. The DO concentration during generation at this period was about 5.8 mg/l, however DO profiles in the basin revealed anoxic conditions below 3 feet less than 24 hours after generation ceased. Lake profiles revealed a chemocline at a depth of about 35 feet . DO below 40 feet was depleted. The chemocline was characterized by conductivity readings increasing from 2,600 to over 6,000 umhos/cm. Leakage of about

10 cfs through the generators apparently caused the tailwater water quality to deteriorate in the absence of generation.

On July 23, a release of 135 cfs was made through the sluice gates. The release passed through a conduit in the spillway, over a hyperbolic lip, and cascaded down to the stilling basin. The release became saturated with DO and in a 4-hour period was able to increase the tailwater DO from 48 to 96% saturation. Releases through the spillway, although high in DO, did not mix with the tailwater because of density differences.

On July 25, a generation release of about 5,000 cfs from 1300 to 1400 hours was monitored to determine the DO and temperature affects. In the basin, the average DO content went from 6.9 to 4.1 mg/l, and the temperature decreased 1.1 from 27.6^{o} C. At a station downstream in a shallow area (6 feet), the DO dropped from 11.0 to 3.9 mg/l. The super-saturated DO condition was probably due to photosynthetic processes. The temperature at this station decreased 2.0 from 28.7^{o} C.

Tenkiller Ferry Dam

Tenkiller Ferry Dam began generation in 1953. The penstocks and conduit inverts are about 132 feet below the top of the power pool. The hypoliminetic releases provide cold enough water throughout the year to maintain a cold water fishery downstream. Current estimates for the fishery ranges from $109,000 to $378,000 for the warmwater fisher and from $358,000 to $646,000 for the coldwater fishery. The two types of fishery exist concurrently because of the state's trout stocking program and the introduction of striped bass in the Arkansas River System. The river reach below Tenkiller Ferry Dam extends about 8 miles to the confluence of the Arkansas River. Backwater effects from Robert S. Kerr Lock and Dam are evident at the confluence. By mutual agreement between the Southwest Power Administration, the Oklahoma Department of Wildlife Conservation, and the Corps, a minimum daily generation is scheduled to protect the coldwater fishery.

The temperature and DO were recorded at 0, 2, 6, and 8 miles downstream of the dam. The temperature of the releases in July was about 10^{o} C. By early October, the release temperature was about 17^{o} C. The river temperature generally increased about 3^{o} C from the dam site to the confluence during nongenerating periods. Temperature increases with generation were generally less than 1.5^{o} C. No temperature readings exceeded the 20^{o} C Oklahoma maximum standard for coldwater fisheries. DO concentrations declined from 5.0 mg/l in late June to less than 2.0 mg/l in September in the generation releases. Between generation periods, DO concentrations increased at all stations about 2 to 3 mg/l. DO increased with downstream distance generally less than 1.0 mg/l without generation. DO concentrations decreased with the onset of generation. DO concentrations were lowest during September and early October as compared to August and early September for both Denison and Keystone downstream values.

On July 28, a test release of about 30 cfs was made through the flood conduit. The release was 10^{o} C and contained 11.0 mg/l of DO compared to a simultaneous generation release of 13.0^{o} C with a DO concentration of 3.0 mg/l. Although a monitoring period of 24 hours after generation ceased was planned, 1.12 inches of rain confounded the data and the monitoring was discontinued after 6 hours.

During most of the year, trout have been stocked at several locations downstream of Tenkiller Ferry Dam. By late July, stocking was limited to only the lower part of the river where DO conditions were considered minimal at best. In the lower river reaches, considerable predation of trout by striped bass occurs during late summer (Deppert, 1976). A continuous release of 50 cfs from mid-July to mid-October may improve the DO sufficiently to allow stocking at locations were predation is not a problem.

Further testing at Tenkiller Ferry Dam is required to determine the instream benefits of a low flow rate, continuous release through the conduit. The operational agreement of a daily generation release should be reconsidered since generation reduces instream DO. The reduced instream flow and temperature affects from reduced generation need further evaluation.

SUMMARY

Recent fish kills below two Oklahoma projects revealed the need for a management practice to prevent fish kills associated with low DO. DO concentrations in releases made through flood conduits were aerated to saturation values from anoxic conditions due to the turbulent nature of the release. A high flow rate, short duration conduit release was tested at Denison Dam. A low flow rate, continuous conduit release was tested at Denison, Keystone, and Tenkiller Ferry Dams. A partial epilimnetic release made through the conduit at Denison Dam was also tested.

A 10,000 cfs release for 30 minutes was tested to determine if this was a desirable management practice during a fish kill. The downstream DO concentrations were raised from near anoxia to near saturation values almost immediately. Observations during generation periods below Denison and Keystone showed the fishery to be actively feeding even though the DO was less than 3.0 mg/l. If a report is received during a fish kill, generation release is recommended for Denison or Keystone Dam. Although the release of 10,000 cfs was effective in improving the downstream DO, a generation release would be sufficient for increasing DO levels. At Tenkiller Ferry Dam, a conduit release should be considered over a generation release to alleviate a fish kill condition.

The lowest DO concentration during nongeneration periods was found to be early morning below Denison and Keystone Dams. A continuous release of 50 cfs through the flood conduits was sufficient to maintain the early morning DO concentrations to near saturation values. A release of 135 cfs was sufficient to increase DO concentrations below Keystone Dam from 48 to 96% saturation in 4 hours. The lowest DO concentrations below Tenkiller Ferry Dam occurred during generation periods in the Fall. A 30 cfs conduit release at Tenkiller Ferry Dam aerated to DO saturation.

By pumping surface water downward to displace the hypolimnion at the conduit intake at Denison Dam, improvement in the release water quality was possible. The maximum reductions of turbidity, hydrogen sulfide, phosphorus, manganese, ammonia nitrate, and total iron was 83, 68, 53, 49, 37 and 21 percent, respectively.

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MOUNT ST. HELENS RECOVERY OPERATIONS

by

Robert E. Willis[1]

Introduction

Following the catastrophic eruption of Mount St. Helens, Portland District, Corps of Engineers began perhaps the most unusual recovery operation in the history of the Corps. The purpose of this presentation is to portray, in general terms, the emergency situation that existed and the recovery measures implemented by Portland District.

The Eruption

Mount St. Helens, located in the southwest corner of the state of Washington, has been the most active volcano in the Cascade Range over the last several thousand years. Typically, periods of dormancy have rarely exceeded 200 years. In late March 1980, this picturesque mountain began exhibiting earthquakes and minor steam and ash ejections, signaling a new era of activity for the 123-year dormant volcano. Minor eruptions continued, becoming larger and larger as the weeks passed, resulting in a massive and explosive eruption on Sunday morning, 18 May 1980.

The eruption and blast disgorged an estimated four billion cubic yards (cy) of material, lowering the height of the mountain by more than 1,200 feet and forming a huge crater more than a mile in diameter. The damage, occurring in a 170-degree arc north of the mountain, devastated a 156-square-mile area. The hot gases and the force of the explosion completely destroyed all trees up to seven miles from the mountain, uprooting trees 12 miles out and destroyed other trees as far as 17 miles away.

As shown in figure 1, the blast and resultant mudflows seriously impacted the river basins of the Toutle, Cowlitz, and Columbia Rivers. The debris and mud avalanche left massive deposits in the Toutle River drainage. This deposit extends down the upper reach of the river for a distance of 17 river miles and is over 600 feet thick in places. Volume estimates of the debris avalanche vary from 2.5-3.5 billion cy.

Mudflows that followed carried material which deposited in the Toutle, Cowlitz, and Columbia Rivers. Approximately 50 million cy of sediment was deposited into 21 miles of the Cowlitz River from the mouth of the Toutle downstream, and approximately 45 million cy in the Columbia River near the mouth of the Cowlitz River.

[1]Wildlife Biloligist, U.S. Army Engineer District, Portland

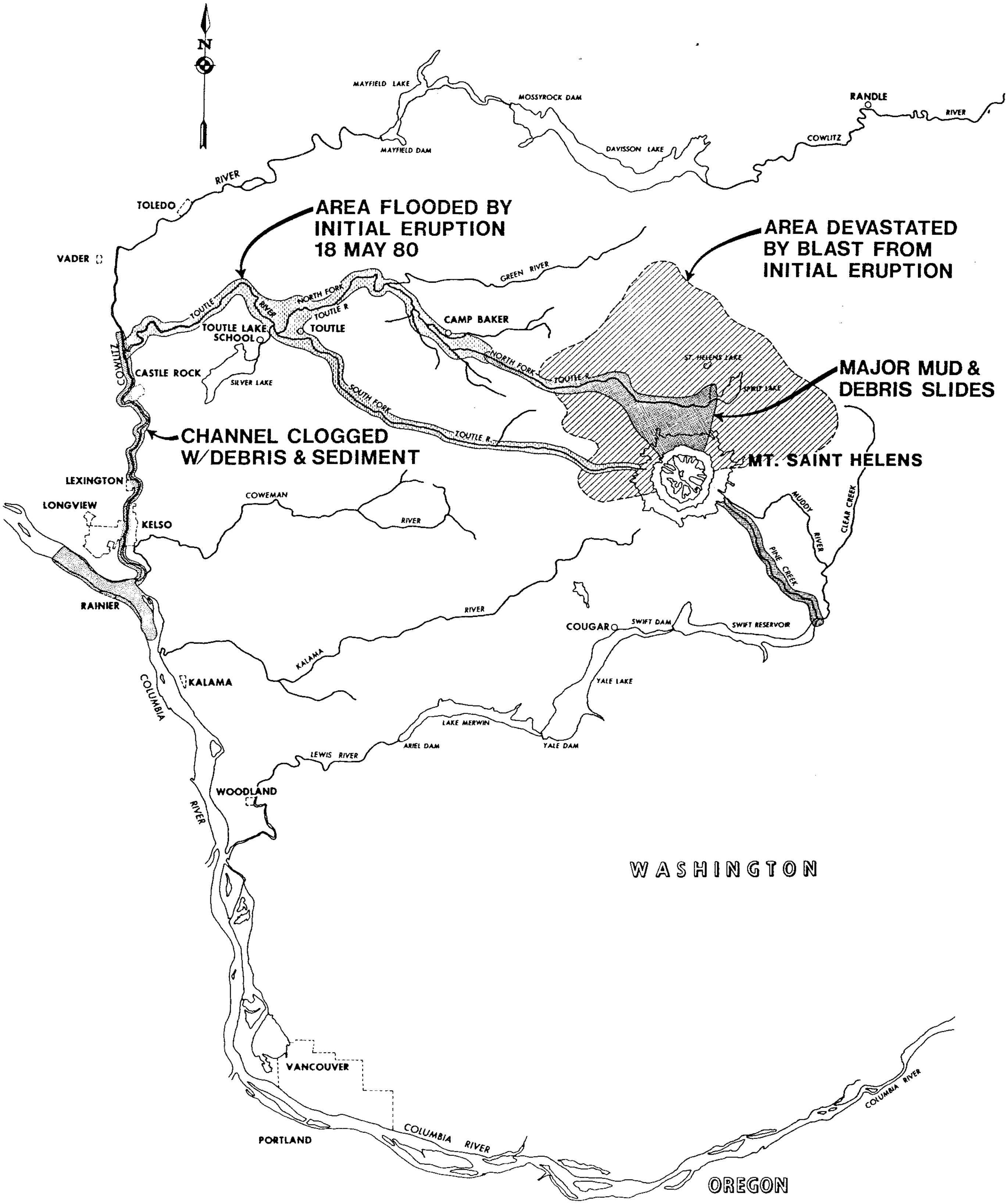

Figure 1 Areas Impacted by the Eruption

COLUMBIA RIVER

The Columbia River navigation channel, from the mouth to Portland, Oregon, is maintained at a 40-foot depth and 600-foot width. The day after the eruption, a vessel ran aground in the middle of this channel. As shown in figure 2, hydrographic surveys revealed a 9-1/2-mile shoal, which had reduced navigation depths to 15 feet. Approximately 14 million of the 45 million cy total infill deposited in the Columbia was in this navigation channel.

On 20 May, a plan for dredging was established (see figure 3) and the Hopper Dredge "Biddle" began work. In 5 days, the three hopper dredges assigned to this emergency had opened an emergency channel that permitted ship passage during high tide "windows" supervised by the U.S. Coast Guard. By 29 May, the channel had been expanded to 25 feet by 200 feet. On 14 June, the last ship of the 31 vessels trapped upstream of the shoal was able to proceed downriver with its cargo of grain. The 14 million cy of infill in the channel project limits were removed generally on schedule, and an unrestricted navigation channel was open to traffic by 30 November 1980. To date, approximately 26 million cy of sediment has been removed to restore and maintain the navigation channel to its pre-eruption state.

COWLITZ RIVER

The 21 miles of the Cowlitz River,from the mouth of the Toutle River downstream to the Columbia River,were impacted severely by the mudflows. Figure 4 illustrates the river profiles of the Cowlitz River before and after the eruption. As shown, natural channel capacities were virtually eliminated by the 50 million cy of infill. Before the ruption, a 76,000-cfs channel was in place. Figure 5 shows the probability of flooding; with even a normal water year, severe flooding would be expected.

Recovery efforts for the Cowlitz River centered around excavating this massive infill to restore its flood carrying capacity to the maximum extent practicable by 1 December 1980. Thirty-three million cubic yards of material was excavated by 1 December, with an addition 23 million cy removed in maintaining this channel, until work was terminated on 30 September 1981.

To remove this 56 million cy of sediment, an intensive and massive effort was required. During the height of operations, the following equipment was in operation: 23 pipeline dredges, 17 tower-type draglines, 52 draglines, 29 backhoes, and 226 hauler-loaders. A total of 4,400 acres were donated as disposal sites by the local landowners. Since an adequate channel would not be in place before the winter rains, flood control storage was obtained from Mossyrock Reservoir on the upper Cowlitz River for the 1980-81 winter.

In addition to the excavation work on the Cowlitz River, the feasibility of other flood protection measures was examined. The construction of levees at certain locations on the Cowlitz were found to be justified. To this end,

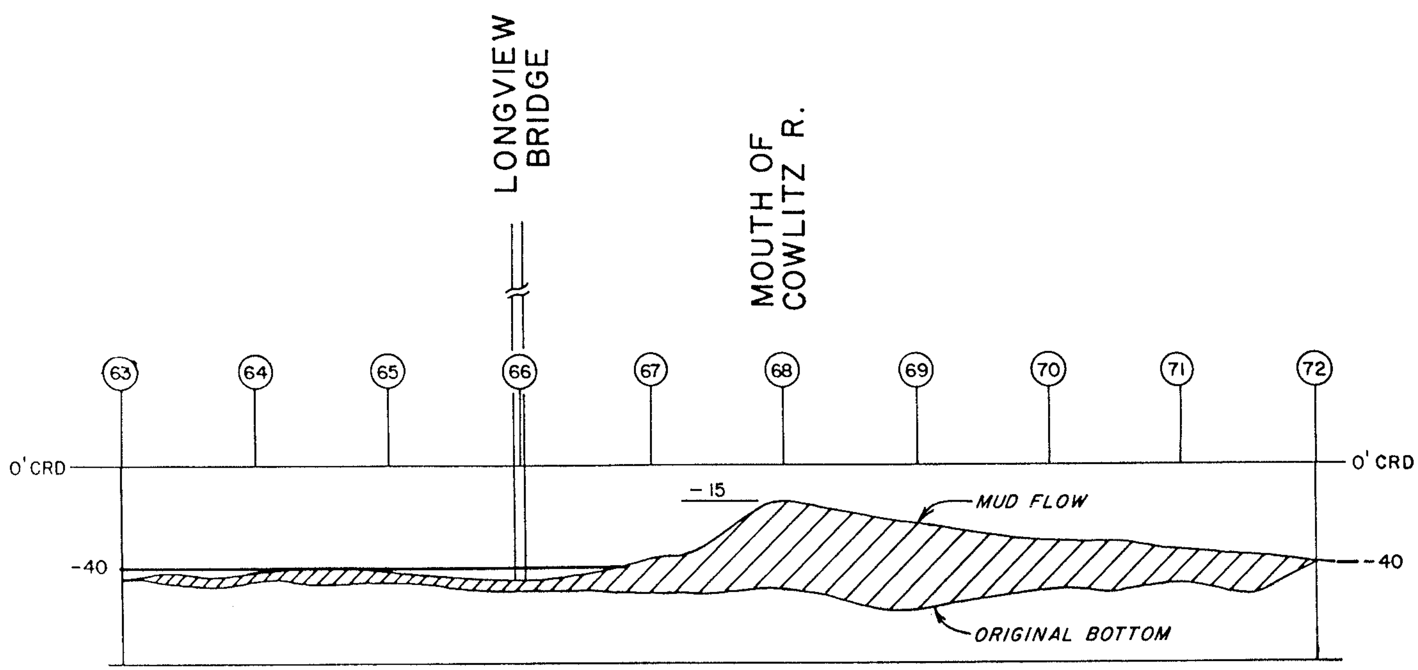

Figure 2

COLUMBIA RIVER LONGITUDINAL PROFILE RM 63 - RM 72

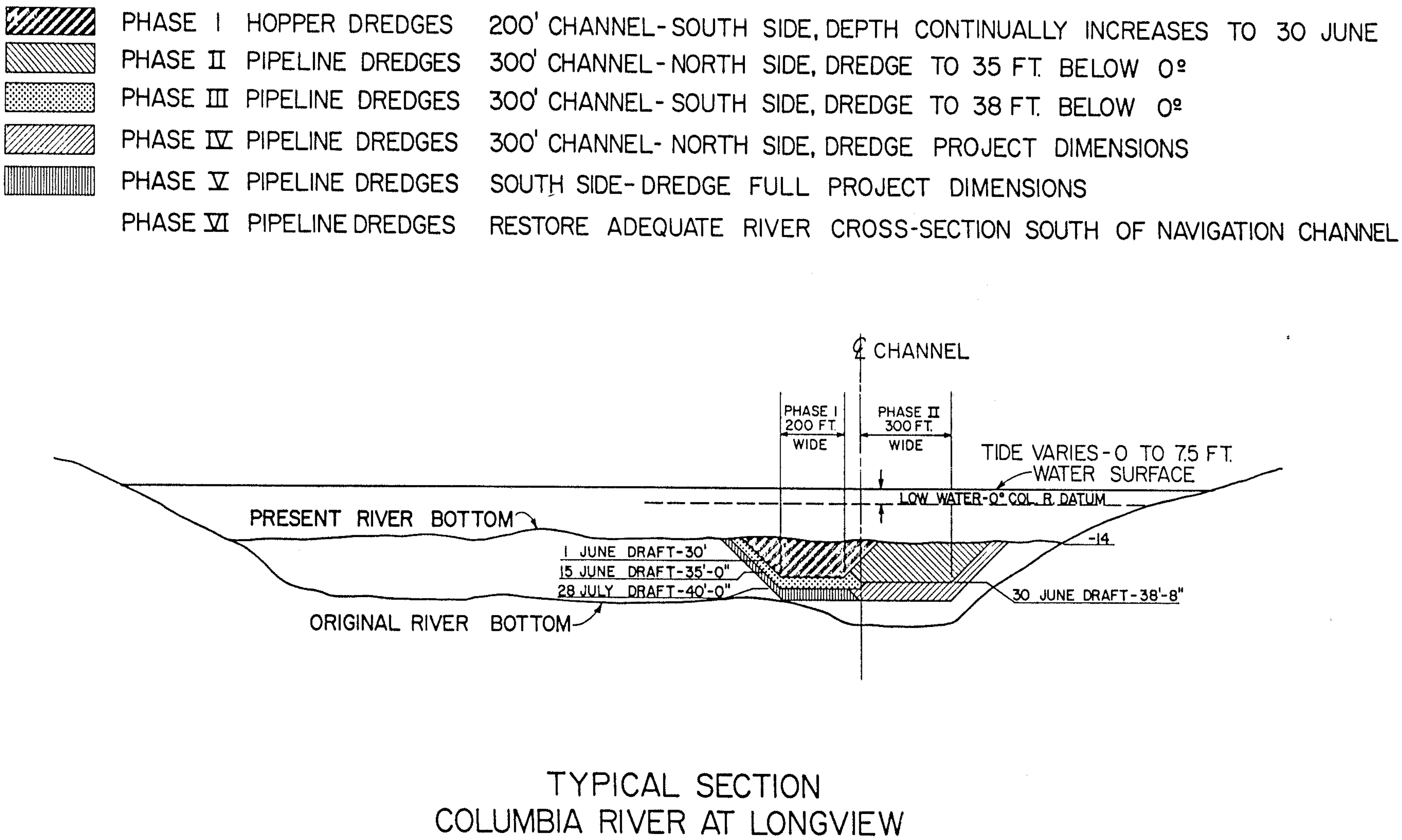

Figure 3 Dredging Plan for the Columbia River

levees providing 500-year flood protection were constructed along the Cowlitz River near the urban areas of Castle Rock, Lexington, Longview, and Kelso; 14,700 feet of existing levee were upgraded and 21,400 feet of new levee were constructed. Bank protection was provided in conjunction with the levees and to control river meandering.

TOUTLE RIVER

Measures implemented in the Toutle River drainage were primarily oriented toward reducing the quantity of sediment eventually depositing in the Cowlitz and Columbia Rivers. Tremendous quantities of sediment continued to erode from the upper watershed mud and avalanche deposits, with the eventual deposition in these lower rivers. Two major techniques were used to reduce this sedimentation: sediment stabilization basins and debris retention structures. The location of these structures is shown in figure 6.

In areas of natural deposition in the Toutle River drainage, eight sediment stabilization basins were excavated. During periods of heavy runoff, sediment was trapped in these basins, therby preventing further infill in the Cowlitz River. During the operation of these structures ending 30 September 1981, 7.5 million cy of sediment was excavated and placed in disposal areas.

Two debris retention structures were constructed: one on the north fork Toutle River and the other on the south fork Toutle River. The debris retention structures, or check dams, resemble earth-fill dams, but they are permeable; they were designed to hold back and impound sediment, which could then be excavated. The north fork structure is 6,000 feet long and 43 feet high, and has a sump capacity of 6 million cy. During the operation of this structure ending 30 September 1981, over 9 million cy of sediment have been removed. The south structure is 600 feet long and 20 feet high, and has a sump capacity of 600,000 cy. During the operation of this structure, approximately 2 million cy of material have been removed. In addition, a fish trap was constructed adjacent to the south fork debris retention structure to trap anadromous fish impeded by this structure.

The debris avalanche, besides contributing sediments, created another problem where recovery operations became necessary. The massive mudfill deposited in the upper 14 miles of the north fork valley had blocked a number of streams, creating ponds and lakes. To prevent catastrophic failure of the debris plugs creating certain of these impoundments, outlet channels were needed at four of the larger ponds. Structural measures were taken to reinforce the outlet channels at Coldwater Lake and South Castle Lake, the larger of these lakes.

