TENNESSEE VALLEY AUTHORITY
KNOXVILLE, TENNESSEE 37902

MAR 11 1987

Mr. Philip L. Stewart, Manager
Chattanooga Field Office
Division of Water Pollution Control
2501 Milne Street
Chattanooga, Tennessee 37406-3399

Dear Mr. Stewart:

SEQUOYAH NUCLEAR PLANT (SQN) - TEMPERATURE AND DISSOLVED OXYGEN (DO)

Enclosed is a study plan developed by TVA to determine the extent and duration of changes in DO concentrations downstream of SQN. TVA committed to provide this study plan in my August 29, 1986 letter to you and to EPA in response to questions raised by your staff about SQN's effect on DO.

The study plan calls for (1) in-plant monitoring of the intake and discharge DO to determine if SQN is having any effect on DO levels in the diffuser discharge; (2) a series of six DO profile surveys, including a dye tracer study, in the immediate vicinity of SQN to determine the role of the underwater dam on the diffuser/underwater dam mixing process; and (3) development and calibration of a 2-dimensional water quality model of DO in Chickamauga Reservoir. TVA has determined that the development of the DO model is crucial for a sound evaluation of potential biological impacts. The primary objective of this model will be to provide information on the extent, frequency, and duration of plant-induced effects on reservoir DO outside the diffuser mixing zone for reservoir conditions other than those encountered during the sampling program. The model will also be used to determine the combined effects of SQN and Watts Bar Nuclear Plant on patterns of DO and temperature when both plants are placed on line.

The studies are scheduled to begin April 1. Therefore, we ask that you provide any comments your staff may have before that time. If you have questions concerning the enclosed plan, please call Madonna Martin at (615) 632-6695 in Knoxville, Tennessee.

Sincerely,

Original signed by
Martin E. Rivers

Martin E. Rivers, Director
Environmental Quality

Enclosure

cc: See Page 2

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Mr. Philip L. Stewart

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MAR 11 1987

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Sequoyah Nuclear Plant
Nonradiological Aquatic Monitoring Program
Study Plan for Investigation of Plant Impact on Dissolved Oxygen Levels in Chickamauga Reservoir

I. Introduction

Recent studies have shown that the Sequoyah Nuclear Plant (SQN) diffuser discharge mixes the water column in the vicinity of the plant. When the reservoir is stratified, bottom dissolved oxygen (DO) concentrations are elevated and surface DO concentrations are depressed downstream of the diffuser as a result of this mixing. While this mixing effect is thought to be largely due to the diffuser, the underwater dam, located about 75 meters upstream of the diffuser, probably also contributes to the mixing. The objectives of this study are to better define the extent and duration of the redistribution of DO in the reservoir, to better understand the role of the underwater dam in the mixing process, and also to determine if DO is being lost (or added) as the reactor