Miscellaneous

Within the timeframe allowed for this presentation, it is impossible to detail the myriad of activities involved in these recovery operations. Normal planning and design had to be accomplished at an expedited rate. An example of this expedited schedule is the rate at which contracts were awarded. On

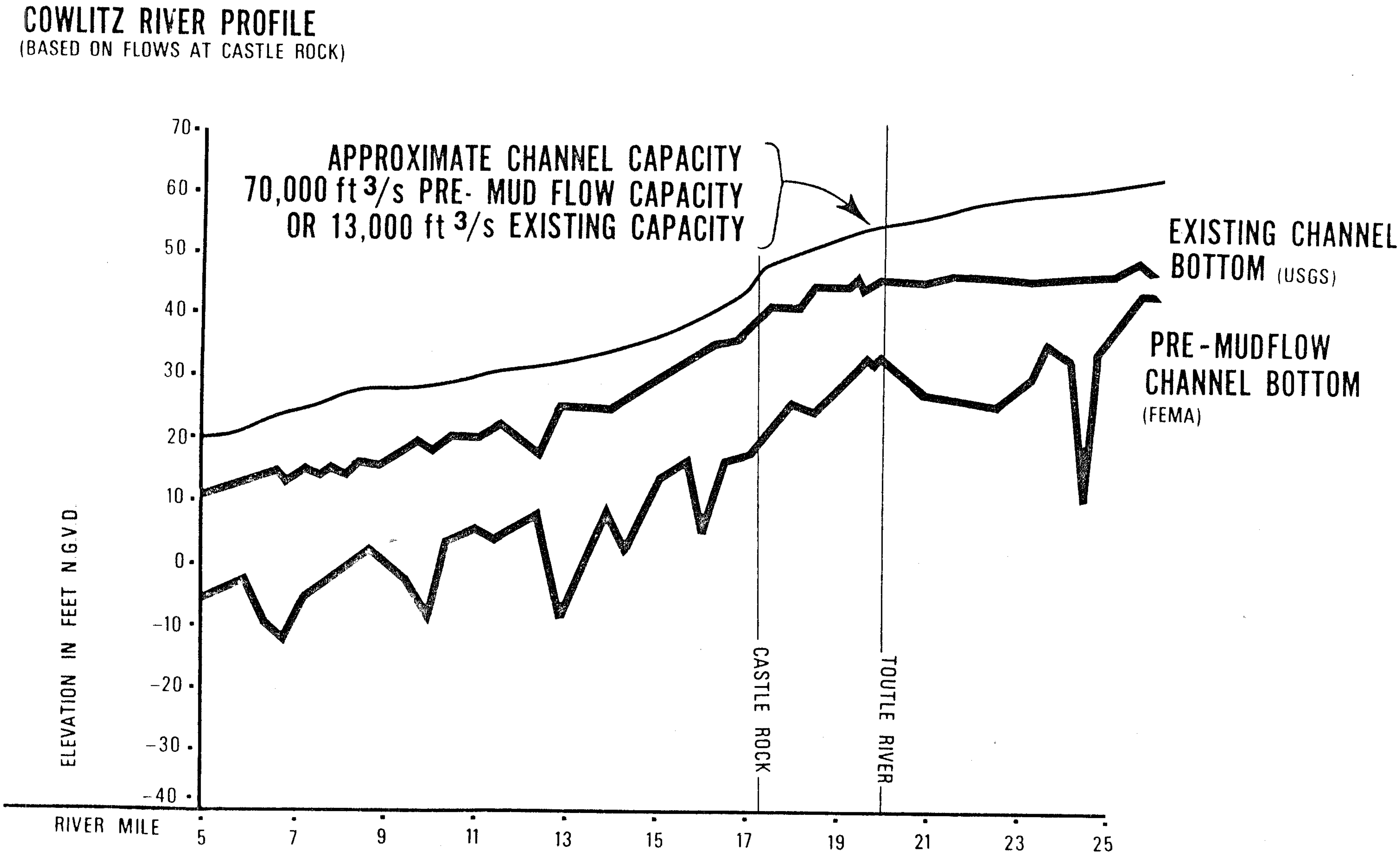

Figure 4 Impact of the Mudflows on the Cowlitz River

COWLITZ RIVER RUN OFF —
COWLITZ RIVER AT CASTLE ROCK

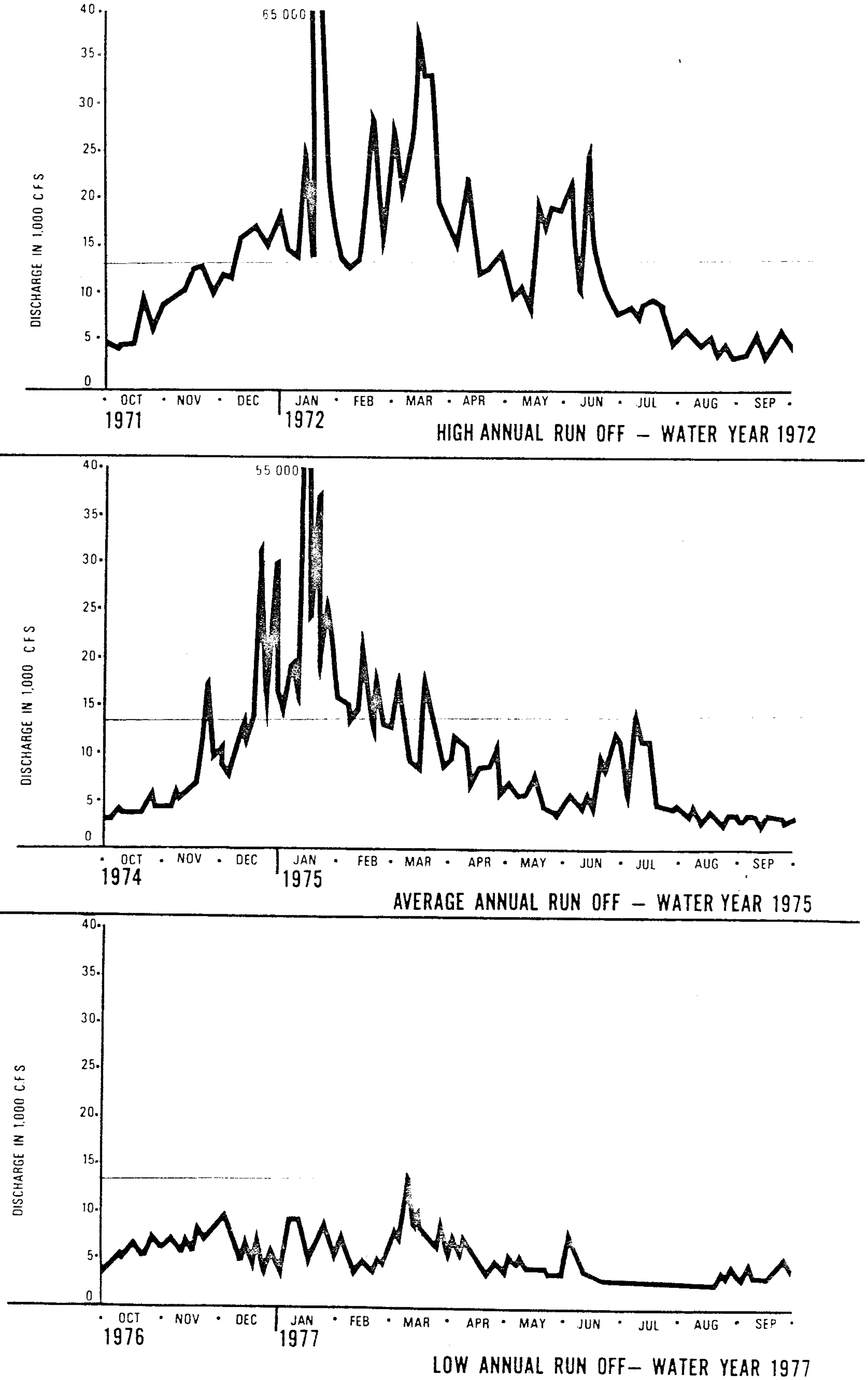

Figure 5 Potential for Flooding on the Cowlitz River

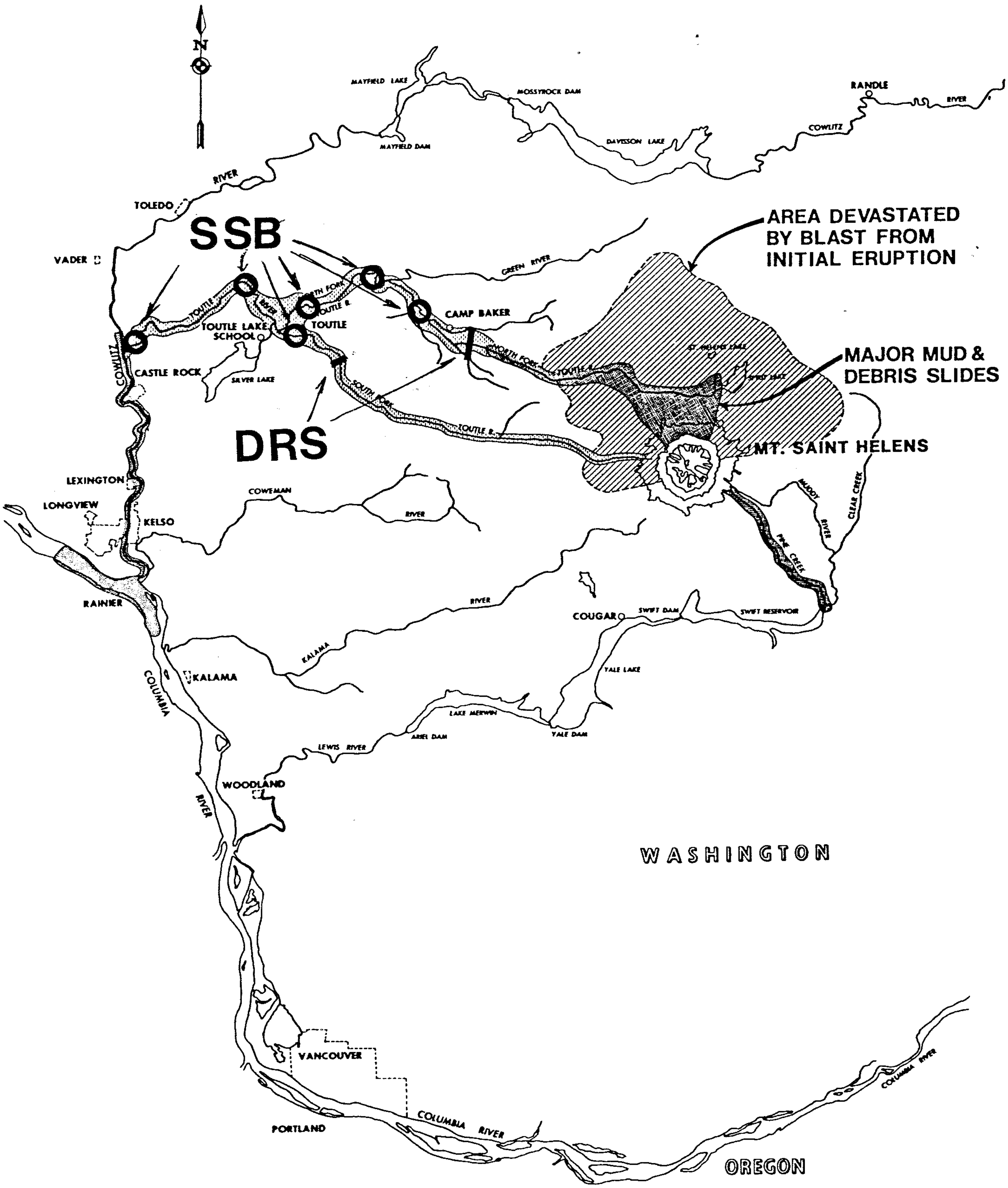

Figure 6 Location of Sediment Stabilization Basins (SSB) and Debris Retaining Structures (DRS)

30 June, over 500 contractors were called to notify them that a pre-bid meeting was to be held tomorrow, 1 July. The next day, 300 contractors from across the country were present for this pre-bid meeting.

Environmental coordination and evaluation occurred at the same rapid pace as the other activities. An environmental impact statement was prepared on an expedited schedule and an environmental taskforce comprised of Federal and State resource agencies was formed; this group met at frequent intervals to insure reasonable measures were taken during this operation to protect the environment.

Water quality evaluations were conducted in conjunction with other environmental assessment and monitoring activities. At first, the major water quality concern was to determine if the ash created any unusual water quality problem beyond the unusually high turbidity. Water quality evaluations continued to determine the effects of the debris retaining structures on the water quality of the Toutle River. But, perhaps the most unusual water quality investigations were associated with the newly formed lakes in the blast zone.

Water quality investigations of these Lahar lakes were conducted in conjunction with evaluations to provide outlet channels for these lakes. Earlier scientific reports indicated that water currently in these lakes was extremely poor in quality, and may be contaminated with pathogenic bacteria and chemical substances. Since a number of downstream communities rely on river water for their drinking water supplies, we commissioned followup water quality studies. In these studies, it was found that massive quantities of organic carbon, sulfur, and metals were loaded into the lakes. Heterotrophic microbial processes, stimulated both by elevated nutrient concentrations and temperature, rapidly consumed the available dissolved oxygen.

This concludes my presentation on Portland District, Mount St. Helens recovery operations. I hope this presentation provided an idea of the complex activities that were necessary in meeting this emergency.

ANALYZING SALINITY RESPONSE IN SAN FRANCISCO BAY

by

John F. Sustar[1]

INTRODUCTION

Management of water systems has become model dependent. These models lead to decisions on future conditions. To be of any value to the decision-making process, we must know the relationship between the model and prototype. One method is to compare qualitative descriptions of the systems' behavior and the differences between the two systems. These comparisons can lead to a strictly quantative analysis of model and prototype data. Integration of these findings will lead to better water management decisions. This is illustrated specifically with respect to the San Francisco Bay System in this paper.

DESCRIPTION OF BAY-DELTA

San Francisco Bay is a shallow, well-mixed, bifurcated estuary consisting of several bays connected by constricted channels illustrated in Figure 1. The tidal forces driving the system are mixed, semi-diurnal. The elevation difference between mean lower low water and mean higher high water is 5.6 feet at the Golden Gate. The tides are modified by the shape of the Bay such that the tidal phasing between the north bay and the south bay are out of phase by 90 degrees as shown in figure 2. The tide in the south bay is a standing wave in phase with the Golden Gate. Slack water occurs at high and low waters with maximum currents during ebb and flood at the Gate. The north bay has a progressive wave. Maximum currents occur during high and low tide at the Gate and slack during ebb and flood. Tidal ranges increase in the south bay and decrease in the north bay.

Precipation is very seasonal with wet winters and dry summers. The hydrograph for 1970 - 80 is shown is figure 3. During the summer, because of the tidal phasing, tidal flows will move from south bay into the north Bay. Evaporation and lack of flushing because of the standing wave and lack of freshwater flows can cause salinity levels to be greater than ocean waters. The freshwater to the system is limited to treatment plant outfalls and minimum reservoir releases through the Delta to prevent salinity intrusion. The flow from the Delta is about 4,000 cubic feet per second during summer low flow periods.

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During the wet season from October through April, the entire drainage of the Central Valley which is about one-third the area of California, flows through Carquinez Strait into the northern portion of the Bay. A classical saltwater wedge will develop in Carquinez Strait with these freshwater flows. The exchange between north and south bay with the difference in tidal phasing is reversed. The degree of the penetration and flushing of the south bay by the freshwater is dependent on the level of flows from the Delta. Typical flood flows are 200,000 cubic feet per second. Tidal flows in Carquinez Strait are about 300,000 cubic feet per second.

Carquinez Strait-Suisun Bay is an important and complex region. It is the migration route for Salmon, Stripped Bass and other fisheries. The fresh-saltwater mixing zone is a high nutrient and critical feeding area. High currents in the constricted channel are complicated with the geometry of bends and embayments which introduce flow reverses both laterally and vertically. Wind setup through the strait can also form a driving force in the system.

DEMANDS ON THE SYSTEM

Because of the seasonal patterns of precipitation and the abundance of water in Northern California versus the scarcity of water in Southern California, extreme demands are placed on the system during the dry summer periods and years of drought. Storage reservoirs around the Central Valley provide flood protection for the extensive flat valley and the deteriorating levees in the fertile Delta. These reservoirs provide water supply for the San Francisco Bay Area, irrigation and water supply for the Central Valley and water supply for Southern California. Instream withdrawals in the Delta serve both irrigation and municipal-industrial water supply. Waters for the San Joaquin Valley (Southern half of the Central Valley) and Southern California flow through the Delta to pumping plants. This flow sets up current reversals with the natural flow patterns.

The freshwater system of the Delta, which is below sea level, is threatened by salinity associated with irrigation return flows and intrusion by the tides. Irrigation returns are internal to the system and, therefore, must be flushed through the maze of channels and sloughs. Ocean salinity must be repulsed by freshwater flow from the Delta.

THE PROBLEM

For this vast water resources system, one station at Chipps Island at the western end of the Delta as established by the State Water Resources Control Board is the management point for salinity levels. The management decision is the maximum allowance salinity concentration. This decision does not address impacts associated with flow patterns and flushing in the bay and Delta. Implementation is based on low flow releases necessary to offset the ocean salinity movement.

Major navigation facilities are along Carquinez Strait-Suisun Bay, Mare Island Strait and at Stockton and Sacramento. The need to deepen the channels to accommodate larger vessels including tankers, freighters and container ships is another demand on the system.

The John F. Baldwin Ship Channel is one example of a deepening project. It is an authorized deep water channel from the San Francisco Bar, through the Bay, to the Port of Stockton. The initial phase across the Bar to a depth of -55 feet mean lower low water was dredged in the early 1970's. The Bar Channel is the only phase completed to date. Extensive model tests were conducted over the years on the physical hydraulic model of the Bay and Delta to determine salinity impacts. The model was constructed in 1956. With the addition of the Delta, the model covers an area of about two football fields. The scales of the model are 1:1000 hortizontal, 1:100 vertical and 1:100 time. The tests indicated that some level of increased salinity intrusion results from deepening the channel through San Pablo and Suisun Bays. The extent of the increase on the model could not be determined because of the variability of data. Relating the results of the model test to the prototype is a major problem because of the size and complexity of the Carquinez Strait-Suisun Bay Hydraulics. In terms of project planning, the probable extent of the increase in the prototype and the effectiveness of mitigation (i.e. increased Delta outflows or sills) to offset the increase must be known. For some water uses, salinity changes of 50 ppm are critical.

FACTORS TO BE CONSIDERED

In comparing the model and the prototype, several differences must be considered. Review of data, from both indicate major variances or spread in data. This is particularly true on repeat model tests. Both systems have three dimensional rotational flows from the geometry of the system and density flows. The prototype has, in addition, pressure flows caused by wind setup. For salinity measurement, the model uses a fixed salt, sodium chloride. The prototype has several different sources of salt; total dissolved solids are usually measured in the Delta. For salinity five different correlation equations are used for different areas in the Delta. Since Delta outflow can not be measured, especially at lower flows, various estimates of outflow are calculated. The differences are based on how many reservoirs and stream gages are included in the calculation. None of the estimates take into account all of the factors affecting outflow. The biggest of these is the estimate of instream withdrawals for irrigation.

The Bay Model has been operating with manually controlled mechanical systems for both freshwater and tidal controls. As such, the hydrology used in dynamic tests to date have used a 5 day average step hydrograph. The tide generator uses an average tide. These factors must be evaluated for interpreting test results in terms of predicting conditions in the prototype. Hydraulically, both the model and the prototype are estuaries. If we are to look at the variances of salinity, two responses must be evaluated. The response or exchange between the channels, the embayments and the shallow will affect mixing and stability of flow patterns. The geometry of the model and prototype are the same except for the vertical distortion in the model. The second response is the salinity change with the Delta outflow.

The Delta outflow can be defined by level of outflow, rate of Delta outflow change and duration of the outflow. In terms of the salinity, the time of response to outflow, the shape or dampening of the time response and the conditions, which also include the lunar and solar changes in the tidal forces, required to change or maintain salinity must be evaluated in order to optimize the utilization of freshwater to prevent salinity intrusion and, regarding the flushing action in the Bay, the impact of management decision.

Specific to the depths associated with navigation channels, the unknowns are the mode of salinity intrusion, whether density flows, entrapment or some combination and the sensitivity of the system to depth changes This sensitivity relates to the mode of intrusion, mixing characteristics and diffusion. Remedial measures to be considered include Delta outflow procedures and design parameters for sills.

FIELD PROGRAM

To use the model to predict changes in the prototype, more knowledge of the hydrodynamics of the Bay was necessary. A two year program was set up for this data collection. Six stations, five full stations from the Delta to San Pablo Bay and one limited station in Suisun Bay, were established. At the full stations, located on Coast Guard navigation aids adjacent to the main channel, conductivity (salinity), temperature, turbidity, current speed and direction and tidal elevation were measured at three levels in the water column at 30 minute intervals. Two additional stations on the Sacramento and San Juaquin Rivers above their confluence were not funded. The locations and installation are shown on figures 4 and 5. Data outputs were assembled on 9-track tape and on microfiche. Temporal, spatial and interparametric plots were presented on the microfiche.

MODEL PROGRAM

Small instrument packages were designed for the model for direct comparison with the field program. The sensors included conductivity (temperature corrected), current speed and direction and tidal elevation. Two levels of probes will collect data at 18 second intervals. The model is presently being upgraded to electronically control freshwater flows and tidal generation. A test program will start with the 1979 - 80 hydrology.

DATA ANALYSIS

An early review of the data indicated very few cases of smooth curves. During some period at particular stations, the jagged peaks at the crest or trough of the tidal curve showed variances of salinity as much as 30 - 40 percent of the total value. These patterns reflect the local geometry of the station and the Delta outflow. A curve classification system was used to review the data. The five basic classifications represented rounded, semi-rounded, pointed, extreme irregular amplitudes and irregular flattened troughs. Sub-classifications further defined the shape as shown in figure 6. Although qualitative, the system gives a basis for what data points can or should be used in numerical analysis. The variances, such as in shape c-, more than account for variations in data from repeat model tests indicating that the questions concerning the model are not repeatibility but sampling procedures. A test run of the new instrumentation on the model shows similar shaped curves. This means that any interpretation of test data at any given location which gives only a single point on the curve must take into account the shape of the curve due to geometry and Delta outflow.

Based on the evaluation of the quality of the data and the shape of the salinity curves, preliminary analysis was run on Station 3 at Benicia with regression analysis of salinity versus outflow. Five day averages were used for comparison with percent variations given for model data. Figure 7 is a plot of the data for 13 Feb - 30 Sep 1979. Exponential regression gives r^2 values of 0.82, 0.83 and 0.81 for surface, mid column and bottom, respectively. Although averaging smooths the curve, the procedure does present the opportunity to numerically compare base model, plan model and prototype data.

Since the Benicia Station is on the main channel, the response should reflect the daily changes in Delta outflow. Suisun Bay (the embayment along with Grizzley Bay) for difference levels of outflow and change of outflow should show as multiple peaks with eddy flow being carried by the tides. The other major forcing function is the tide. Regression analysis is being done on the daily outflow, maximum salinity, variance at the maximum salinity and minimum salinity. Salinity factors for the solar year, lunar month and declination will be subtracted from the salinity value. The regression analysis will be run to optimize the r^2 value to obtain the salinity factor due to the tides. Numerical analysis can then be made between base and model tests and prototype irrespective of time.

CONCLUSION

San Francisco Bay and Delta offers a challenge to uncovering its mysteries. Variances in data can not be ignored. The variances probably reflect a real perturbation in the system. Qualitative procedures can often times reveal approaches to quantitative analysis.

ACKNOWLEDGEMENT

The information for this paper is based on the experience of the author in conducting Corps of Engineer studies in San Francisco Bay. Publication of this paper has been approved by the Corps of Engineers, but any views, interpretations or conclusions are those of the author only.

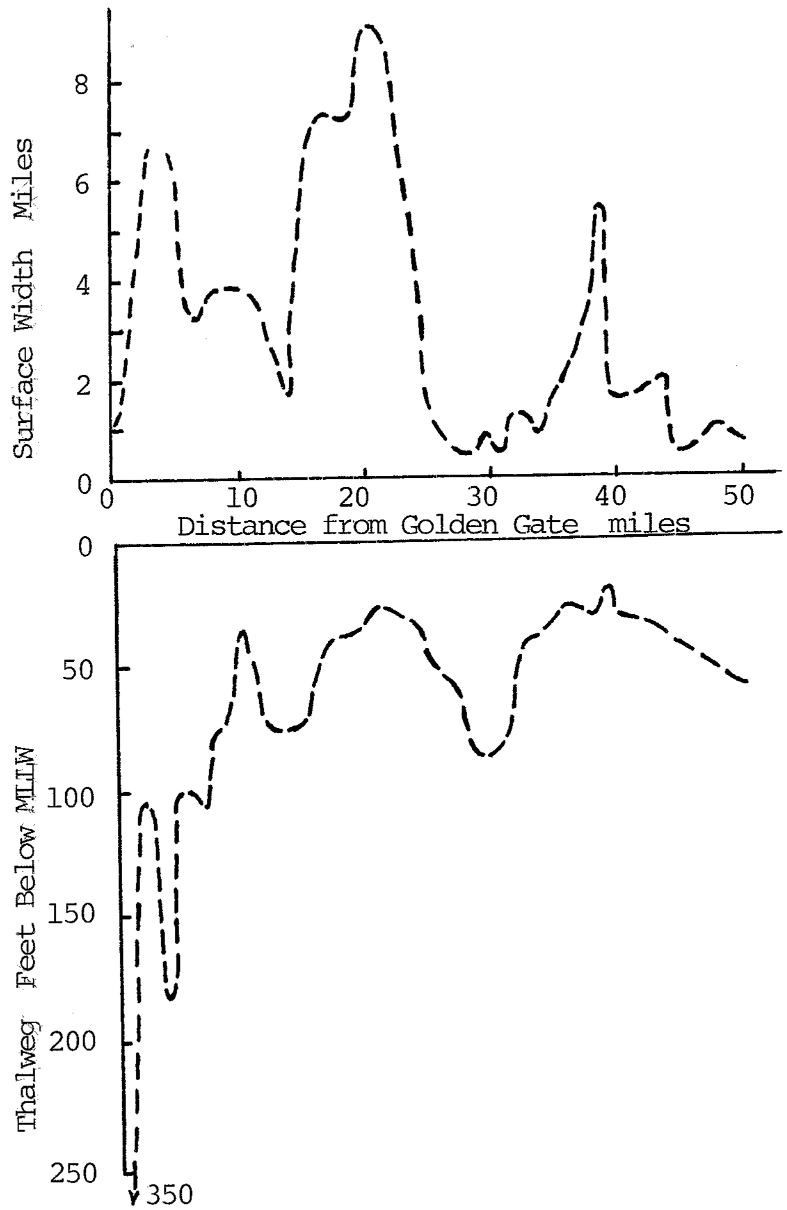


FIGURE 1 Depth-Width of Bay

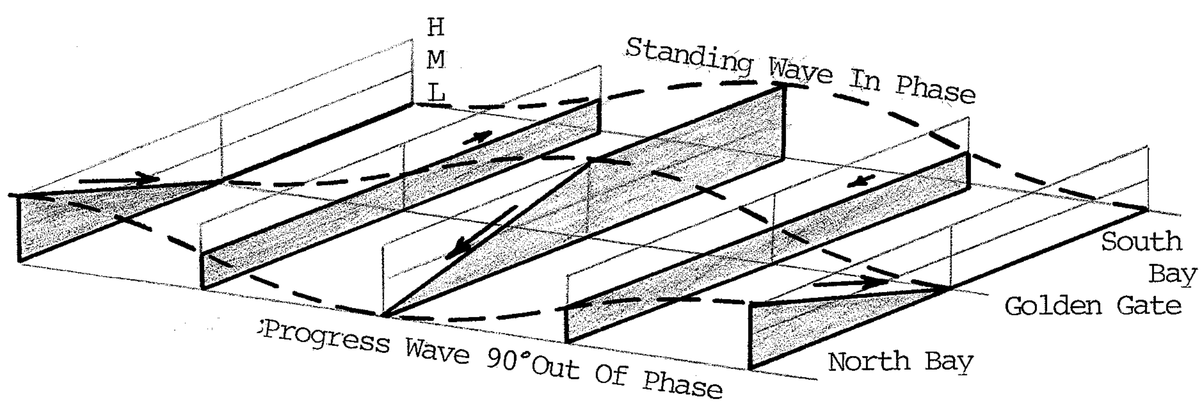


FIGURE 2 Tidal Phasing

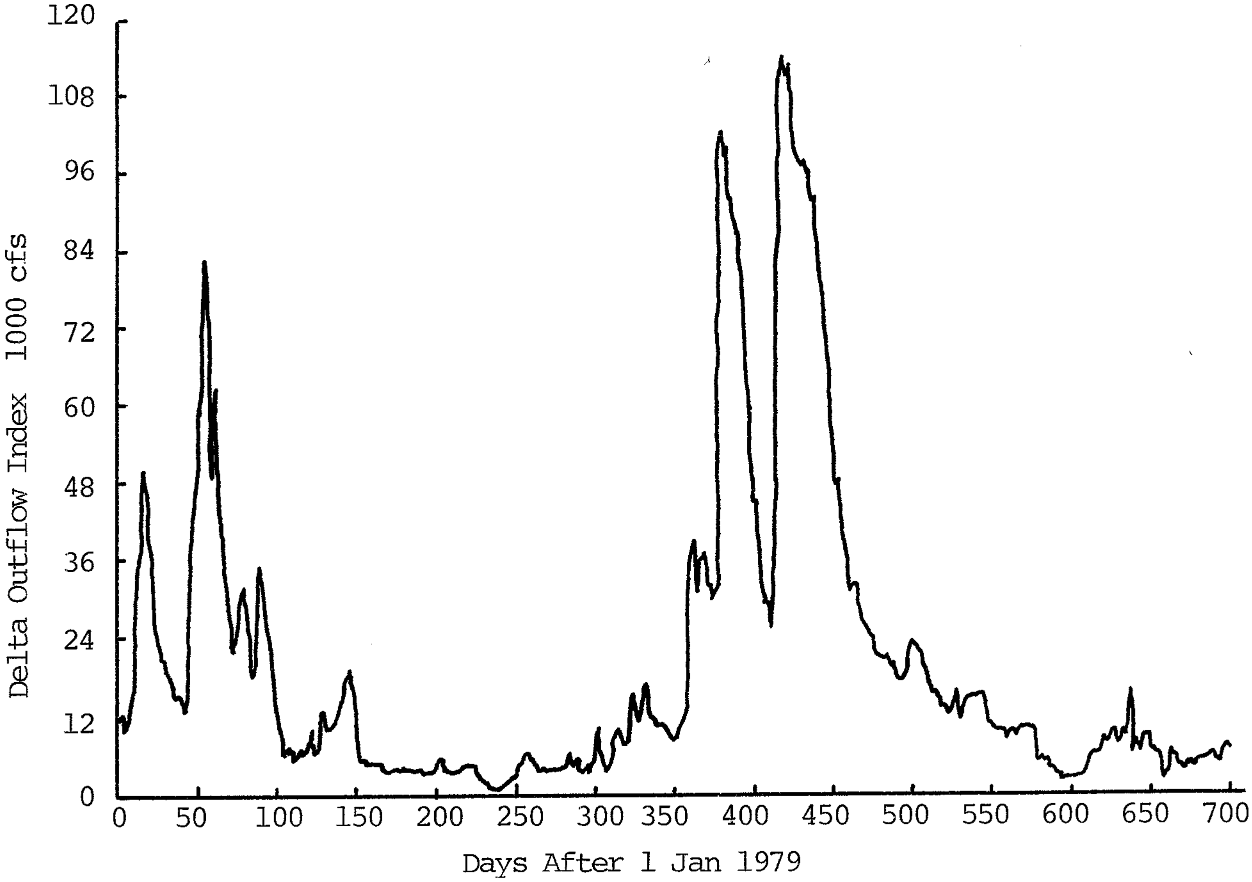
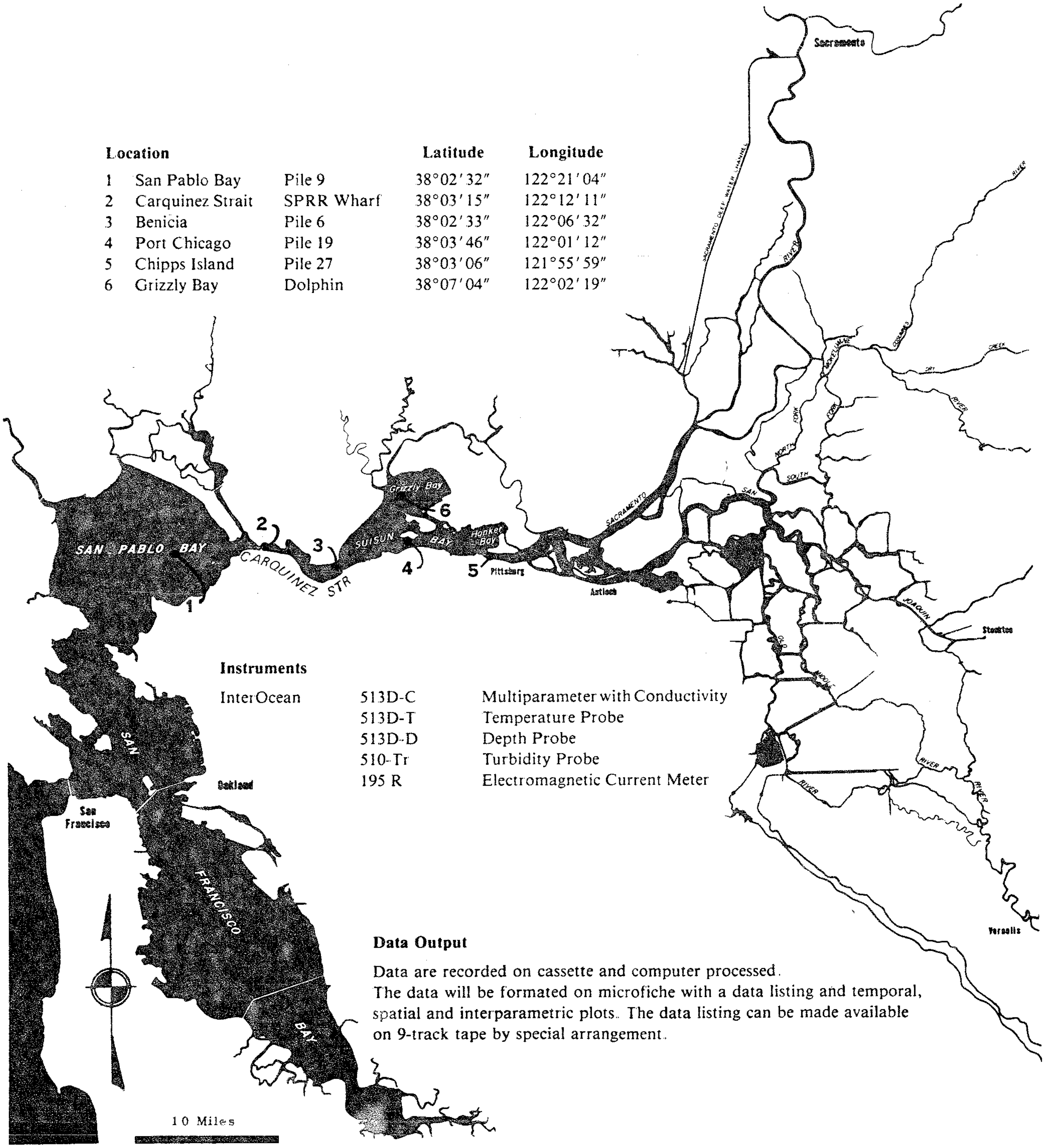


FIGURE 3 Hydrograph

Prototype Data Acquisition System
San Francisco Bay

The San Francisco District, U.S. Army Corps of Engineers, through Kinnetic Laboratories, Inc., is operating six hydrometric stations in the northern portion of San Francisco Bay. The stations were installed in February 1979 and will collect data for a minimum of two years. Each of five stations along the main channel has sensors at the bottom, mid-depth and near surface to record tidal elevation, current speed and direction, salinity, temperature and percent of light transmission. An additional station in Grizzly Bay has one set of sensors at mid-depth for salinity, temperature and percent of light transmission. Data are collected at 30 minute intervals. The program's purpose is to gain further understanding of the hydrodynamics of the freshwater-saltwater mixing area of the Bay and to further verify the physical model.

	Location		Latitude	Longitude
1	San Pablo Bay	Pile 9	38°02′32″	122°21′04″
2	Carquinez Strait	SPRR Wharf	38°03′15″	122°12′11″
3	Benicia	Pile 6	38°02′33″	122°06′32″
4	Port Chicago	Pile 19	38°03′46″	122°01′12″
5	Chipps Island	Pile 27	38°03′06″	121°55′59″
6	Grizzly Bay	Dolphin	38°07′04″	122°02′19″



Instruments

InterOcean	513D-C	Multiparameter with Conductivity
	513D-T	Temperature Probe
	513D-D	Depth Probe
	510-Tr	Turbidity Probe
	195 R	Electromagnetic Current Meter

Data Output

Data are recorded on cassette and computer processed.
The data will be formated on microfiche with a data listing and temporal, spatial and interparametric plots. The data listing can be made available on 9-track tape by special arrangement.

FIGURE 4 Prototype Stations

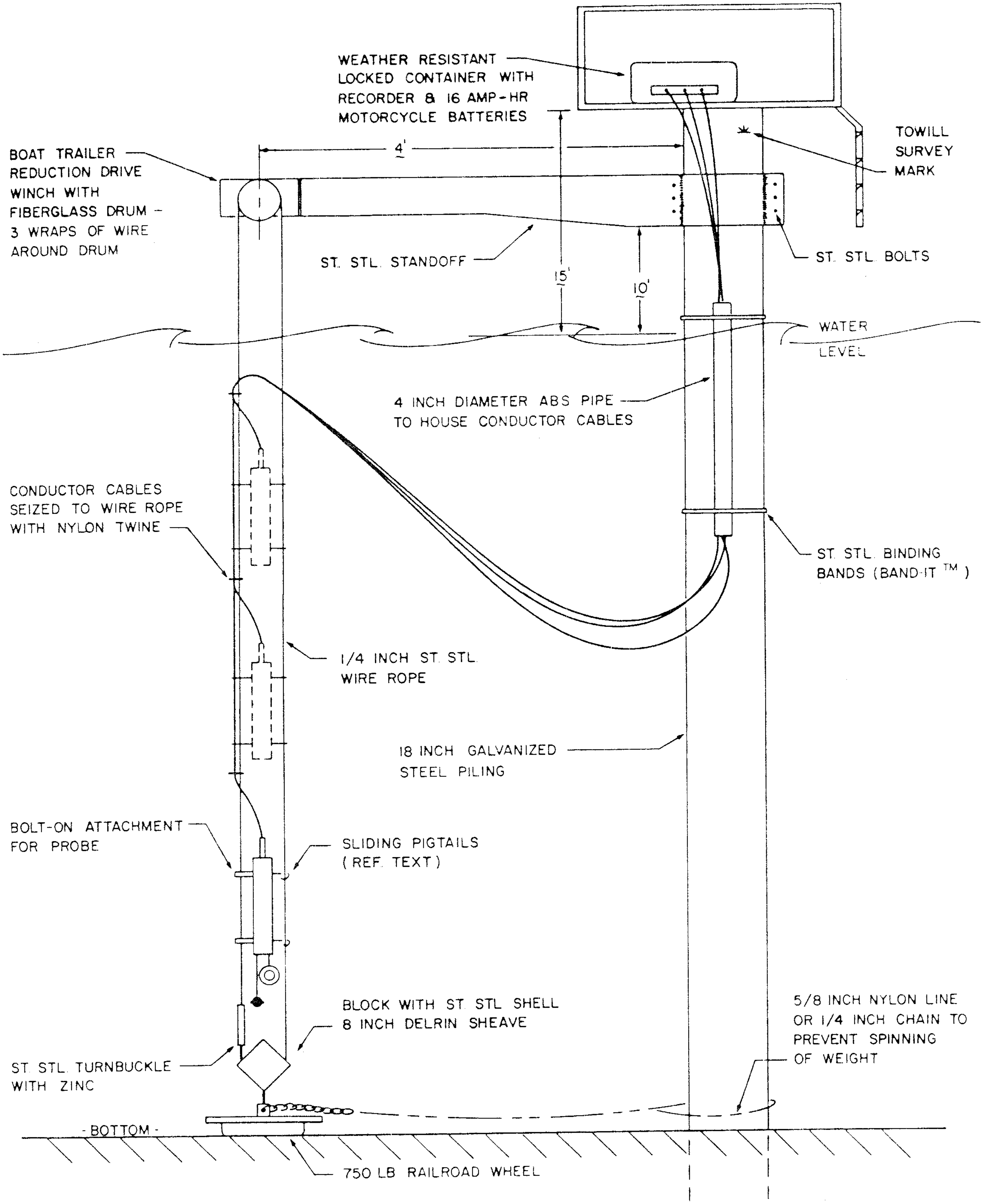


FIGURE 5 Station Deployment

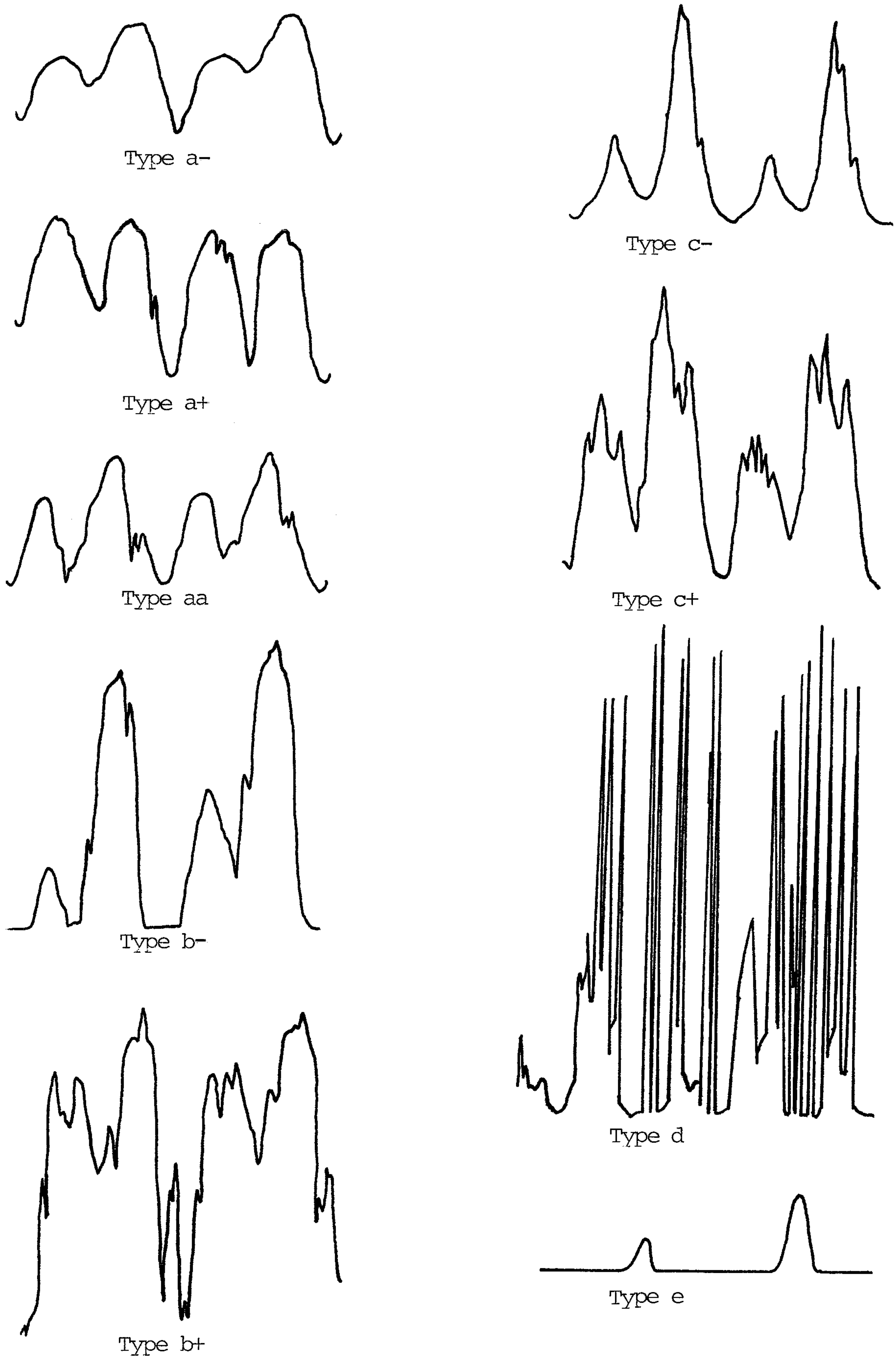


FIGURE 6 Salinity Curve Classification

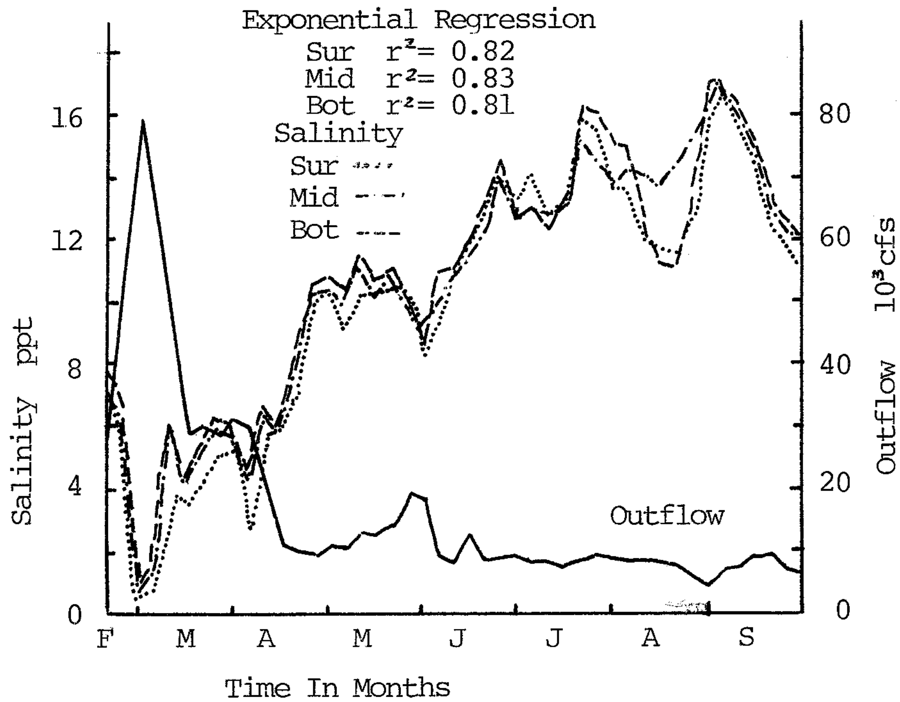


FIGURE 7 Salinity-Outflow Analysis

TURBINE VENTING AT CLARKS HILL DAM

by Gary V. Mauldin[1]

INTRODUCTION

The Savannah District, U. S. Army Corps of Engineers, operates and maintains Clarks Hill Dam and Lake Project, located 238 miles from the mouth of the Savannah River and 22 miles northwest of Augusta, Ga. Clarks Hill Lake has a surface area of 71,000 acres and a storage of 2 1/2 million acre-feet of water which makes it one of the largest inland bodies of water in the southeast. Clarks Hill Dam has seven turbine units rated at 40 megawatts (MW) each for a total capacity of 280 MW at an average head of 146 ft. Clarks Hill Dam was placed into operation in 1952 for peaking power, flood control and navigation on the lower Savannah River.

Like most deep water bodies, Clarks Hill Lake undergoes thermal stratification during the summer and early fall resulting in a relatively cold, oxygen depleted bottom layer of water termed the hypolimnion. The turbine intakes are located far below the surface in this hypolimnion; therefore, it is this lower layer of water that is released from the dam year-round, and during the summer, the waters released have relatively low dissolved oxygen (D.O.) concentrations.

Georgia and South Carolina state water quality standards for the Savannah River below Clarks Hill Dam require an average daily D.O. concentration of 5 milligrams per liter (mg/l) with a minimum of 4 mg/l[1,2].

Various methods have been investigated to improve the D.O. concentrations in the releases from Clarks Hill Dam. One method is to vent air into the draft tube below the hydropower turbine.

BACKGROUND

During the summer of 1969, turbine venting tests were conducted at Clarks Hill Dam using the existing free-air vent system. Francis-type turbine wheels, like those that are installed in Clarks Hill Dam, are equipped with a free-air vent system to prevent cavitation and excessive vibration by eliminating the vacuum that develops during low flow or sudden flow cutoff situations. At Clarks Hill Dam this system consists of an 8" air supply pipe and an automatic vacuum breaker valve used to supply atmospheric air to the turbine when the turbine unit is operating below 43 percent gate opening. The air flow enters the draft tube from the supply line through eight equally spaced 3" by 7" vents located high on the cone-shaped turbine hub. During this test the automatic vacuum breaker valve was held open continuously. At very low gate opening, the sub-atmospheric pressure in the draft tube allowed large amounts of air to be aspirated through the free-air vent system raising the D.O. in the turbine releases up to 2.5 mg/l. However, at moderate to high gate openings the static pressure in the draft tube became higher than atmospheric pressure thus preventing the aspiration of any air and the uptake of any dissolved oxygen.

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Research by Alabama Power Company and Tennessee Valley Authority (TVA) has demonstrated that localized sub-atmospheric pressures could be developed in the draft tube even at high gate openings with the use of baffle plates. Baffle plates installed on the turbine hub above the vents cause the water flow to separate from the turbine hub wall producing a pressure lower than the free-stream static pressure in the wake of the baffle plates. The localized negative pressure created by the baffles induces an air-flow through the hub vents. During the summer of 1981, this technique was tested in two units at Clarks Hill Dam.

FIELD TEST

During the spring of 1981, two turbine units at Clarks Hill Dam were scheduled to be taken out of service for maintenance inspections. This period of maintenance inspection provided an opportune time for installing the hub baffles at a minimum of cost.

Two different shapes of baffle plates were installed. One set of baffle plates had a 45 degree leading angle and the other set had a 60 degree leading angle. Both of these shapes were based on previous studies by Alabama Power Company and TVA. The size of the baffle plates were designed according to the size of the hub vents as well as the space limitations between the hub vents and the turbine head cover.

The 60 degree baffle plates, 8" long, 3" wide, and 5.2" high, were made of 1/2" carbon steel, cut and welded together by Corps personnel, and were welded onto the hub of turbine unit number three. The location of the baffle plates on the hub was ground smooth to obtain a stronger weld. A jig was fabricated to make welding of the baffle plates onto the hub easier and to insure proper alignment for all eight baffle plates. Previous studies by Raney [3] determined the maximum negative pressure due to 60 degree baffle plates would be 1.5 inches wide and would occur 5.5 to 7 inches from the the opposite face of the 60 degree angle. The hub baffles were located so that this area of maximum negative pressure occurred at the existing hub vents. Alignment of the baffle plates with the hub vents was determined by viewing through the turbine blades to determine the direction of the water flow as it exits the blades and visually lining up the baffle plates with the hub vents so that the water exiting the blades would flow over the baffle plates. The 60 degree baffle plates weighed an average of 7.8 pounds each and were installed statically balanced on the turbine hub . Installation of the 60 degree hub baffles took 3 days including dewatering and rewatering the turbine unit.

The 45 degree baffle plates, 8" long, 3" wide, and 3" high, were made of stainless steel and were welded onto the turbine hub of unit number four. The maximum negative pressure created by the 45 degree hub baffles occurs 3.5 to 4.5 inches from the opposite face of the 45 degree angle. Like the 60 degree hub baffles, the 45 degree hub baffles were aligned to insure that the 1 inch wide area of maximum negative pressure would occur at the hub vents. A jig was used to properly align all eight baffle plates with the hub vents. The 45 degree baffle plates weighed an average of 5.3 pounds each and were installed statically balanced on the turbine hub. Installation of the 45 degree baffle plates took 4 days including dewatering and rewatering the turbine unit.

In July, 3 months after installing the hub baffles, both turbine units were dewatered to check the condition of the baffle plates. All 16 hub baffles previously installed were still aligned properly and there were no signs of cavitation occurring around the hub vents. The 60 degree baffles, made of carbon steel, had developed a coating of rust on the sides but not on the deflecting face. This indicated that the hub baffles were aligned properly with respect to the water exiting the turbine blades. The 45 degree hub baffles, made of stainless steel, did not have a coating of rust; however, the deflecting face of the 45 degree baffles was shinier than the sides of the baffles, which also indicated that the 45 degree hub baffles were aligned properly with respect to the water flow exiting the turbine blades. As in the 1969 tests, the vacuum breaker valve on the free-air vent system was blocked open to provide a continuous flow of atmospheric air.

To determine the impacts of turbine venting on the D.O. levels in the water released from Clarks Hill Dam, D.O. concentrations were collected at three locations; in Clarks Hill Lake, in the draft tube 4 feet below the hub vents, and in the tailrace 200 feet downstream from the dam. In Clarks Hill Lake, profiles were taken biweekly at the face of the dam. A YSI D.O. meter calibrated by the Modified Winkler method was used to collect D.O. and temperature every 5 ft. throughout the water column. For D.O. sampling in the draft tube area, an automatic D.O. monitoring system was used to collect samples from turbine unit number three (the 60 degree baffles installed), turbine unit number four (45 degree baffles installed) and turbine unit number seven (no hub baffles installed). Water from each draft tube was collected every half hour for a duration of 9 minutes per turbine. The water samples from the draft tube were analyzed for D.O. and temperature by a YSI 56 D.O. meter and the data was recorded continuously on a strip chart recorder.

Dissolved oxygen concentrations were measured at the sampling location in the draft tube and the sampling location in the tailrace of turbine unit number 7, a unit with no hub baffles installed, to determine the normal D.O. uptake that occurs as water travels through the draft tube and into the tailrace. During low generation when the automatic vacuum breaker valve was open, D.O. concentrations increased approximately 0.5 mg/l. During normal to high generation, no D.O. uptake was observed. Since no D.O. uptake occurred between the draft tube monitor and the tailrace monitor during normal operating conditions, the D.O. uptake observed by the tailrace monitor was due solely to turbine venting.

Dissolved oxygen monitoring in the tailrace presented some difficulties. Continuous monitoring during generation was preferred, however, continuous monitoring in the tailrace from a boat was impractical. Monitoring should be conducted close enough to the dam to eliminate intermixing of the released water with other water in the tailrace but far enough away from the dam to eliminate errors caused by rising air bubbles affecting the membrane of the D.O. probe and to eliminate disturbances caused by the boiling action of the water exiting the draft tube. After some initial investigation, it was decided that 175 to 200 ft. downstream from the dam was the best location to collect D.O. data in the tailrace. A large buoy connected to the draft tube deck by two lines was used to position the D.O. probe directly in front of the turbine unit operating. The D.O. probe connected to this buoy system was calibrated daily by the Modified Winkler method. The D.O. probe was weighted to maintain the probe slightly below the surface of the water. The probe maintained at least a 6" depth during generation and no incidences of the probe bouncing out of the water were observed. The D.O. probe was calibrated daily using the Modified Winkler Method. Water temperature was measured periodically using the thermistor attached to the D.O. probe and checked against a mercury filled hand thermometer. The tailrace D.O. data was collected continuously during generation and recorded on a strip chart recorder.

The 8" free-air vent pipe was accessible for air flow monitoring at the check valve located in a pit near the vacuum breaker valve. The air velocity probe was located immediately upstream of the check valve location to prevent any disturbances by the compressed air system. Air velocities were measured by a Kurz portable air velocity meter which uses a thermal anemometer probe to measure the cooling effect of the air as it passes over the heated velocity sensor. Velocity profiles were taken in the 8" pipe to determine at what location the velocity sensor should be set to monitor the average velocity in the pipe. This average velocity location occurred 1" below the center line of the pipe. Due to the inability of thermal anemometers to measure very high velocities, velocity measurements were limited to 12,000 feet per minute (fpm) or approximately 70 cubic feet per second (cfs). This was not a major limitation however, because air velocities over 70 cfs only occurred during very low generation or when the tailwater was below elevation 185 which only occurs at the beginning and possibly the end of each period of generation.

Index tests were conducted by powerplant personnel measuring water discharge and turbine output to determine the relative efficiency of the turbine unit over a varying range of wicket gate openings. Data was collected on turbine unit number 3 prior to installing the 60 degree hub baffles, after installing the 60 degree hub baffles but with the vacuum breaker valve operating normally, and after installing the 60 degree hub baffles with the vacuum breaker valve held open. Index tests were also conducted on turbine unit number four prior to installing the 45 degree hub baffles, and after installing the 45 degree hub baffles with the vacuum breaker blocked open.

Miscellaneous parameters required for hub baffle testing including pool elevations, tailwater elevations, water discharge and power output were taken from the daily station log of the powerhouse at Clarks Hill Dam.

RESULTS

a. Air Flow

The amount of air flow induced into the draft tube due to the presence of hub baffles depends on the effective pressure at the hub vents. This effective pressure is a function of:

1. The difference between the hub vent elevation and tailwater elevation.

2. Water velocity.

3. Air velocity.

4. Water density.

5. Head loss in the draft tube.

6. Baffle plate geometry.

The difference in elevation between the tailwater and the hub vents was found to be the most influential parameter affecting air flow. The higher the hub vents are in relation to the tailrace, the greater the air flow that can be induced through turbine venting. At Clarks Hill Dam the bottom edge of the hub vents are located at elevation 192 feet mean sea level (msl). The tailwater elevation normally ranges from 185 msl with one unit running to 193 msl with all seven units operating at maximum efficiency and a 136-foot head. Raising the hub vents could increase air flow through the vents; however, at Clarks Hill Dam the existing hub vents are already located as high as possible on the turbine hub considering the space required for the baffle plates.

The air flow is also affected by the water discharge rate. Figure 1 compares air flow versus tailwater elevation for the 45 degree hub baffles for water discharge rates of approximately 3,400 and 4,000 cfs. For every 1-foot rise in tailwater elevation, the air flow rate dropped 8 cfs for both water discharge rates. At a constant tailwater, the air flow dropped 2.5 cfs for every 100 cfs increase in water discharge between 3,400 and 4,000 cfs. Figure 2 shows similar results for the 60-degree hub baffles.

Figure 3 depicts the change in air flow versus the change in tailwater elevation for the 45 and 60 degree hub baffles for a water discharge of 3,600 cfs. At this water discharge, practically no difference in air flow between the 45 and 60 degree hub baffles was observed.

Figure 4 illustrates the effectiveness of the baffle plates by comparing the change in air flow versus the change in tailwater elevation at a constant water discharge of 4000 cfs for the 45 and 60 degree hub baffles and turbine unit number 2 which had the vacuum breaker valve held open but no hub baffles installed. A small quantity of air is induced through the turbine at low tailwater elevations even with no hub baffles installed, but practically no air flow occurs above tailwater elevation 188.5 msl.

b. <u>Dissolved Oxygen Uptake</u>

Figure 5 depicts the average daily D.O. levels at the tailrace sampling location and the draft tube sampling location from August through September. The average daily increase in D.O. between the background D.O. and the tailrace D.O. ranged from 1.0 to 2.8 mg/l with an average of 1.4 mg/l during the study period. The background D.O. levels varied from 2.8 to 4.2 mg/l with an average of 3.3 mg/l. The increase in D.O. levels between the draft tube and the tailrace shown in figure 5 results from turbine venting, since no D.O. uptake was observed without turbine venting between the draft tube and the tailrace.

Normally the D.O. concentration in the releases during the month of September is approximately 2.5 mg/l. However, due to significant increases in inflows upstream from Hartwell Dam, which are naturally reaerated before entering

Clarks Hill Lake, the D.O. concentration in the releases rose to over 4 mg/l during September. The bulge in the tailrace D.O. at day 253 is apparently an error. A slight tear in the membrane on the tailrace D.O. probe was discovered on day 254 and the membrane was subsequently replaced.

The average oxygen absorption efficiency during this study period was slightly over 40 percent. Oxygen absorption efficiency is a function of pressure and time in the draft tube, oxygen deficiency of the water, and the water temperature.

The average D.O. uptake versus air flow at an average background D.O. level of 3.3 mg/l is shown in figure 6. Notice the reduction in the slope as the air flow increases. This implies that a maximum D.O. uptake slightly over 2 mg/l would be obtainable at Clarks Hill Dam for a D.O. background level of 3.0 to 3.5 mg/l. Since D.O. uptake is a function of the D.O. deficit, for background D.O. levels below 3 mg/l the curve would shift upwards raising the D.O. uptake level obtainable through turbine venting and for the same reasons, D.O. background levels above 3 mg/l would cause the curve to shift downward lowering the D.O. uptake level obtainable through turbine venting.

The D.O. levels in the releases from Clarks Hill Dam for an average year are below 5 mg/l for 136 days per year. The number of days below 5 mg/l could be cut to 102 days per year if 1 mg/l of D.O. uptake could be maintained through turbine venting, 43 days per year if 1.5 mg/l could be maintained, 22 days per year if 2.0 mg/l could be maintained and 0 days per year if 2.5 mg/l could be maintained. The average D.O. uptake obtained during this test period was 1.4 mg/l. Maintaining this uptake level reduces the number of days that the D.O. is below 5 mg/l by 61 percent. D.O. levels above 4 mg/l could be maintained year-round without further refinement to the turbine venting system at Clarks Hill Dam.

c. Dissolved Nitrogen Uptake

Dissolved nitrogen (D.N.) data was collected in the tailrace by the U.S. Army Waterways Experiment Station (WES) during a 2-day test conducted in September 1981. Samples were collected with and without air flow in the releases of turbine unit number 4 and were analyzed with a portable gas chromatograph. Background D.N. levels ranged between 101 and 102 percent of saturation. With air flow induced by turbine venting, D.N. levels ranged from 106 to 109 percent of saturation. This is below the 110 percent of D.N. saturation established by EPA as maximum safe limit permissible. However, additional D.N. measurements should be collected to insure that allowable levels of D.N. would not be exceeded for a variety of operating conditions.

d. Power Losses

With turbine venting using hub baffles, the presence of the baffle plates and the induced air flow impact the performance of the turbine unit. For the 60 degree baffles, figure 7 shows that at best gate conditions, 40 MW, the presence of hub baffles reduced the turbine efficiency by 0.3 percent and the presence of the induced air flow reduced the turbine efficiency by 0.7 percent, for a total efficiency loss of 1.0 percent. At full gate, approximately 50 MW, a slight efficiency loss was observed. Maximum efficiency loss, 2.6 percent, occurred at a low generation output of 20 MW. For the 45 degree hub baffles, the baffle plates and the induced air flow reduced the turbine efficiency by 1.5 percent at best gate, 40 MW (figure 8). At full gate, approximately 50 MW, a slight efficiency loss was observed. Maximum efficiency loss of 1.7 percent occurred between 25 and 30 MW.

e. Costs

In terms of lost revenue, hub baffles installed year-round on all seven units at Clarks Hill Dam would cost $102,000 annually; $39,000 in lost energy revenues and $63,000 in lost capacity revenues.

If a D.O. uptake of only 1.0 mg/l could be maintained through turbine venting, the total oxygen absorbed during the period between July 15 to November 1 would be approximately 2,900 tons. Using lost power revenues as a total cost of this oxygen, the cost per ton would be $35.

The initial cost for installing hub baffles is low due to the use of the existing free-air vent system. At Clarks Hill, the total cost of manufacturing and installing the hub baffles was $3,000 per turbine unit.

FURTHER STUDIES

Future plans at Clarks Hill Dam include a possible joint effort between the District and WES using large blowers to reduce the efficiency losses due to the presence of hub baffles. Structural modifications such as by-passing the vacuum breaker valve and enlarging the hub vents are being considered. Additional nitrogen measurements in the releases will also be collected.

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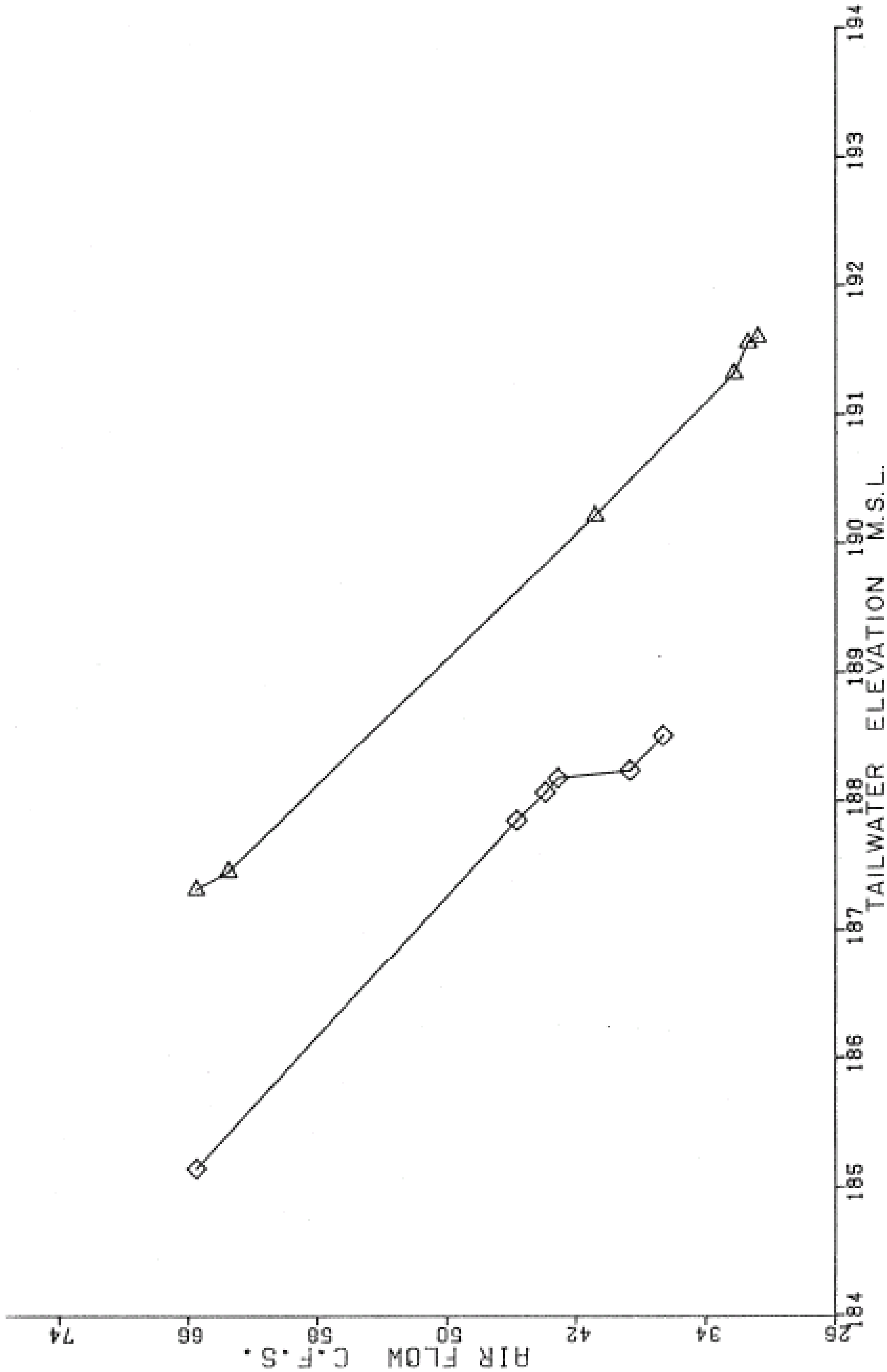
2. State of South Carolina, Water Classification Standards System for the State of South Carolina, Department of Health and Environmental Control, July 81, p. 16.

3. Raney, D. C., "Final Report on Water Tunnel Modelling of Turbine Aspiration Systems," BER Report No. 187-30, Prepared for Alabama Power Company, Birmingham, Ala., June 1975.

4. Tennessee Valley Authority, Improving Reservoir Releases, Office of Natural Resources, Division of Water Resources, December 1981.

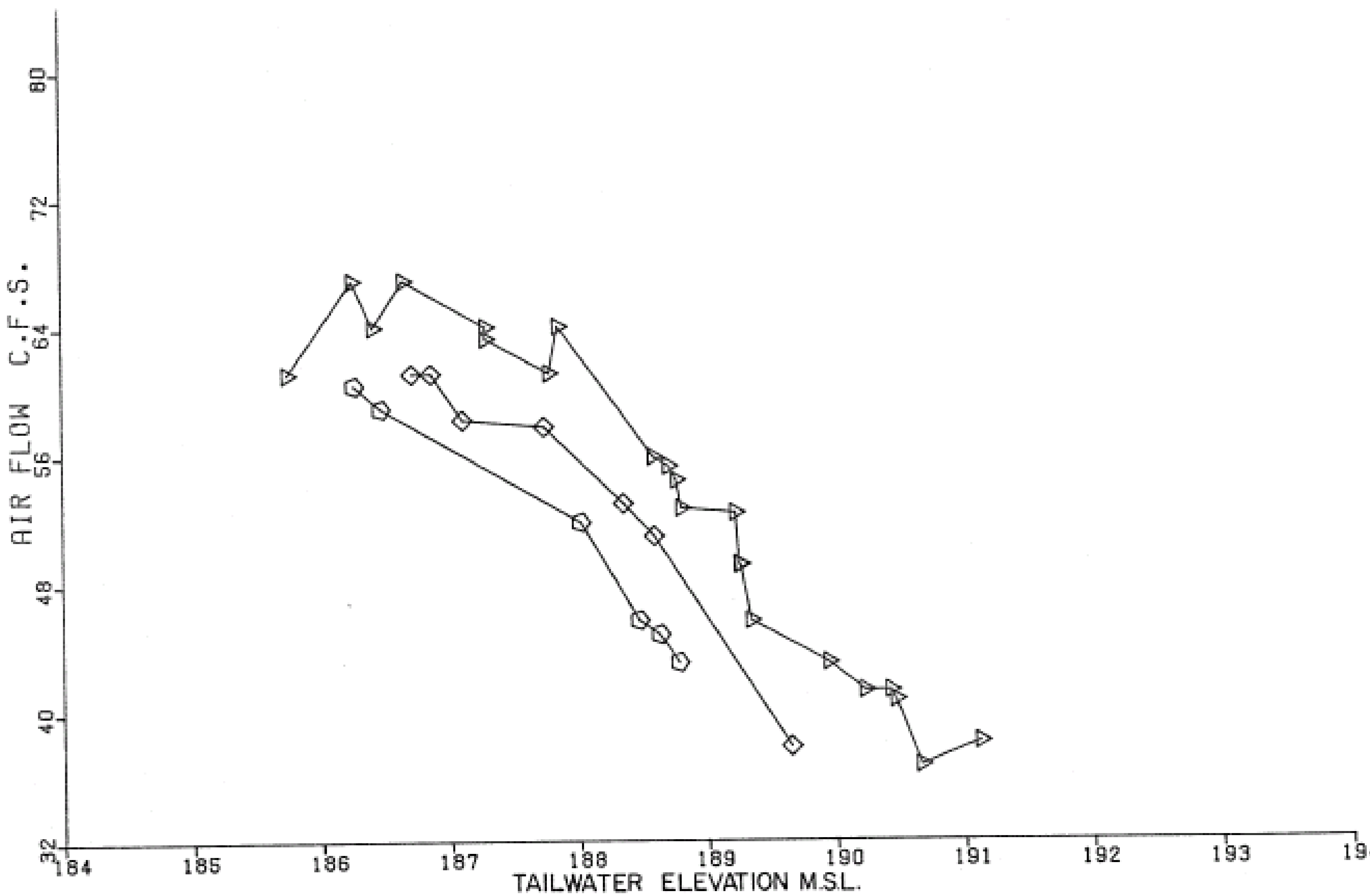


EFFECTS OF TAILWATER ELEVATION AND WATER DISCHARGE RATE ON AIR FLOW

45 DEGREE BAFFLE

◇ WATER DISCHARGE AT 4000 C.F.S.
△ WATER DISCHARGE AT 3400 C.F.S.

FIGURE 1

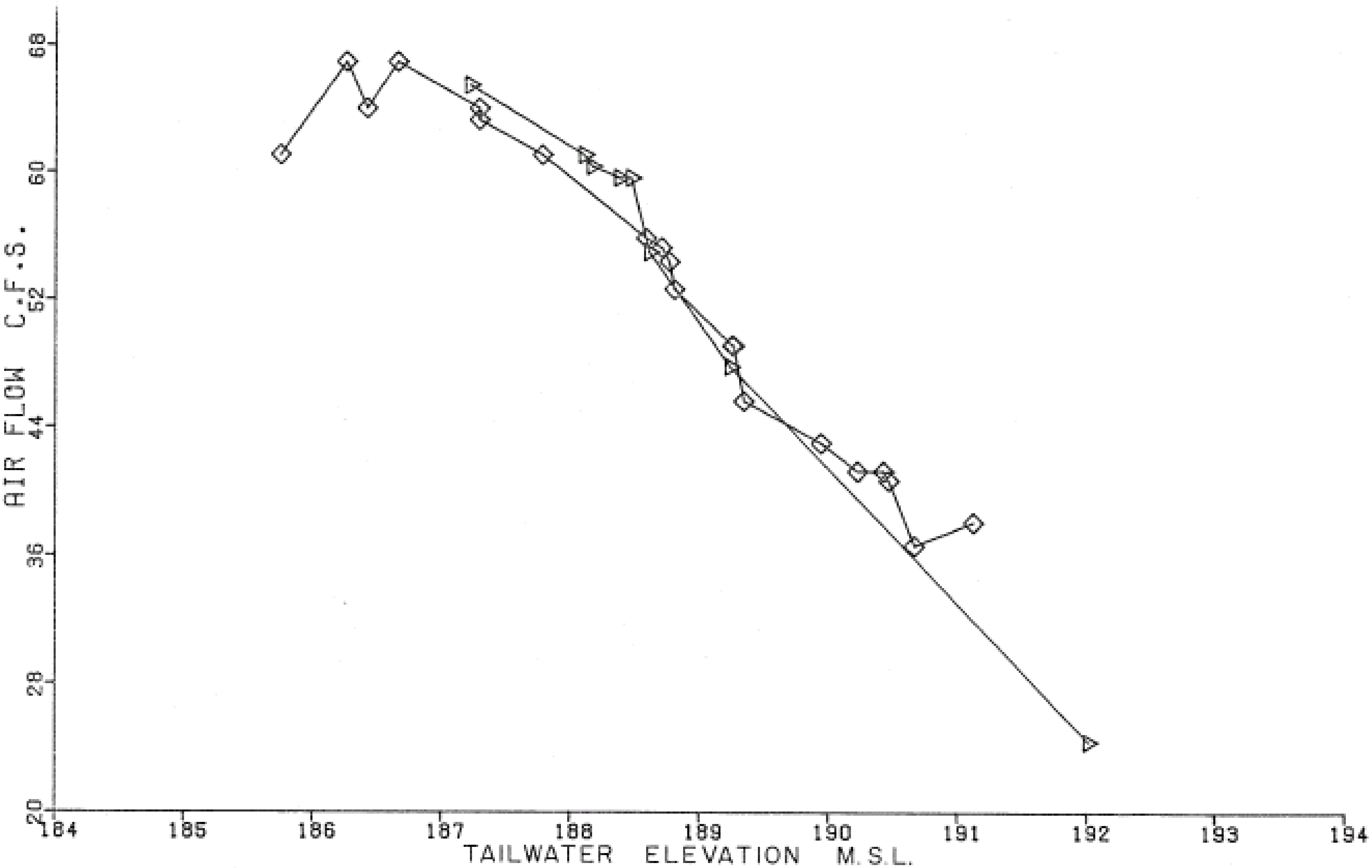


EFFECTS OF TAILWATER ELEVATION AND WATER DISCHARGE RATES ON AIR FLOW

60 DEGREE BAFFLE

⬠ WATER DISCHARGE AT 4000 CFS
◇ WATER DISCHARGE AT 3800 CFS
▷ WATER DISCHARGE AT 3600 CFS

FIGURE 2

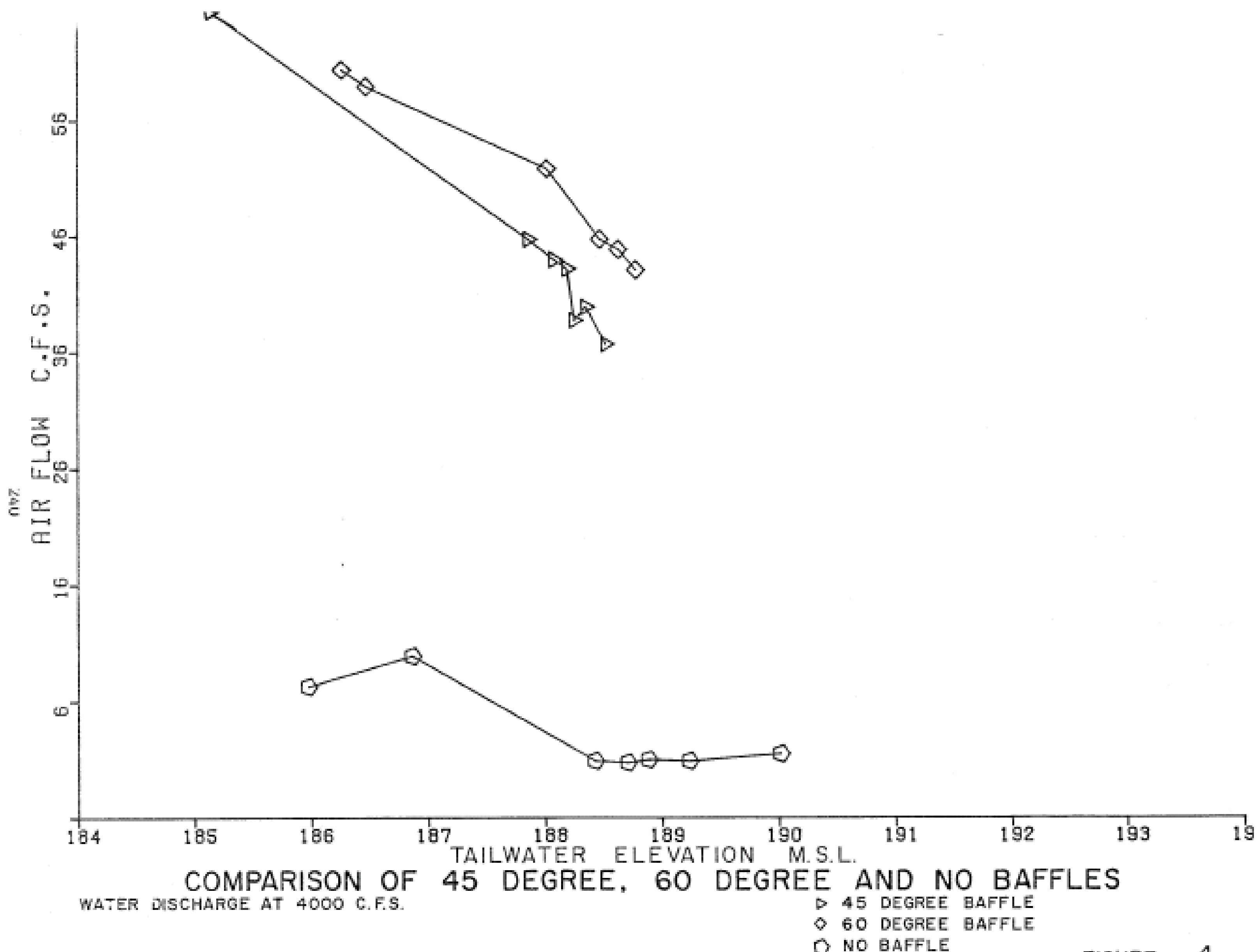


COMPARISON OF 45 DEGREE AND 60 DEGREE BAFFLES

WATER DISCHARGE AT 3600 C.F.S.

▷ 45 DEGREE BAFFLE
◇ 60 DEGREE BAFFLE

FIGURE 3



COMPARISON OF 45 DEGREE, 60 DEGREE AND NO BAFFLES

FIGURE 4

DISSOLVED OXYGEN UPTAKE DUE TO TURBINE VENTING

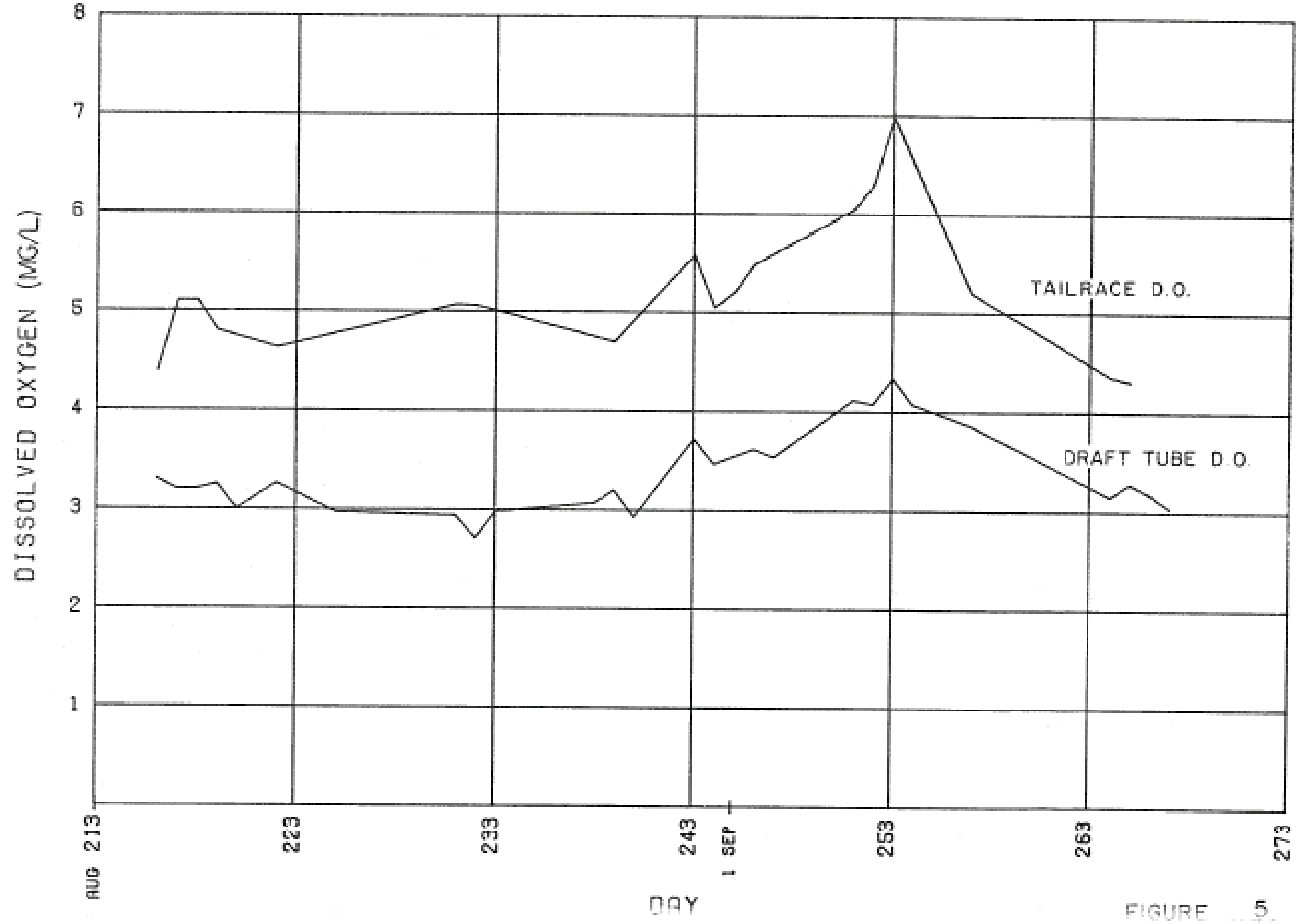
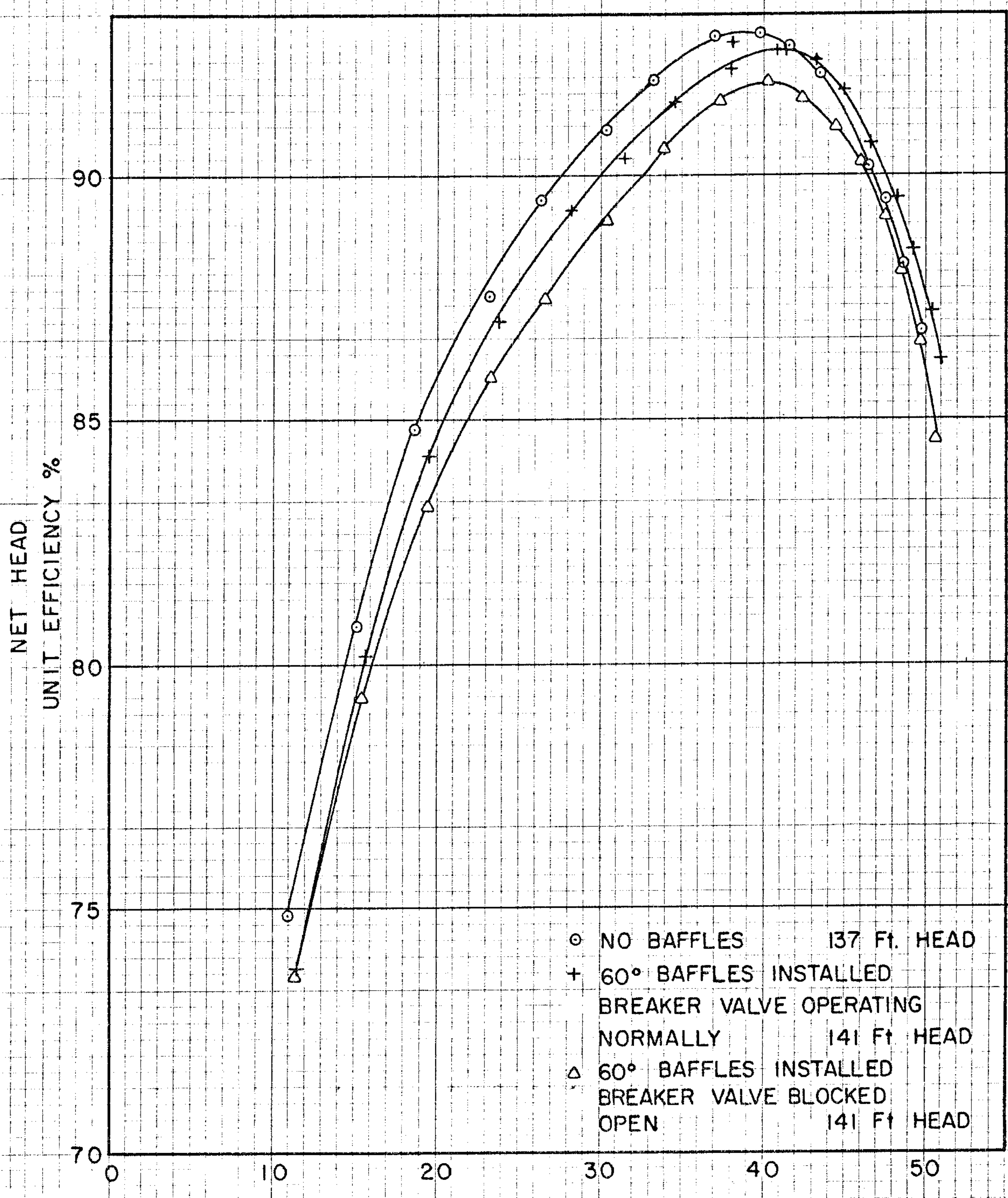
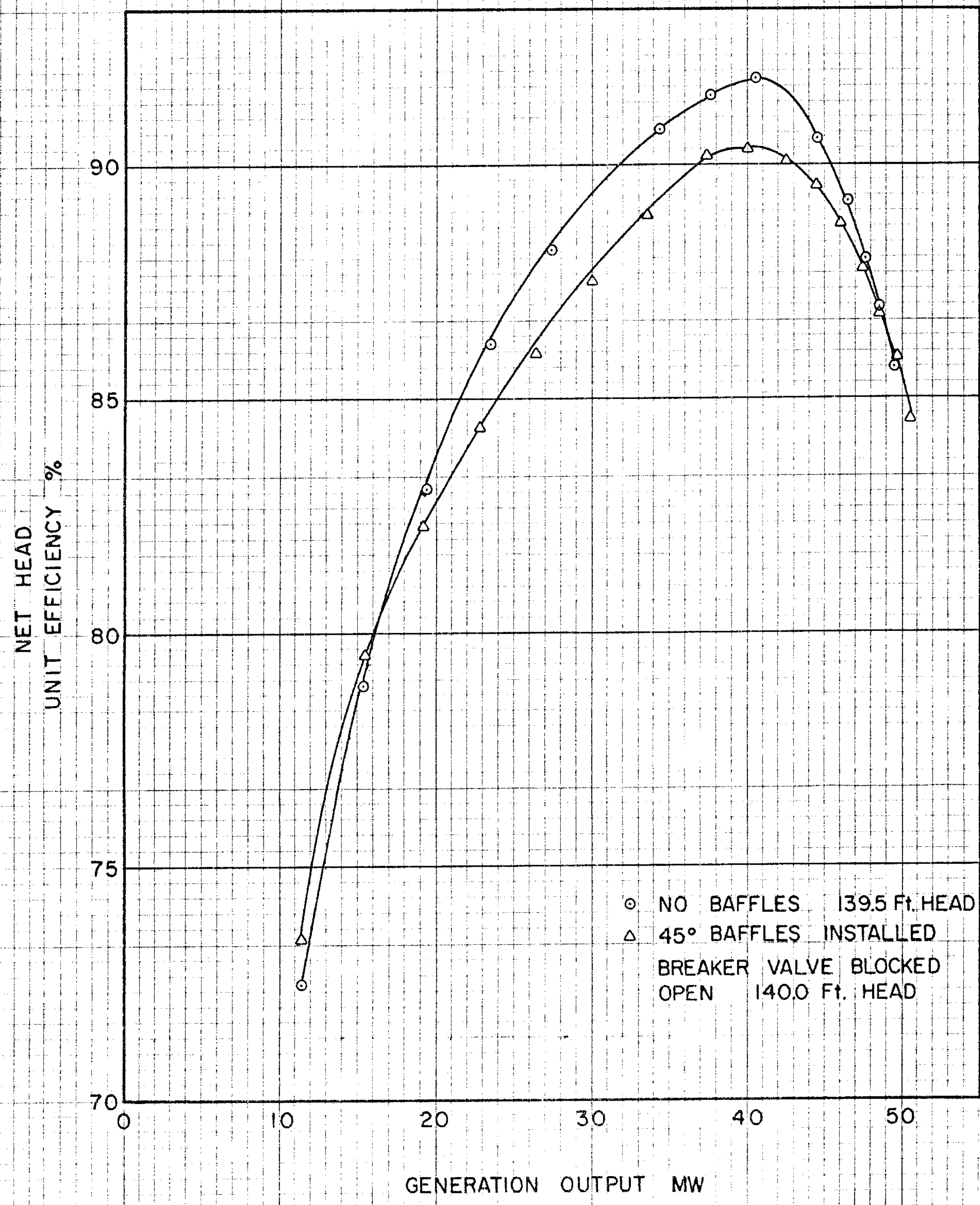


FIGURE 5.



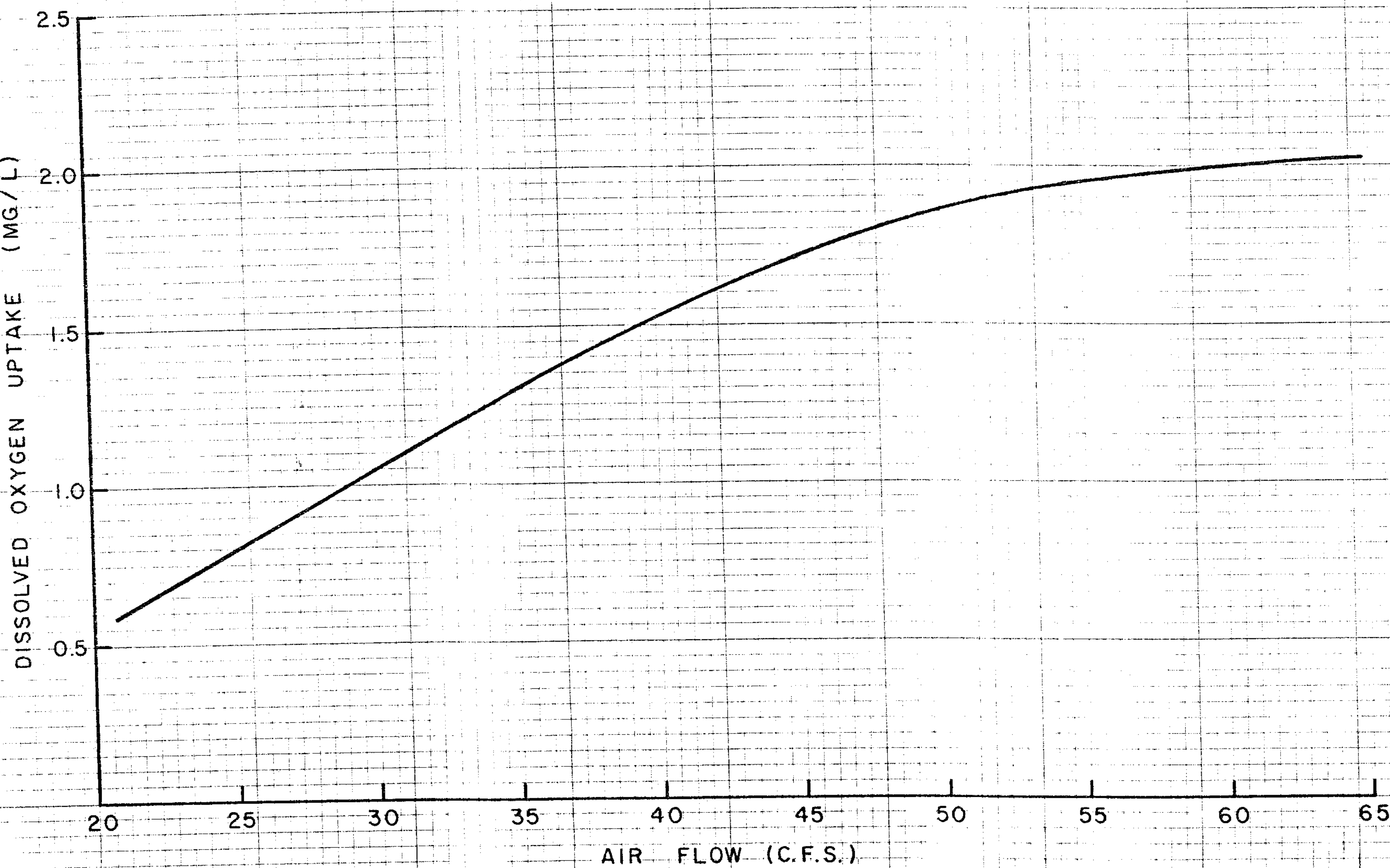
HUB BAFFLE EFFECTS ON TURBINE EFFICIENCY

FIGURE 6



HUB BAFFLE EFFECTS ON TURBINE EFFICIENCY

FIGURE 7



D.O. UPTAKE VS. AIR FLOW FOR WATER RELEASED FROM CLARKS HILL DAM

FIGURE 8

WATER QUALITY MANAGEMENT AT HARRY S. TRUMAN DAM AND RESERVOIR

By

Walter M. Linder[1]

INTRODUCTION

Harry S. Truman Dam is located in west central Missouri on the Osage River and in the headwaters of the well known Lake of the Ozarks, which is one of the most highly developed recreational lakes in the entire Midwest. Construction and operation of the Harry S. Truman project has created the potential for directly affecting the water quality of the Lake of the Ozarks. This paper describes the features of the Harry S. Truman project, the development of a water quality monitoring program for the project, and operating experience since closure of the embankment in July 1977. Major fish kills have occurred as a result of supersaturation downstream of Harry S. Truman Dam. Brief periods of depressed dissolved oxygen levels in the tailwater area have also occurred. In both cases structural modifications and adjustments in project operations have provided solutions that will significantly reduce downstream water quality problems.

PROJECT FEATURES

Construction of Harry S. Truman Dam and Reservoir was initially authorized by the Flood Control Act of 1954 (Public Law 83-780). The stated project purpose was flood control, with a capacity established at 3,918,00 acre-feet. The Flood Control Act of 1962 (Public Law 87-874) authorized multipurpose use including hydropower. Project benefits were expanded to add hydroelectric power, recreation, and enhancement of fish and wildlife conservation. Total capacity of the project was to be 5,202,000 acre-feet.

The total drainage area above the dam is approximately 11,500 square miles. Twenty-six hundred square miles of this drainage area are controlled by the five upstream Corps of Engineers lakes, Stockton, Pomme de Terre, Melvern, Pomona, and Hillsdale. This leaves an uncontrolled drainage area of 8,900 square miles. Figure 1 presents a map showing the location of the Osage River basin.

The Osage River rises in east-central Kansas, flows in an easterly direction nearly 500 miles, and joins the Missouri River in central Missouri near Jefferson City. The basin has two distinctly different topographic divisions. The western portion is located in the gently rolling uplands of the Osage Plains section of the Central Lowlands Physiographic Province, while the eastern portion is located in the rough and hilly Ozark Plateau. A transition

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zone, known as the Springfield Plateau, lies generally between the two areas. The upper end of the multipurpose pool marks the approximate boundary of the transition from the Osage Plains to the Springfield Plateau.

The Osage Plains consist of gently rolling to low hilly land with wide, shallow valleys 1 to 3 miles in width. The area is underlain by easily eroded sandstone and shales of Pennsylvanian age. Streams in the area exhibit a well developed dendritic drainage pattern. Land elevations range upwards to around 1,450 ft above mean sea level at the headwaters of the major streams.

The Springfield Plateau is characterized by older shales, limestones, and dolomites of the Mississippian age. These formations are more resistant to erosion than those of the Osage Plains and fairly steep sided valleys have formed. In contrast to the Osage Plains, the Ozark Plateau is a submaturely to maturely developed region dissected by narrow valleys, generally less than a mile in width, which are incised up to 200 feet below the adjacent ridges.

Most of the lands in the western part of the basin are devoted to agriculture. In the eastern part, much less area is cultivated and large tracts are in timber or timber pasture. Approximately 70,000 acres in central and western Missouri have been strip-mined for coal. Approximately 25,000 of these acres lie within the Harry S. Truman drainage area. Except for about 100 acres, all of this lies above the elevation of the flood pool. None of this strip-mined area has been reclaimed by grading to reduce erosion or by covering to prevent leaching of acidic water. Approximately 170 miles of streams in the Osage basin receive some contaminants from strip-mined lands.

The climate of the Osage basin is characterized by moderate winters and comparatively long summers. High and low temperature extremes have ranged from a high of 113^{o}F to a low of minus 22^{o}F. Normal mean temperatures range from approximately 80^{o}F to slightly below freezing. Annual precipitation ranges from about 34 inches in the western edge of the basin to about 40 inches over the Harry S. Truman Reservoir. Annual evaporation in the area of the reservoir is about 55 inches per year. About 70 percent of the yearly precipitation occurs during the crop growing season. For the period of available records, inflow to the reservoir, had it existed at that time, would have varied from a high of 14,192,000 acre-feet in 1973 to a low of 844,000 acre-feet in 1954. The computed average discharge from the basin above Harry S. Truman Dam is 5,557,450 acre-feet. This corresponds to slightly over 9 inches of runoff from the 11,500 square miles of drainage area. Had the project been in operation in 1943, the peak mean-daily inflow to the reservoir would have been 164,200 cubic feet per second (c.f.s.). Inflows approaching zero would have occurred in the droughts of the 1930's and 1950's.

The Osage Plains contribute a moderate sediment load to the streams, while sediment yields from the Springfield and Ozark Plateau regions are very low. Overall, the annual volume of sediment contributed by the basin is relatively small compared to other basins of similar size in this geographical area. Based on surveys of existing sediment deposits in the Lake of the Ozarks, the average annual sediment transport is estimated to be about 2.3 million tons or a little over 2,000 acre-feet per year. The sediment transported by the

Osage River is quite uniform in composition and is composed primarily of silt and clay, with traces of fine sand. The median grain size is approximately 0.02 mm (20 microns). Suspension of this very fine material in the water results in high turbidity levels in the Osage River and the upper reaches of the Truman Reservoir.

Water quality data collected during the period 1973 through 1975 for preimpoundment studies show that the overall water quality of streams within the Osage River basin is generally satisfactory. The streams within the Osage Plains are more turbid, slightly warmer, less oxygenated, more highly mineralized, and have a greater nutrient load than those in the Springfield and Ozark Plateau regions. The most important factors affecting the Osage River, its tributaries, and Truman Reservoir are the high nutrient and turbidity levels and, to a lesser extent, strip mine runoff. The nutrient levels of the streams flowing out of the Osage Plains would be considered eutrophic, but, principally because of the high turbidity levels, the potential for biological overproduction is depressed. Water quality in portions of streams draining strip-mined lands is unsuitable for public drinking water supplies, recreation, irrigation, and livestock watering.

The dam is a gravity type structure consisting of a compacted earthfill main embankment, approximately 5,000 ft long and 126 ft in height above the streambed, and a concrete spillway with powerhouse structure 964 ft long. The spillway is a gated-concrete overfall type with a crest elevation of 692.3 ft above mean sea level (m.s.l.), which is 13.7 ft below the multipurpose pool elevation of 706.0 ft, m.s.l. The spillway is located near the right abutment and adjacent to the powerhouse section. The width of the spillway crest is 160 ft and flow is controlled by four 40-ft wide by 47.3-ft high tainter gates. The spillway will normally not be used unless flood discharge requirements exceed the powerhouse capacity.

The powerplant consists of six slant type reversible pump turbines that have a discharge capacity of 65,000 c.f.s. at full plant capability. Capacity in the pumpback mode varies with head, but averages 27,500 c.f.s. Invert elevation of the inlets to the power units is 603.5 ft, m.s.l., or 102.5 ft below the elevation of the multipurpose pool. Tailwater elevations are dependent upon the level of the Lake of the Ozarks, but can be expected to vary between 650 and 660 ft, m.s.l. Normal tailwater elevation at the start of a period of generation can be expected to be in the 656 to 658 ft, m.s.l., range of elevations. Except for extended periods during evacuation of stored flood water, the powerplant will normally be operated for power peaking, which will result in relatively high discharges for short periods of time. During periods of low inflow during the summer months and assuming pumpback power is available, the weekly power operation would be generation for 6 to 8 hours a day 5 days a week, with sufficient pumpback occurring at night and over the weekend to return the pool to its initial elevation at the beginning of the week.

At multipurpose pool elevation of 706.0 ft, m.s.l., the Harry S. Truman Reservoir has a surface area of 55,600 acres and a shoreline length of 958 miles. The volume of water in storage at this elevation is 1,203,400 acre-feet, which includes 106,400 acre-feet for power generation and 163,000 acre-feet for sediment deposition. The average flood plain elevation above the dam site is approximately 660.0 ft, m.s.l., which gives an average water depth over the flood plain of about 46 ft. Depths in the former river channel are about 30 ft greater. A channel was not excavated between the powerhouse intakes and the river channel. Since the river channel is located nearly a half-mile from the powerplant intake, it was anticipated that power releases would not draw water from the deeper river channel. A more detailed description of the Osage River basin and project features may be found in the "Lake Regulation Manual," Reference 5.

Thermal simulation studies of Truman Reservoir were conducted in 1972 and again in 1976 and 1977. These thermal simulation model studies used what has become known as the "Eiker Model" to predict the degree of thermal stratification, the effect of power releases and pumpback on downstream water temperatures, the effectiveness of an upstream skimming weir at various crest elevations. The 1972 studies assumed the upstream flood plain at elevation 660 ft, m.s.l., would act as a broad crested weir. In 1976 and 1977 the flood plain elevation and the three higher elevations of 670, 780, and 686 ft, m.s.l., were considered as possible weir crest elevations. These studies indicated the reservoir would be somewhat thermally stratified, with the strongest stratification occurring in late summer and early fall. It was also concluded that, while the reservoir would be stratified during this period, the portion of the reservoir above elevation 660 ft, m.s.l., would be essentially homogenous. As a result, releases would be cooler than natural stream temperature during the spring months, nearly the same as the natural state during part of the summer, and warmer than the natural level during the late summer and early fall. Studies with the higher weir crests indicated no significant beneficial effect on the outflow temperatures except in the spring.

Closure of the river channel occurred in July 1977 and flow was diverted through the unfinished spillway which had been left at elevation 660.0 ft, m.s.l. Fill material for the embankment closure section, which was located at the left abutment, had to be obtained from borrow areas located upstream of the dam on the right side of the valley. In order to transport this fill material to the embankment closure area, a haul road was constructed approximately to elevation 703 ft, m.s.l., and about 800 ft upstream of the spillway and powerhouse. The opening in the haul road for the diversion channel was spanned with a bridge.

Temperature and dissolved oxygen data collected in the Harry S. Truman Reservoir in July 1977, after closure of the river section, and again in 1978 and 1979 showed thermal stratification to be similar but stronger and more classical than predicted by the thermal model. The thermal stratification was also accompanied by a very severe oxygen depletion in the mid-levels of the pool, with anaerobic conditions near the bottom.

These observations led to a decision to remove only the top portion of the upstream haul road and fill in the bridge opening. The remaining portion of the embankment would then act as an upstream skimming weir and provide warmer water with higher oxygen levels for power generation releases. Since the thermal model studies indicated very little improvement could be made in the temperature of the release water, the elevation of the weir crest had to be located so as to prevent, to the extent possible, the withdrawal of the anaerobic hypo or metalimnetic water. Evaluation of observed water temperature and dissolved oxygen profile data suggested a weir crest 15 to 20 feet below the surface of the multipurpose pool would be the most desirable from an overall standpoint. Initially the intent was to lower the haul road to elevation 686 ft, m.s.l. However, construction delays were encountered along with high pool elevations in the reservoir. As a result, the lowest elevation to which the road embankment could be practically lowered was 693.0 ft, m.s.l. Although the final weir crest is 7 ft higher than originally intended, it should assure a more satisfactory downstream water quality during power generation from the multipurpose pool and be more effective during periods of higher reservoir levels. A detailed discussion of design studies for the skimming weir may be found in Reference 4, Design Memorandum No. 49, "Maintenance of Satisfactory Downstream Water Temperatures and Dissolved Oxygen Concentrations Through Use of a Skimming Weir." A plan view of the left-hand portion of the dam and the upstream skimming weir are shown on Figure 2.

WATER QUALITY MONITORING PROGRAM

Preimpoundment water quality surveys were conducted over a 3-year period, 1973-75, on the Osage River and those tributaries that would be affected by Harry S. Truman Dam and Reservoir. These surveys were made in order to determine baseline water quality conditions that existed prior to impoundment and to provide data for documentation of any changes in water quality after impoundment. The data were also used to predict conditions likely to occur and the capability of the project to meet desired water quality objectives. Fifty-seven water quality stations, including one station in the tailwater area, were established for this study. Specific information obtained included:

a. Density and diversity of benthic macroinvertebrates.

b. Density and diversity of phytoplankton.

c. Fecal coliform and fecal streptococcus.

d. Measurements of water temperature, pH, turbidity, suspended solids, conductivity, and dissolved oxygen.

e. Chemical analysis for chemical oxygen demand, total phosphorus, orthophosphate-phosphorus, ammonia-nitrogen, nitrate-nitrogen, sulfate, chloride, iron, manganese, sodium, potassium, calcium, magnesium, fluoride, and silica dioxide.

Collection of samples and analysis of data relative to items a through d above were conducted by personnel of the Water Quality Unit of the Kansas City District. Chemical analysis of water samples was performed by the State of Missouri, Division of Environmental Quality. Detailed results of the preimpoundment water quality studies are presented in Reference 2, "Preimpoundment Water Quality of Harry S. Truman Reservoir."

The Kansas City District and the Missouri Department of Natural Resources agreed late in 1976 to a cooperative venture to collect additional water quality data. Under the terms of this agreement, personnel from the Kansas City District would conduct routine monthly water quality surveys to collect and analyze biologic samples and obtain physical measurements of water quality indicators. Water samples would be furnished to the State of Missouri for chemical analysis. This agreement initially included Harry S. Truman Reservoir and two other Kansas City District lakes in the State of Missouri. In 1978, the State discontinued providing chemical analysis of waters from the two lakes other than Harry S. Truman. Routine monthly sampling is conducted at three sites: (1) the reservoir about 1 mile upstream of the dam, (2) the tailwater area, and (3) the Lake of the Ozarks about 5 miles below Harry S. Truman Dam.

At each location, water samples are collected from the surface and also collected from near the bottom in the Truman Reservoir and the Lake of the Ozarks. These samples are analyzed onsite in a mobile laboratory to determine levels of calcium, chloride, alkalinity, hardness, turbidity, and pH. Other water samples are preserved as necessary and sent to the State of Missouri, Division of Environmental Quality, for further chemical analysis. Physical measurements of water quality parameters are also made at each station. In addition to the chemical and physical measurements, biological sampling is conducted. Sediment samples are dredged from the bottom and analyzed for larval insects and other microscopic organisms, while surface water samples are analyzed for algae. These biological analyses are performed in the District's water quality laboratory in Kansas City. Bacterial concentrations at public use areas such as swimming beaches and marianas are also determined. Bacterial samples may also be collected in the vicinity of municipal sewage treatment plants that discharge effluents into reservoir inflows.

During May and June 1980, an extensive postimpoundment water quality survey was conducted in the Truman Reservoir. Water quality measurements and samples were obtained at several locations in each of the major arms of the reservoir. As expected, a strong thermal stratification had developed with very low oxygen levels below the thermocline. Other than high levels of dissolved manganese in the lower levels of the water column, the water quality was found to be quite good.

Data concerning the quality of water discharged from the Harry S. Truman project is obtained automatically. Electronic monitoring equipment has been installed in the tailwater area at a location approximately 2,200 feet downstream of the powerhouse. This equipment includes (1) an acoustic velocity meter which continuously measures flow velocity and computes the discharge, (2) a standard U.S. Geologic Survey bubbler type stage recorder, (3) water quality monitoring equipment, and (4) a meteorologic station. The water quality monitoring equipment consists of a submerged pump which continuously circulates water from the discharge channel through sampling chambers where sensors measure temperature, dissolved oxygen, pH, conductivity, turbidity, and total gas pressure relative to atmospheric pressure. The latter measurement is obtained by a tensionometer, which when working properly gives an indication of supersaturation levels, if any, in the water. Velocity and discharge data are listed by a teletype printer located in the equipment shelter. This information can also be accessed in the Kansas City District office via telephone. Dissolved oxygen values are continuously recorded on a strip chart. All data, except velocity and discharge, are collected hourly by a Data Collection System and transmitted every 4 hours via Geostationary Environmental Satellite (GOES) to the National Oceanic and Atmospheric Administration, National Environmental Satellite System (NOAA/NESS) facilities in Suitland, Maryland. These data are then obtained by telephone line from the NOAA/NESS facilities. The raw satellite data are converted to engineering units, stored in a water quality data base, and printed by a micro-processor in the Water Control Section, Kansas City District. Thus, near real time downstream water quality data is available for use in making operating decisions relative to water quality. Figure 3 shows a schematic of how water quality data is transmitted from Truman Dam to the District Office. Table 1 is a printout of data obtained from the Data Collection System at Truman Dam.

OPERATING EXPERIENCE

Supersaturation.

When closure of the river sections occurred in July 1977, flow was diverted through the uncompleted spillway which had been constructed to an interim elevation of 660 ft, m.s.l. Completion of the spillway to its operating elevation of 692.3 ft, m.s.l., could not be started until the embankment in the closure section had reached an elevation that would be capable of containing the flood of record. An unexpected major fish kill occurred downstream of the dam during the spring and early summer of 1978. The cause of the fish kill was determined to be supersaturation of the water passing through the uncompleted spillway. Air entrained in the water plunging into the stilling basin was forced into solution by hydrodynamic pressure, creating supersaturated concentrations of dissolved atmospheric gases in the water. Saturation levels immediately downstream of the dam reached a maximum of 143 percent and levels above 115 percent were observed as far as 60 miles downstream in the Lake of the Ozarks.

Hydraulic model studies were initiated early in June 1978 at the Waterways Experiment Station. As a result of these model studies, it was found that removal of a section of concrete from the downstream end of the uncompleted spillway crest would cause the water to flow across the surface rather than plunge to the bottom of the stilling basin. During the summer of 1978 approximately 6 feet of concrete for a length of 30 feet from the downstream end of the existing spillway crest was removed from three of the four bays.

Model studies also showed that the addition of a 7-foot wide deflector or "flip lip" on the downstream face of the spillway at elevation 655 ft, m.s.l., would provide the best long term solution for prevention of supersaturation during spillway flows. Construction of these deflectors was completed in November 1978 and work was started on raising the spillway to its final crest elevation. However, severe winter weather and high flows in late winter and early spring of 1979 limited the amount of work that could be accomplished. By early April the spillway elevation had only reached 671 ft, m.s.l., in three of the four bays. High flows through the spillway in mid-April resulted in downstream supersaturation levels of 138 percent and another major fish kill occurred. These high supersaturation levels occurred because the spillway crest was too low for the deflectors to operate properly. By late May, the spillway crest had reached 676.0 ft, m.s.l. Despite high flows in June, supersaturation levels remained between 110 and 115 percent due to the effectiveness of the deflectors. Construction of the spillway was completed in October of 1979 and the gates closed to initiate impoundment of the reservoir.

High inflows to the reservoir in 1980 and 1981 resulted in maximum pool elevations of 712.0 and 722.3 ft, m.s.l., respectively. Since none of the power units were as yet available, releases from the flood control pool had to be made through the spillway. The deflectors were not totally effective in preventing supersaturation, since they were designed to operate with tailwater levels produced by combined flows from the powerplant and spillway. However, by limiting spillway discharges to about 25,000 cubic feet per second (c.f.s.) in 1980 and 30,000 c.f.s. in 1981, supersaturation levels in the tailwater area were held within a range of 118 to 123 percent. Even though supersaturation remained at that level for a period of approximately 6 weeks, there were few, if any, fish killed as a result of supersaturation.

Figure 4 presents a graph which shows conditions under which the flow from the spillway will plunge or be deflected across the surface. You will note that in 1980 and 1981 the tailwater elevations were slightly below the plunging line. As a result, some portion of the flow partially overrode the deflectors and plunged into the stilling basin. When the powerplant can discharge to its full capacity, flows of approximately 50,000 c.f.s. can be passed through the spillway before the jet overrides the deflectors. A description of the hydraulic model studies conducted at the Waterway Experiment Station to find a solution to the supersaturation problem is presented in Reference 3, "Model Study of Harry S. Truman Spillway, Osage River, Missouri." Reference 1, "Supersaturation Studies, Osage River, Missouri, Downstream from the Harry S. Truman Dam and Reservoir," describes the supersaturation problem that occurred at Harry S. Truman Dam and presents data collected during and after the period of supersaturation.

Reservoir Water Quality and Skimming Weir Performance During 1981.

High inflows in May and June of 1981 raised the reservoir level to 722.3 ft, m.s.l. This was over 16 ft into the flood pool and 10.3 ft higher than had been experienced in 1980. Actively growing vegetation around the perimeter of the reservoir was submerged, and large amounts of organic material were carried into the reservoir by flood inflows. This created a very heavy oxygen demand in the reservoir waters. Dissolved oxygen (D.O.) levels of less than 1.0 milligram/liter (mg/l) existed only 3 to 5 feet below the water surface in some parts of the reservoir. Longitudinal thermocline and dissolved oxygen profiles observed in the two major arms of the reservoir on the 7th of July are shown in Figures 5 and 6. Similar profiles for the Osage River arm obtained on the 12th of August are shown on Figure 7. Inflow to the reservoir had fallen substantially about a week prior to the August 12th observations. As a result, the thermocline was no longer being suppressed and was generally located nearer the surface in the upstream part of the reservoir. The D.O.

level in part of the water column was also improved. Temperature and dissolved oxygen profiles obtained 1 mile upstream of the dam on the 20th of July 1981 are shown on Figure 8. This shows D.O. levels of approximately 0.5 mg/l existed from elevation 694 down to the bottom.

Flow velocity, temperature, and dissolved oxygen profiles were obtained in the vicinity of the skimming weir on the 22nd of July, 1981. These are shown on Figures 9 and 10. Figure 2 shows the location where these measurements were obtained. The reservoir elevation on July 22nd was approximately 10 ft above the multipurpose pool and the spillway was discharging 30,000 c.f.s. The velocity profiles obtained approximately 100 ft upstream of the weir and at the weir crest show that water was generally being drawn from the upper portion of the reservoir. After passing over the weir, the flow appeared to plunge, as shown by the velocity profile obtained approximately 300 ft downstream of the weir. The D.O. profile obtained upstream of the weir shows the elevation of the oxycline was located well above the weir crest. The profile at the crest shows water with low D.O. levels was being drawn over the weir as one would expect. The D.O. profile downstream of the weir showed the oxycline to be located 5 to 6 ft above the spillway crest. Even though some water with reduced oxygen levels was being drawn through the spillway, reaeriation in the stilling basin resulted in downstream D.O. levels of 7.7 and was causing supersaturation values of 119 percent.

A second set of dissolved oxygen and temperature profiles in the vicinity of the skimming weir were obtained on 11 August 1981. Releases through the spillway had been stopped and testing of one power unit was in progress. The reservoir elevation had also dropped a little over 8 ft since the July measurements and was only 1.6 ft above the multipurpose pool level. The oxycline was probably located near or below the elevation of the weir crest, although no profiles were obtained upstream of the weir. The first set of profiles was obtained downstream of the weir and showed D.O. levels of above 5.0 mg/l nearly to the bottom. Except for brief shutdown periods, one power unit had been operating since about noon the previous day. One of these shutdown periods occurred during the time the profiles were being obtained downstream of the skimming weir. Several hours later when the profiles over the weir crest were obtained, the power unit was discharging approximately 7,400 c.f.s. The D.O. profile at the weir shows levels above 5.0 mg/l to within a few feet of the crest, indicating the weir was effective in preventing withdrawal of water with low D.O. levels from the upstream side of the weir. These profiles are shown in Figure 11.

These two sets of measurements essentially confirmed performance expectations of the skimming weir. At high pool levels when the thermocline and oxycline are located above the weir crest, the weir cannot be expected to be effective in preventing withdrawal of water with low D.O. levels. Had the powerhouse been in operation on the 22nd of July without the benefit of the skimming weir, water with very low D.O. levels would have been released. With the weir in place, at least some surface water would have mixed with the releases and raised the D.O. level of any water passing through the powerhouse. As shown by the measurements on 11 August, the weir was effective in preventing the release of water with low D.O. levels, at least for the rate being discharged through the powerhouse at that time. At higher powerhouse discharges, some water with low D.O. may be drawn over the weir, but the weir should prevent total withdrawal of water with low D.O. levels from the bottom of the reservoir.

Low Downstream Dissolved Oxygen Levels.

Low dissolved oxygen levels downstream of the dam also occurred in 1981 as well as supersaturation. In late July, during evacuation of the flood control pool, heavy rains increased flows in the lower Missouri River to well over flood stage on that stream. The flood control operation of Harry S. Truman Dam calls for no releases when the flow of the Missouri River at Hermann, Missouri, exceeds 260,000 c.f.s. and is increasing. This situation occurred late in July, and spillway releases were reduced from 30,000 c.f.s. to zero at 3 p.m. on the 27th of July. A small fish kill was observed the following day. A Winkler test for dissolved oxygen early in the morning on the 28th showed the D.O. content of the water in the tailwater area to be 3.5 mg/l, below the desired 5 mg/l. Outflow remained at zero through the 28th. A Winkler test on the morning of the 29th showed a D.O. level of 3.2 mg/l. Stages on the Missouri River upstream of Hermann had started to drop and at 10 a.m. that morning the spillway gates were opened to release a discharge of 20,000 c.f.s. Examination of the recorder chart from the dissolved oxygen monitor indicated the D.O. started to fall approximately 1 hour after the spillway gates were closed. The D.O. content in the tailwater area fell steadily to a low of about 1.4 mg/l shortly before midnight the 27th, rose to about 3.4 mg/l shortly before noon the following day, and fell again during the night of the 28th to 1.0 mg/l. When the spillway gates were opened the morning of the 29th, the D.O. level immediately responded and within an hour after opening the gates the D.O. had risen to almost 10 mg/l. Figure 12 shows the D.O. levels as recorded by the downstream monitor during this period.

Low downstream D.O. levels occurred a second time in mid-August when spillway flows were shut off on the morning of August 12th in order to resume testing of power unit No. 6. Spillway flows of 9,000 c.f.s. were shut off at 8:30 a.m. Unit No. 6 was brought on line between 10 and 11 a.m. at a discharge of approximately 8,600 c.f.s. Downstream D.O. levels were measured at 6.6 mg/l that morning. Unit No. 6 remained on line for the remainder of the day and through that night. At 7:00 a.m. on the morning of the 13th the unit was shut down due to low governor oil pressure. A measurement in the tailwater area at 7:25 a.m. showed a D.O. level of 4.5 mg/l. It was anticipated the unit would be down for only a short period of time and since there was a relatively small amount of water remaining in the flood pool, the spillway gates were not opened. The unit remained off line all day and that night. Downstream D.O. levels remained at approximately 4.5 mg/l during the day, but dropped to about 3.0 mg/l that night. Measurements immediately downstream of the powerhouse at 10:00 a.m. the morning of the 14th showed D.O. levels of 2.7 mg/l at the surface and 2.2 mg/l near the bottom. A minor fish kill was observed in the area of the powerhouse tail race, apparently as a result of the low D.O. levels. Unit No. 6 was restarted at 11:30 a.m. and D.O. levels increased to 4.2 mg/l on the surface by noon and to 5.4 mg/l at 1:30 p.m. By evening D.O. levels at the downstream monitor had increased to approximately 6 mg/l.

Generator testing continued until the 21st of August when Unit No. 6 was again shut down. Downstream D.O. levels were satisfactory during the day, but declined that night and ranged between 3 and 5 mg/l at the time of the morning measurements. When Unit No. 6 was shut down on 21 August, the spillway gates were opened to discharge 500 c.f.s. in an effort to determine if small spillway releases would maintain satisfactory downstream D.O. levels. Spillway releases were reduced to 400 c.f.s. at 8:00 a.m. and to 250 c.f.s. at 4:00 p.m. on August 24th to determine the minimum spillway release required to maintain a satisfactory downstream D.O. level. D.O. levels ranged from 5 to 8 mg/l during the day on 25 August, but dropped to slightly under 4 mg/l by the morning of the 26th. D.O. levels increased to 5.9 mg/l during the day on the 26th and then dropped to 4.5 mg/l during the night. At 4:00 p.m. on 27 August spillway releases were increased to 500 c.f.s. and D.O. levels dipped below 5 mg/l only briefly during the night and then ranged between 5 and 7 mg/l for the next several days. This indicated a release of 500 c.f.s. from the spillway would maintain downstream D.O. levels at an acceptable level. Figure 13 shows the D.O. levels recorded by the downstream monitor for the period 25 through 29 August. The daily rise in D. O. levels, which peaked between noon and 6 p.m., was apparently due to photosynthesis during the daylight hours.

The rapid decline of downstream D.O. levels during periods of zero outflow from the dam has not been fully accounted for. Water quality measurements had indicated neither the chemical or biological demand for oxygen could account for the decline. At one time during this period, a pail of water from the tailwater area was placed in the monitor house which is climate controlled and dark unless the lights are turned on. The D.O. content of this water was periodically measured over a length of time. These measurements showed little or no decline of the D.O. of the water sample. One plausible explanation that has been brought forth to date is the rapid consumption of oxygen by the large concentration of fish in the tailwater area during this period. Several other possible causes might be leakage of water with a low D.O. content through the gates of the power units, or the upstream flow of a density current carrying deoxygenated water from below the thermocline on the Lake of the Ozarks. However, neither of these seem very probable. The region of low D.O. was confined to the immediate tailwater area in the outlet channel. Measurements in the river several miles downstream did not show a significant decline in D.O. levels during periods of zero release. Outflow from the dam was reduced to zero over several weekends in January of 1982. D.O. levels in the tailwater area during these periods of zero release remained at satisfactory levels.

CONCLUSIONS

During the four and one-half years that have elapsed since closure of Harry S. Truman Dam, several water quality problems have occurred. These have been corrected either by structural modifications or by adjustments in operation. The occurrence of downstream supersaturation was substantially reduced by the construction of deflectors or "flip lips" on the downstream face of the spillway and by limiting the amount of spillway discharges until completion of the construction of power facilities. Adaptation of the upstream haul road as a skimming weir should reduce the amount of deoxygenated water released during high reservoir levels and may totally prevent the occurrence during normal pool levels. Depression of downstream D.O. levels during periods of non-generation may be avoided by making small releases from the spillway during certain times of the year.

REFERENCES

1. Emanual, Douglas, and Vandenberg, Raymond, "Supersaturation Studies, Osage River, Missouri, Downstream From the Harry S. Truman Dam and Reservoir," Water Quality and Sediment Unit, Kansas City District Corps of Engineers, 1981.

2. Kersh, Garland M. Jr., "Preimpoundment Water Quality of Harry S. Truman Reservoir," Water Quality and Sediment Unit, Kansas City District Corps of Engineers, June 1977.

3. Pickering, Glen A., Murray, D. Bruce, "Model Study of Harry S. Truman Spillway, Osage River, Missouri," Technical Report HL-79-20, Hydraulic Laboratory, U.S. Army Engineer Waterways Experiment Station, Nov. 1979.

4. U.S. Army Corps of Engineers, "Maintenance of Satisfactory Downstream Water Temperatures and Dissolved Oxygen Concentrations Through the Use of a Skimming Weir," Design Memorandum No. 49, Harry S. Truman Dam and Reservoir, Kansas City District, Kansas City, Mo., Nov. 1979.

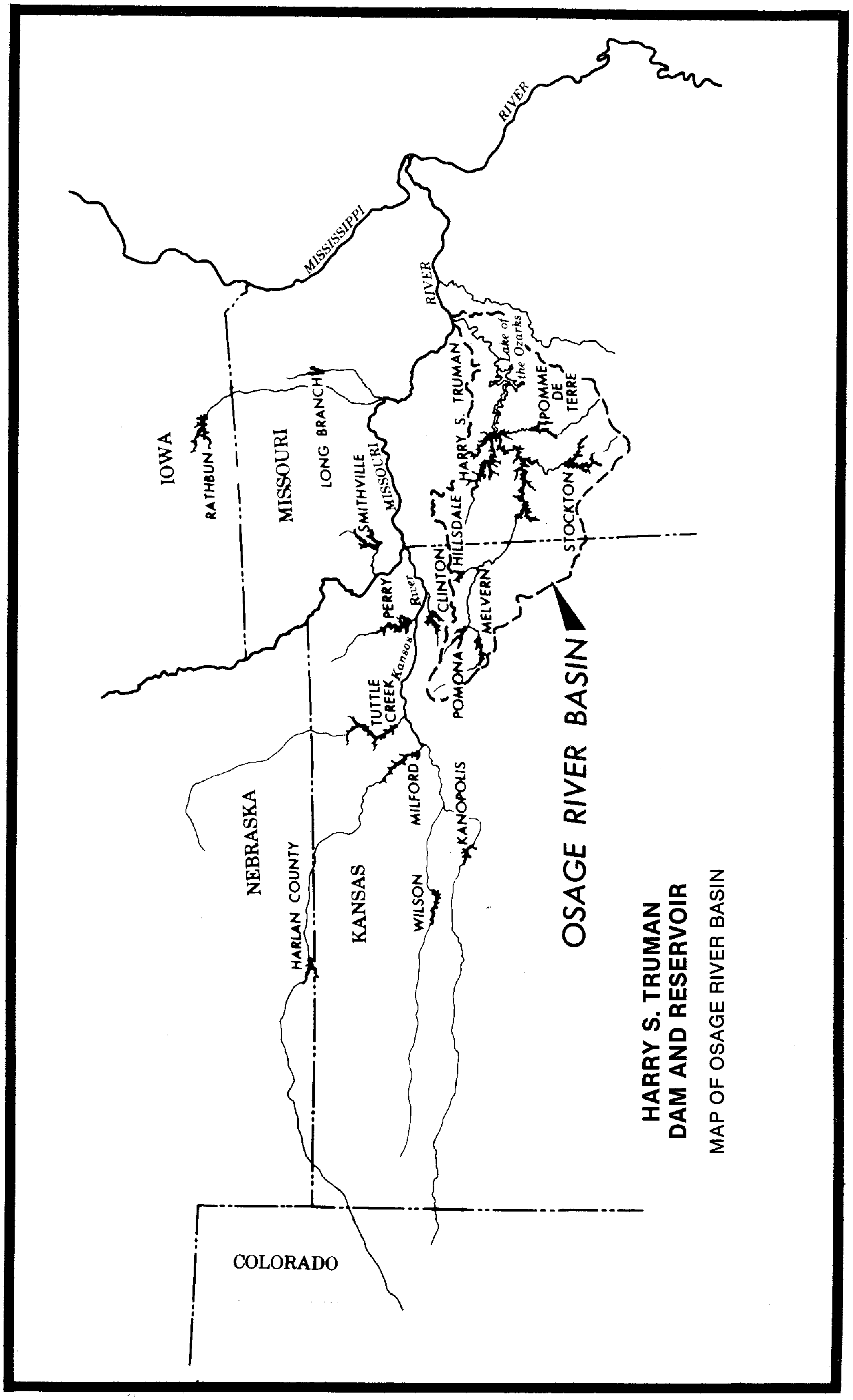
5. U.S. Army Corps of Engineers, "Preliminary Lake Regulation Manual, Osage River Basin, Harry S. Truman Reservoir, Missouri," Volume No. 4, Kansas City District, Kansas City, Mo., Jan. 1981.

TABLE 1

HARRY S TRUMAN WATER QUALITY DATA
BY
GEOSTATIONARY ENVIROMENTAL SATELLITE

HARRY S TRUMAN (DS) STA:CE513F22
JULIAN DAY: 59 SUNDAY 28 FEB, 1982 CHANNEL 7E

LOCAL TIME	STAGE	POOLEL	PRECP	EV-TP	TENSON	D.O.	TEMP	P.H.	COND.	TURBID
00:00	654.66	707.42	2.13	0.00	755.00	8.79	3.60	7.93	277.00	4.30
01:00	654.64	707.41	2.13	0.00	755.00	8.57	3.60	7.93	278.00	4.20
02:00	654.62	707.40	2.13	0.00	755.00	8.57	3.60	7.93	279.00	4.10
03:00	654.61	707.38	2.13	0.00	755.00	8.59	3.60	7.93	280.00	3.90
04:00	654.62	707.17	2.13	0.00	755.00	8.48	3.70	7.94	281.00	3.90
05:00	654.67	707.16	2.13	0.00	755.00	8.56	3.70	7.94	281.00	3.70
06:00	654.71	707.34	2.13	0.00	755.00	8.42	3.70	7.94	282.00	3.80
07:00	654.73	707.33	2.13	0.00	755.00	8.39	3.70	7.94	283.00	3.70
08:00	654.73	707.32	2.13	0.00	755.00	8.52	3.70	7.95	283.00	3.60
09:00	654.77	707.30	2.13	0.00	755.00	8.44	3.80	7.95	285.00	3.50
10 00	654.77	707.29	2.13	0.00	756.00	8.47	3.90	7.96	284.00	3.50
11:00	654.79	707.07	2.13	0.00	756.00	8.43	4.00	7.96	285.00	3.60
12:00	654.84	707.07	2.13	0.00	756.00	8.32	4.10	7.96	285.00	3.60
13:00	654.85	707.05	2.13	0.00	757.00	8.37	4.00	7.96	286.00	3.40
14:00	654.87	707.24	2.13	0.00	757.00	8.36	3.90	7.96	287.00	3.30
15:00	654.88	707.23	2.13	0.00	757.00	8.45	4.10	7.96	287.00	3.20
16:00	654.91	707.21	2.13	0.00	756.00	8.50	4.00	7.96	287.00	3.30
17:00	654.93	707.20	2.13	0.00	756.00	8.56	4.00	7.96	288.00	3.20
18:00	654.96	707.18	2.13	0.00	756.00	8.52	3.80	7.95	286.00	3.20
19:00	654.97	707.17	2.13	0.00	756.00	8.49	3.80	7.96	287.00	3.20
20:00	654.98	707.16	2.13	0.00	756.00	8.54	3.80	7.95	287.00	3.10
21:00	654.97	707.14	2.13	0.00	756.00	8.43	3.80	7.95	289.00	3.00
22:00	654.97	707.12	2.13	0.00	756.00	8.36	3.90	7.96	290.00	3.00
23:00	654.98	707.11	2.13	0.00	756.00	8.45	3.90	7.96	291.00	2.80



HARRY S. TRUMAN DAM AND RESERVOIR
MAP OF OSAGE RIVER BASIN

FIGURE 1

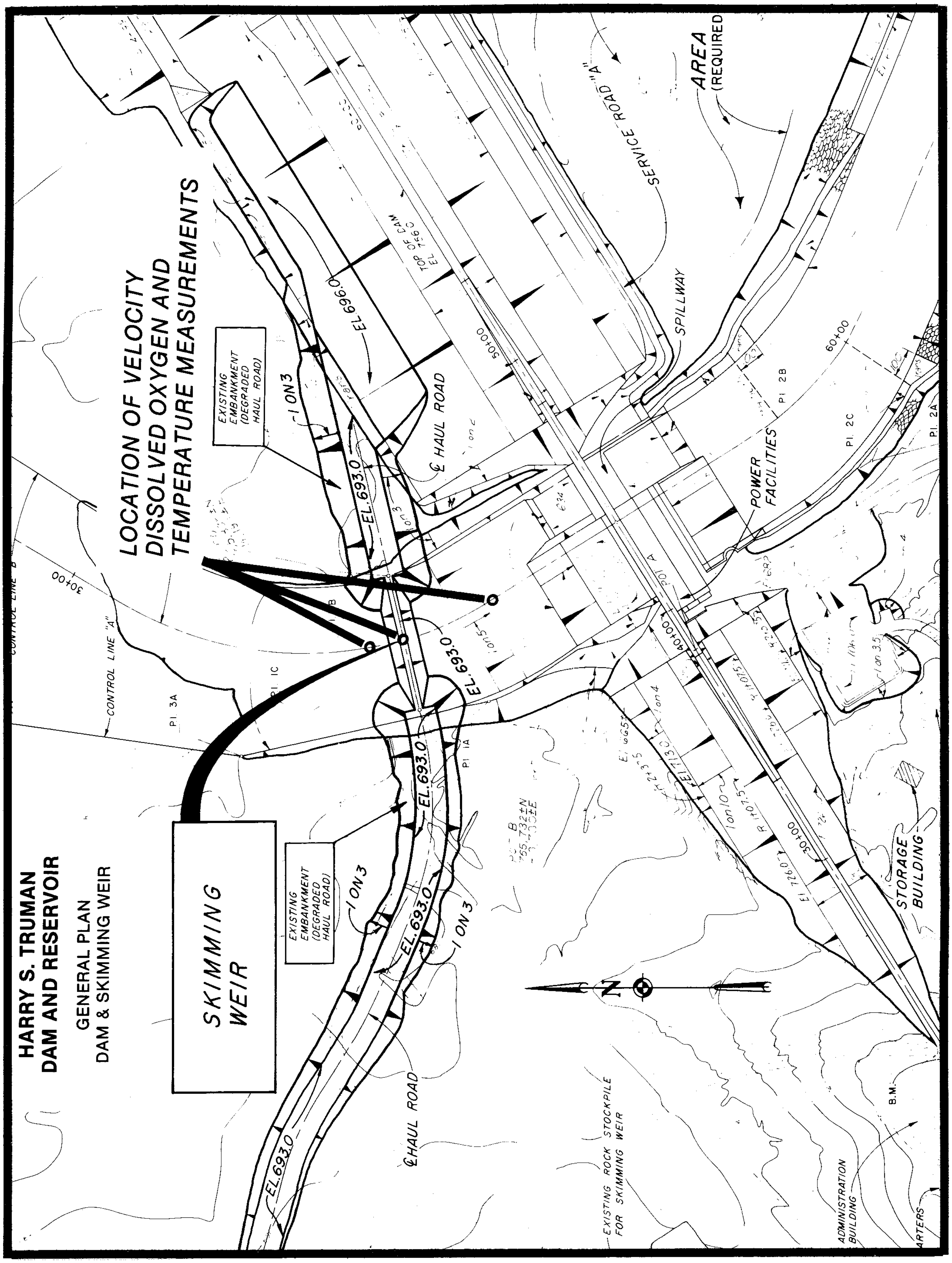

HARRY S. TRUMAN
DAM AND RESERVOIR
GENERAL PLAN
DAM & SKIMMING WEIR
SKIMMING
WEIR
LOCATION OF VELOCITY
DISSOLVED OXYGEN AND
TEMPERATURE MEASUREMENTS
EXISTING
EMBANKMENT
(DEGRADED
HAUL ROAD)
EXISTING
EMBANKMENT
(DEGRADED
HAUL ROAD)
EL.693.0
EL.696.0
1 ON 3
℄ HAUL ROAD
℄HAUL ROAD
TOP OF DAM
EL 756.0
CONTROL LINE "A"
CONTROL LINE "B"
30+00
40+00
50+00
60+00
SERVICE ROAD "A"
AREA
(REQUIRED
SPILLWAY
POWER
FACILITIES
STORAGE
BUILDING
EXISTING ROCK STOCKPILE
FOR SKIMMING WEIR
ADMINISTRATION
BUILDING
B.M.
PI 3A
PI 1C
PI 1A
PI 2B
PI 2C
PI 2A
N

FIGURE 2

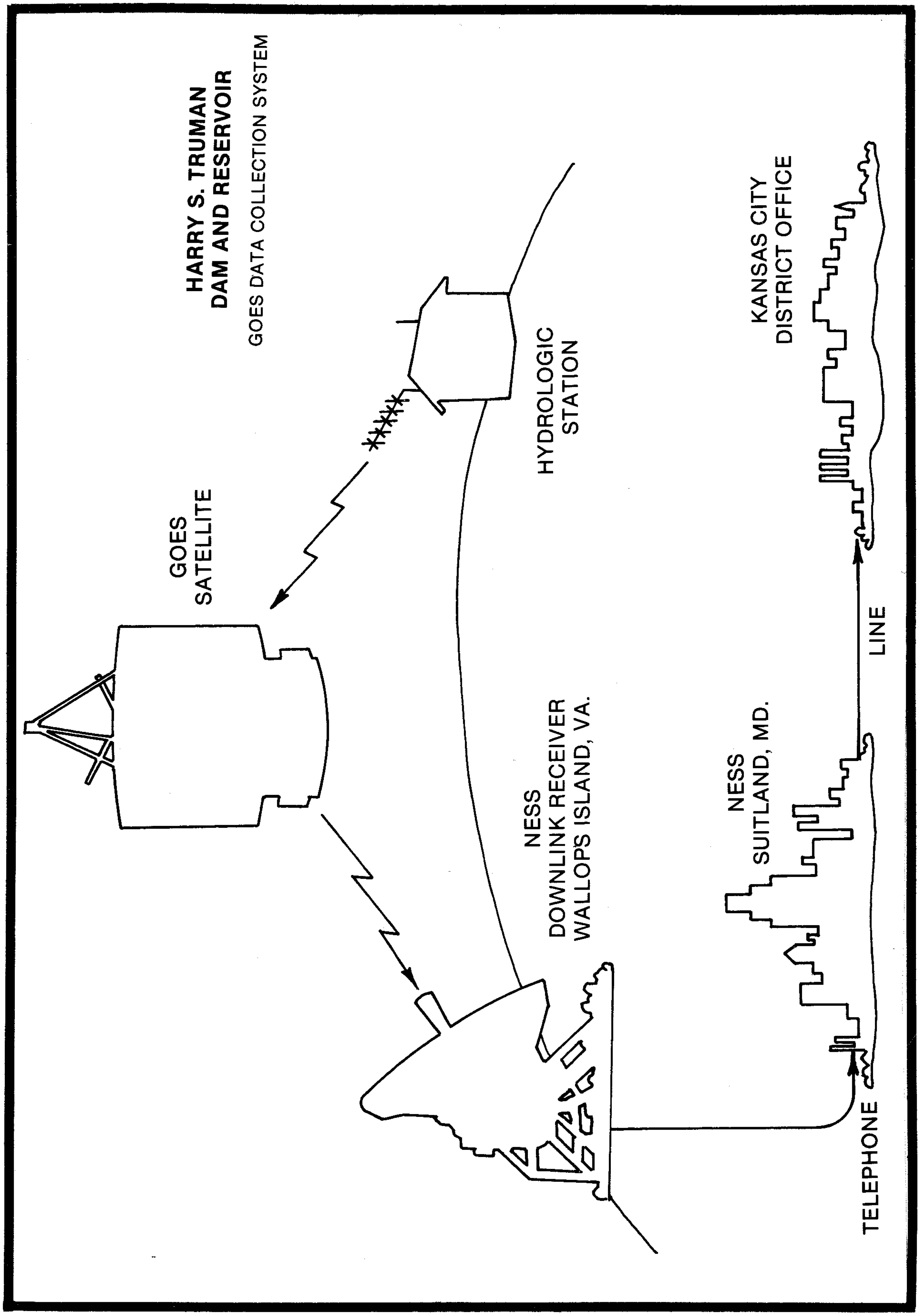

HARRY S. TRUMAN
DAM AND RESERVOIR
GOES DATA COLLECTION SYSTEM
GOES
SATELLITE
HYDROLOGIC
STATION
KANSAS CITY
DISTRICT OFFICE
NESS
DOWNLINK RECEIVER
WALLOPS ISLAND, VA.
NESS
SUITLAND, MD.
TELEPHONE
LINE

FIGURE 3

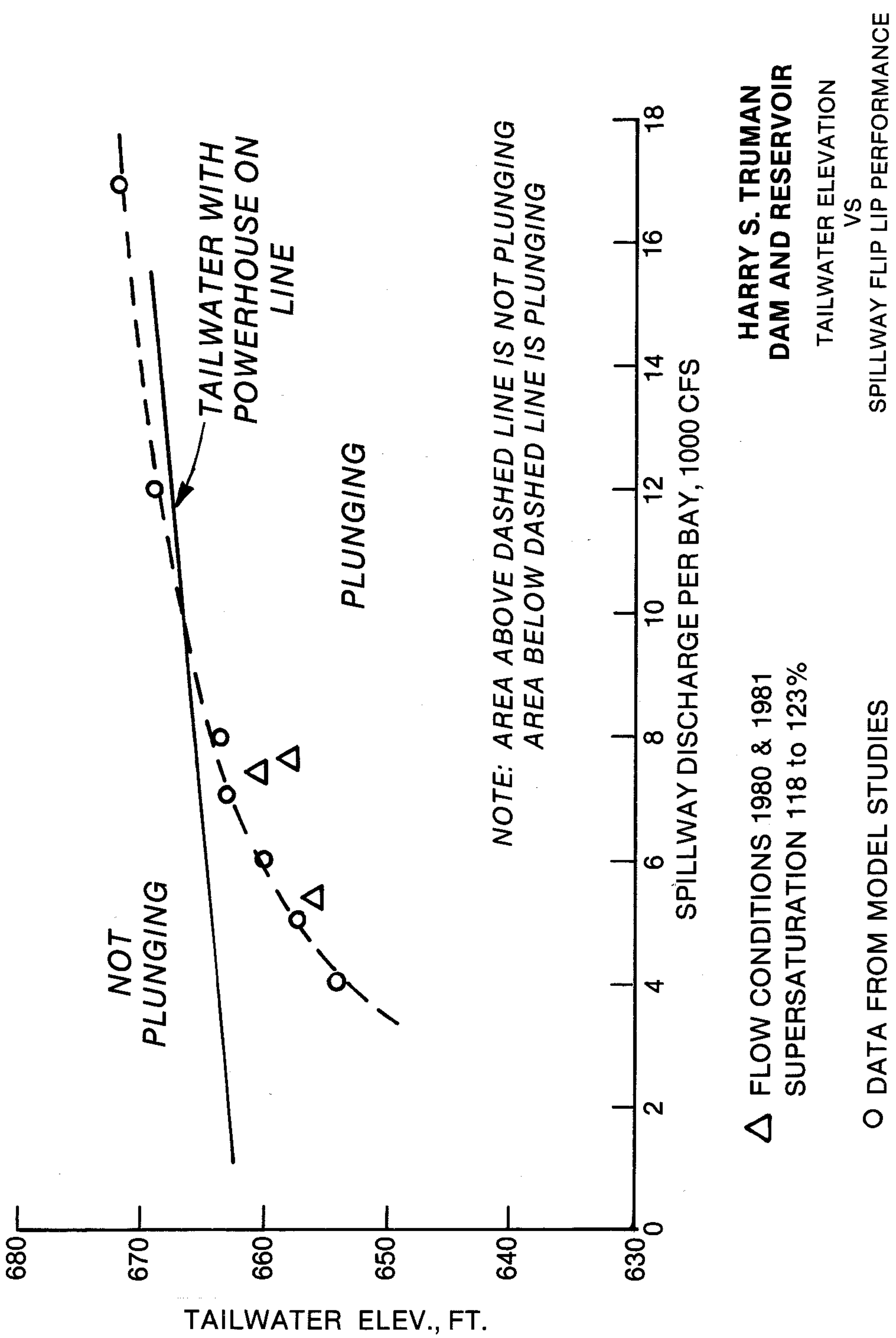
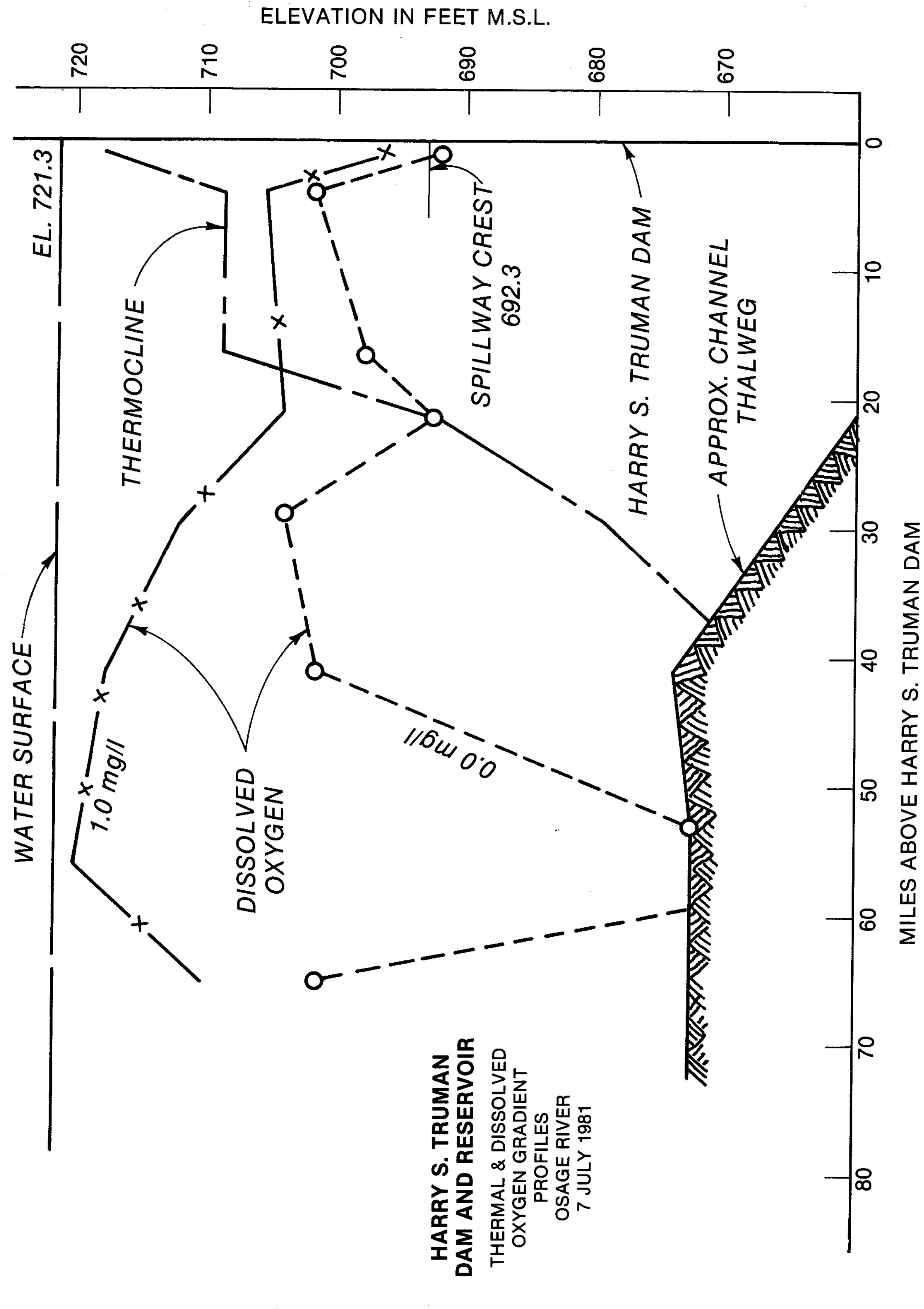
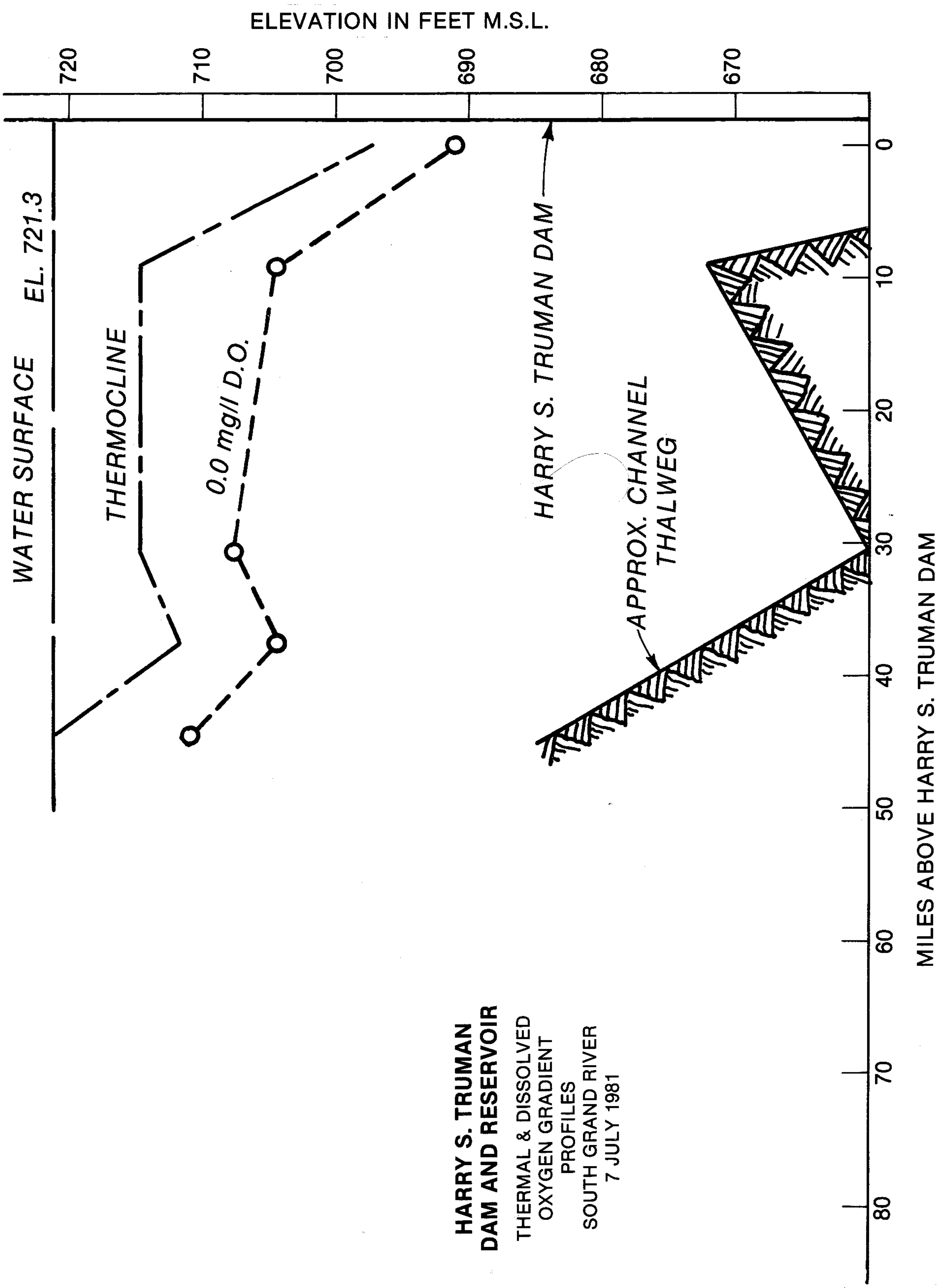

TAILWATER ELEV., FT.
680
670
660
650
640
630
SPILLWAY DISCHARGE PER BAY, 1000 CFS
0
2
4
6
8
10
12
14
16
18
NOT PLUNGING
PLUNGING
TAILWATER WITH POWERHOUSE ON LINE
NOTE: AREA ABOVE DASHED LINE IS NOT PLUNGING
AREA BELOW DASHED LINE IS PLUNGING
HARRY S. TRUMAN DAM AND RESERVOIR
TAILWATER ELEVATION VS SPILLWAY FLIP LIP PERFORMANCE
Δ FLOW CONDITIONS 1980 & 1981 SUPERSATURATION 118 to 123%
O DATA FROM MODEL STUDIES

FIGURE 4



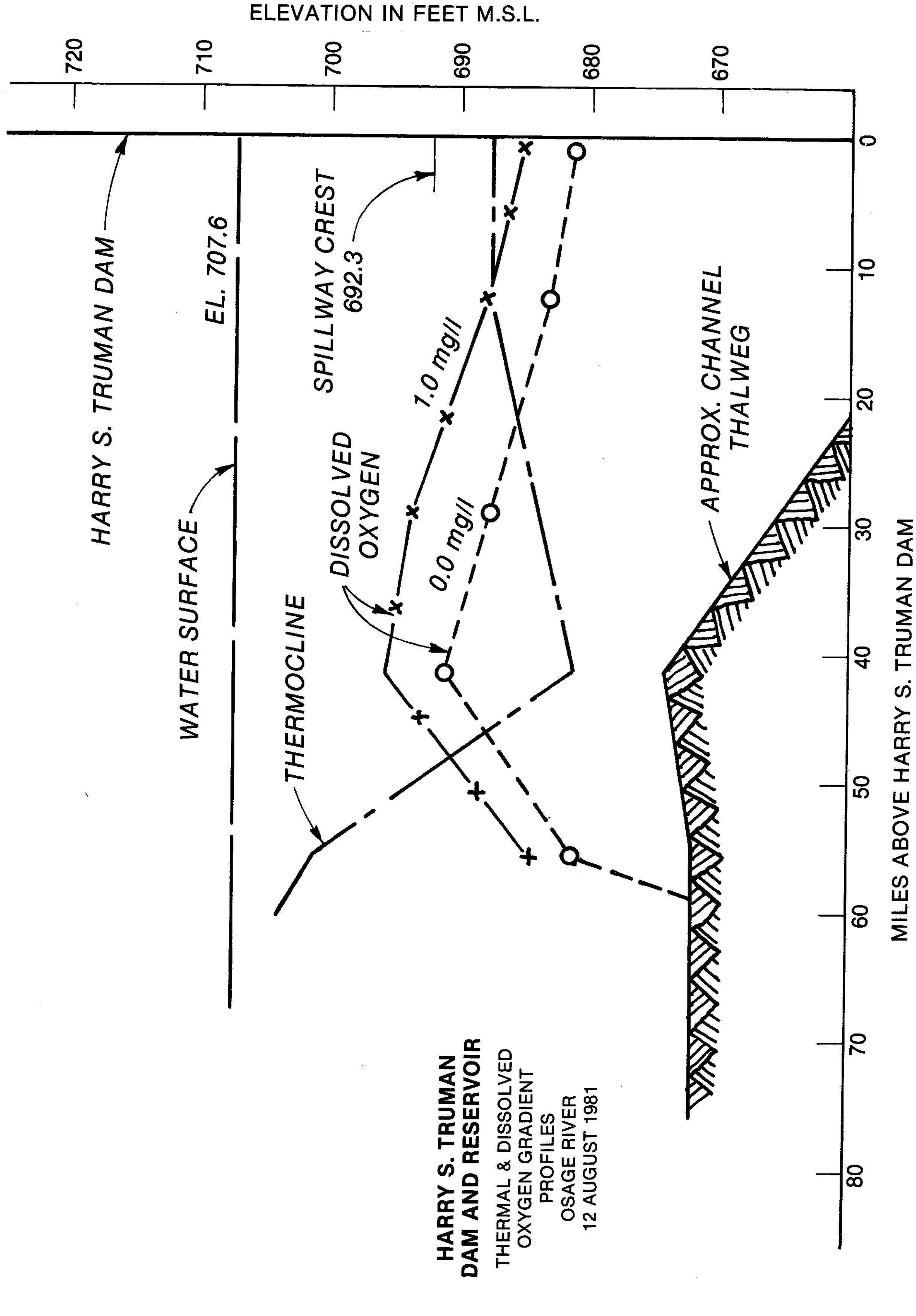
ELEVATION IN FEET M.S.L.
720
710
700
690
680
670
EL. 721.3
WATER SURFACE
THERMOCLINE
SPILLWAY CREST
692.3
HARRY S. TRUMAN DAM
APPROX. CHANNEL
THALWEG
DISSOLVED
OXYGEN
1.0 mg/l
0.0 mg/l
0
10
20
30
40
50
60
70
80
MILES ABOVE HARRY S. TRUMAN DAM
HARRY S. TRUMAN
DAM AND RESERVOIR
THERMAL & DISSOLVED
OXYGEN GRADIENT
PROFILES
OSAGE RIVER
7 JULY 1981

FIGURE 5



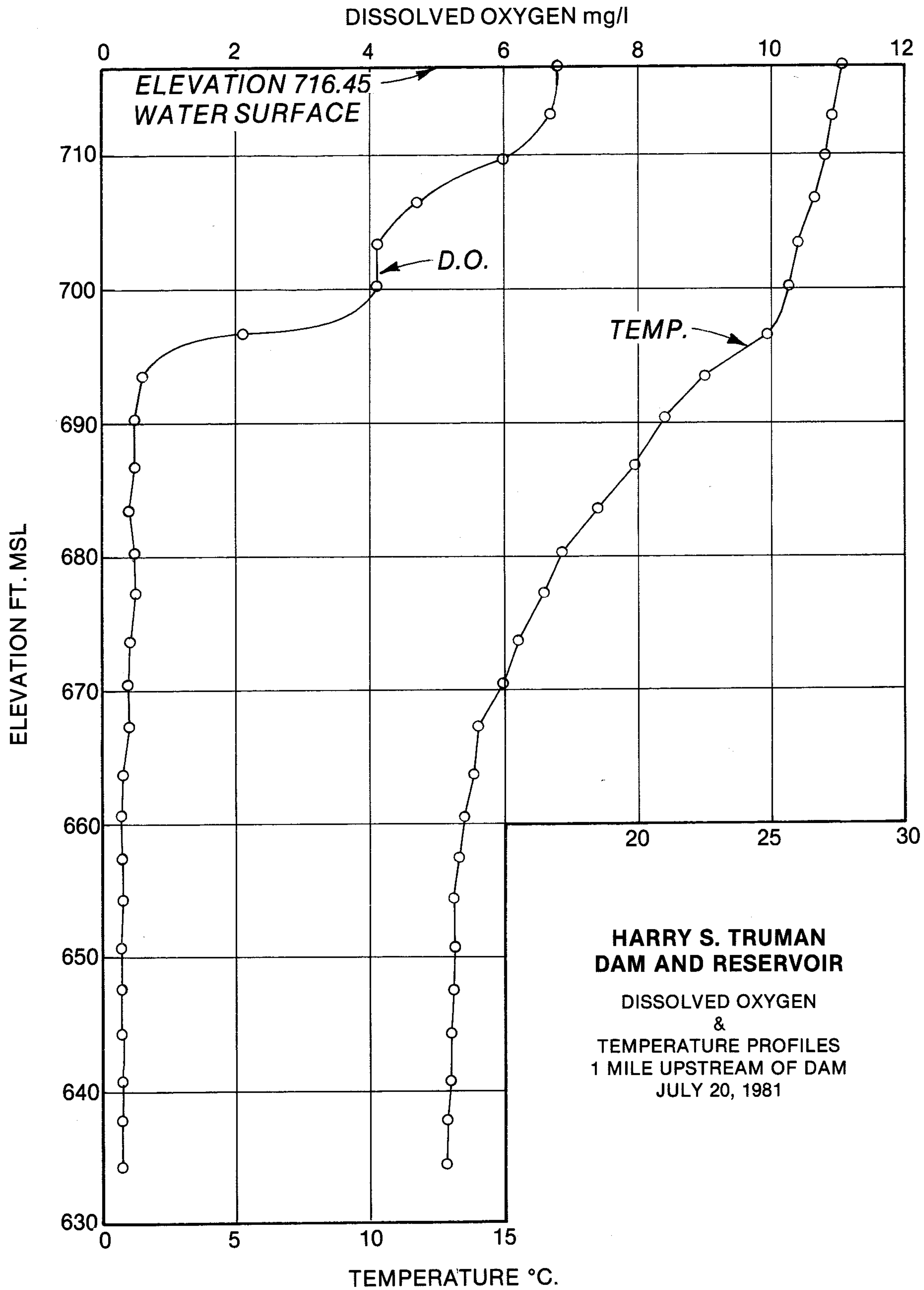
ELEVATION IN FEET M.S.L.
720
710
700
690
680
670
WATER SURFACE
EL. 721.3
THERMOCLINE
0.0 mg/l D.O.
HARRY S. TRUMAN DAM
APPROX. CHANNEL
THALWEG
0
10
20
30
40
50
60
70
80
MILES ABOVE HARRY S. TRUMAN DAM
HARRY S. TRUMAN
DAM AND RESERVOIR
THERMAL & DISSOLVED
OXYGEN GRADIENT
PROFILES
SOUTH GRAND RIVER
7 JULY 1981

FIGURE 6



ELEVATION IN FEET M.S.L.
720
710
700
690
680
670
HARRY S. TRUMAN DAM
WATER SURFACE
EL. 707.6
SPILLWAY CREST
692.3
THERMOCLINE
DISSOLVED
OXYGEN
1.0 mg/l
0.0 mg/l
APPROX. CHANNEL
THALWEG
0
10
20
30
40
50
60
70
80
MILES ABOVE HARRY S. TRUMAN DAM
HARRY S. TRUMAN
DAM AND RESERVOIR
THERMAL & DISSOLVED
OXYGEN GRADIENT
PROFILES
OSAGE RIVER
12 AUGUST 1981

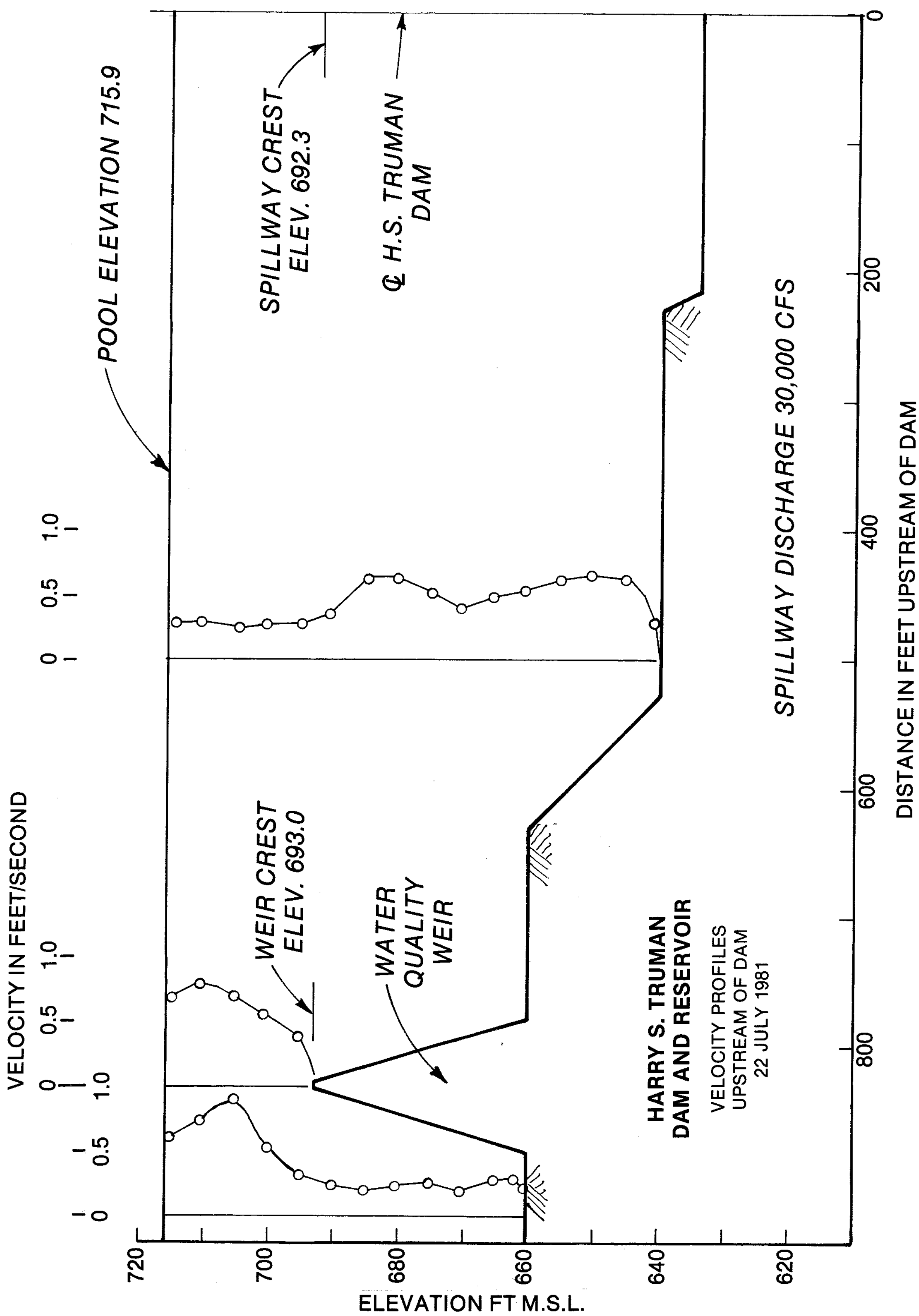
FIGURE 7



HARRY S. TRUMAN
DAM AND RESERVOIR

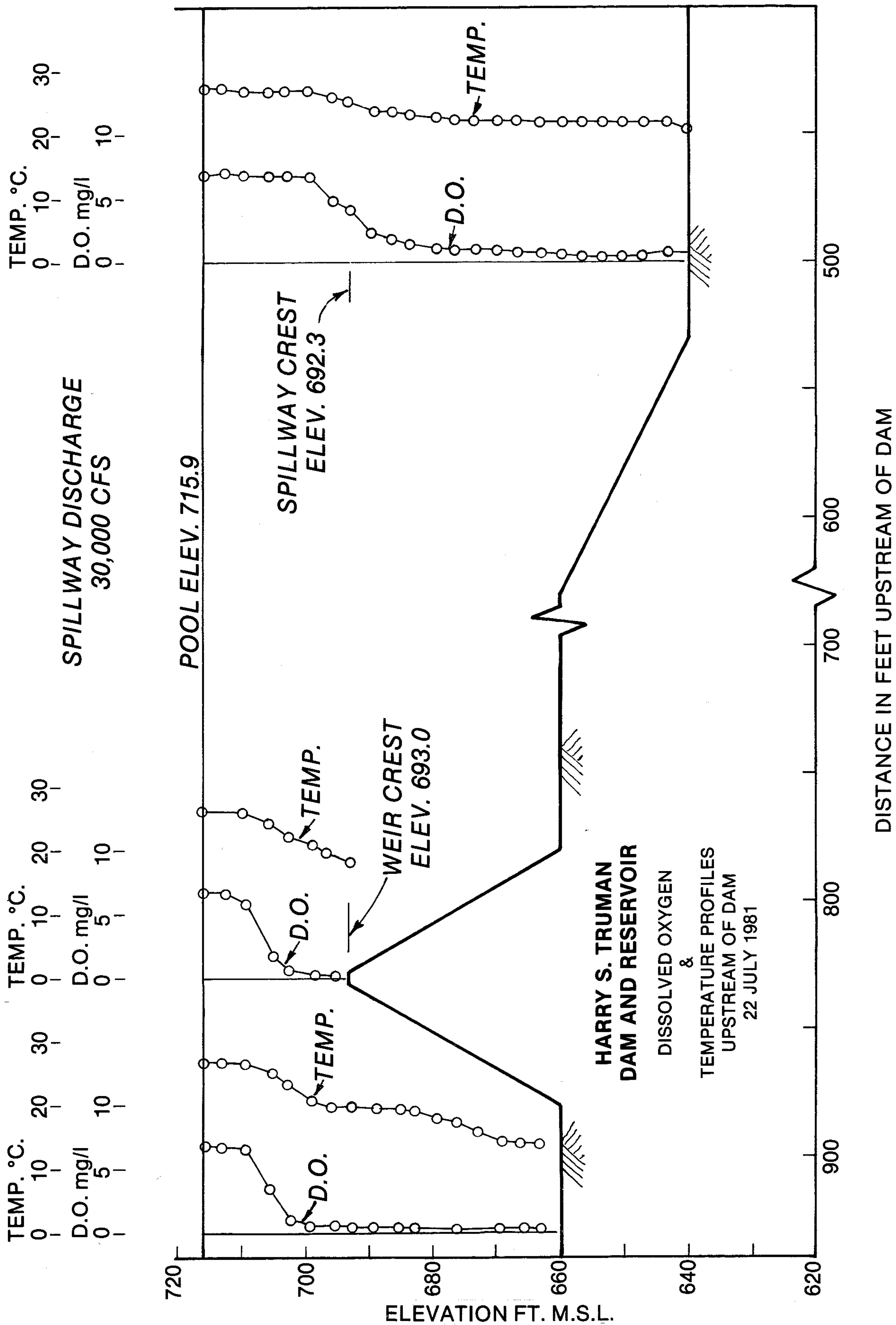
DISSOLVED OXYGEN
&
TEMPERATURE PROFILES
1 MILE UPSTREAM OF DAM
JULY 20, 1981

FIGURE 8



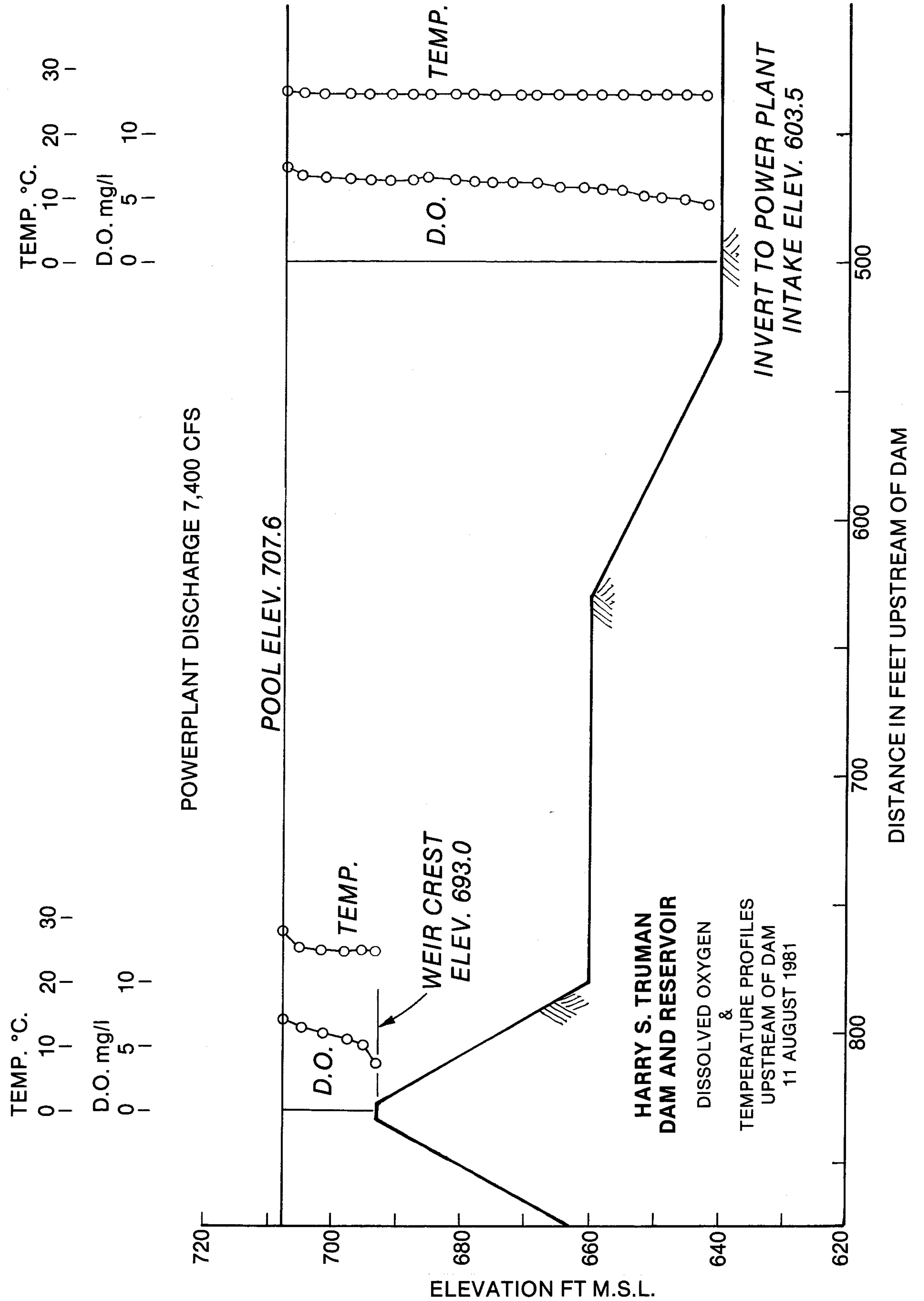
VELOCITY IN FEET/SECOND
0
0.5
1.0
POOL ELEVATION 715.9
SPILLWAY CREST
ELEV. 692.3
℄ H.S. TRUMAN
DAM
WEIR CREST
ELEV. 693.0
WATER
QUALITY
WEIR
HARRY S. TRUMAN
DAM AND RESERVOIR
VELOCITY PROFILES
UPSTREAM OF DAM
22 JULY 1981
SPILLWAY DISCHARGE 30,000 CFS
720
700
680
660
640
620
ELEVATION FT M.S.L.
0
200
400
600
800
DISTANCE IN FEET UPSTREAM OF DAM

FIGURE 9



SPILLWAY DISCHARGE
30,000 CFS
POOL ELEV. 715.9
SPILLWAY CREST
ELEV. 692.3
WEIR CREST
ELEV. 693.0
TEMP. °C.
D.O. mg/l
TEMP.
D.O.
HARRY S. TRUMAN
DAM AND RESERVOIR
DISSOLVED OXYGEN
&
TEMPERATURE PROFILES
UPSTREAM OF DAM
22 JULY 1981
ELEVATION FT. M.S.L.
DISTANCE IN FEET UPSTREAM OF DAM

FIGURE 10



TEMP. °C.
0 10 20 30
D.O. mg/l
0 5 10
D.O.
TEMP.
POWERPLANT DISCHARGE 7,400 CFS
POOL ELEV. 707.6
WEIR CREST
ELEV. 693.0
INVERT TO POWER PLANT
INTAKE ELEV. 603.5
HARRY S. TRUMAN
DAM AND RESERVOIR
DISSOLVED OXYGEN
&
TEMPERATURE PROFILES
UPSTREAM OF DAM
11 AUGUST 1981
DISTANCE IN FEET UPSTREAM OF DAM
500
600
700
800
ELEVATION FT M.S.L.
720
700
680
660
640
620

FIGURE 11

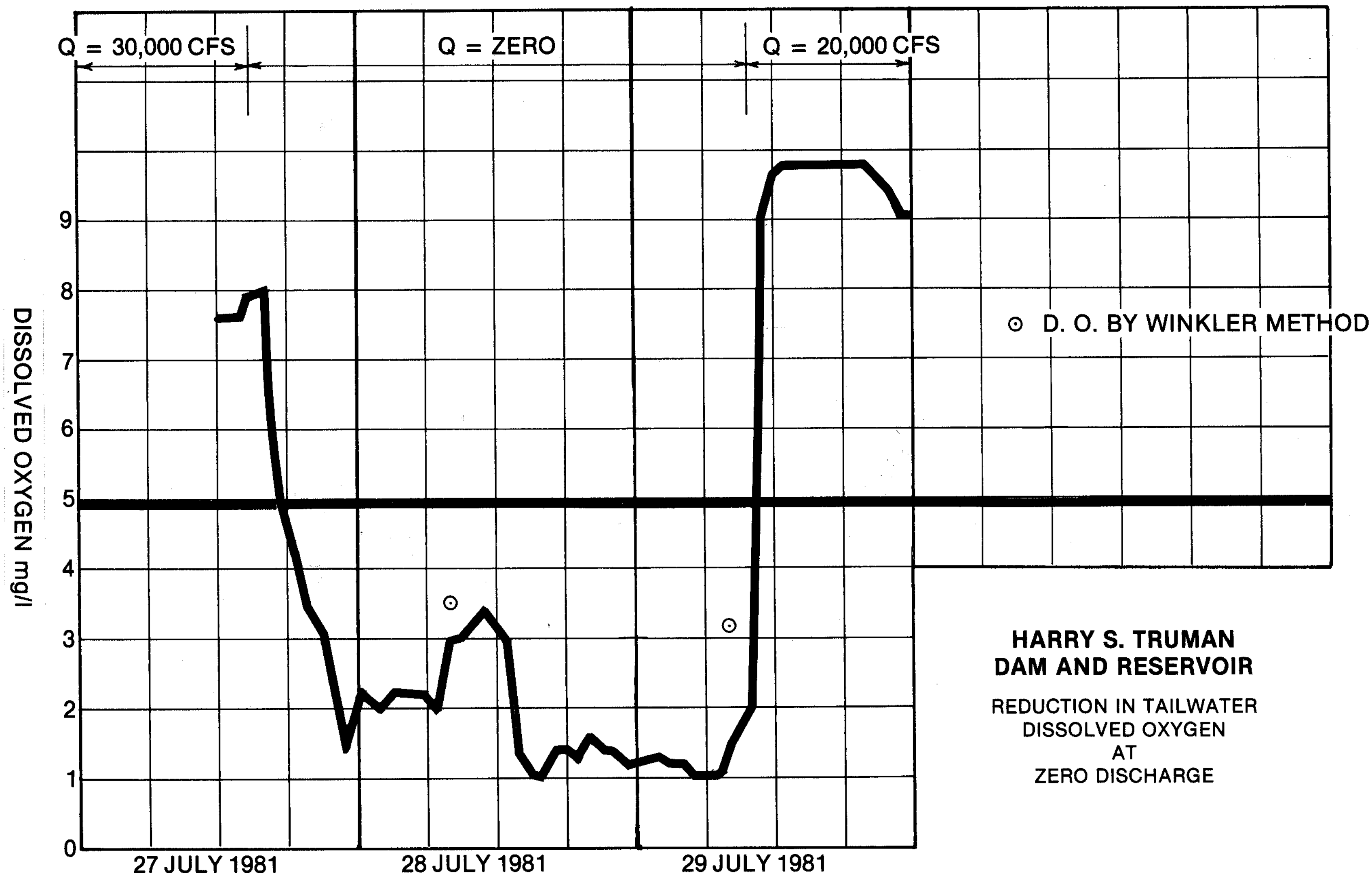

Q = 30,000 CFS
Q = ZERO
Q = 20,000 CFS
DISSOLVED OXYGEN mg/l
0
1
2
3
4
5
6
7
8
9
27 JULY 1981
28 JULY 1981
29 JULY 1981
⊙ D. O. BY WINKLER METHOD
HARRY S. TRUMAN
DAM AND RESERVOIR
REDUCTION IN TAILWATER
DISSOLVED OXYGEN
AT
ZERO DISCHARGE

FIGURE 12

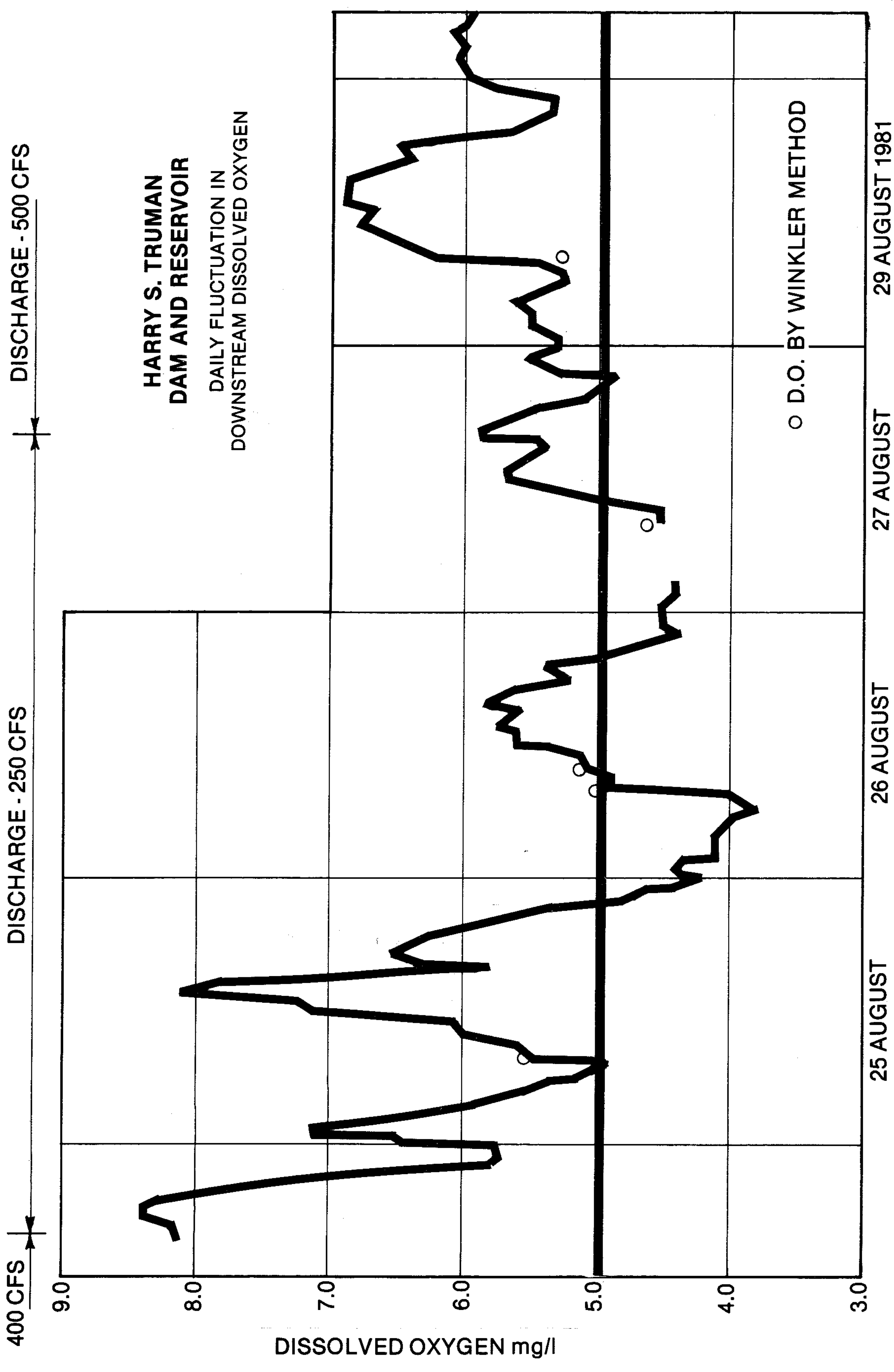

DISCHARGE - 250 CFS
DISCHARGE - 500 CFS
400 CFS
HARRY S. TRUMAN
DAM AND RESERVOIR
DAILY FLUCTUATION IN
DOWNSTREAM DISSOLVED OXYGEN
o D.O. BY WINKLER METHOD
9.0
8.0
7.0
6.0
5.0
4.0
3.0
25 AUGUST
26 AUGUST
27 AUGUST
29 AUGUST 1981
DISSOLVED OXYGEN mg/l

FIGURE 13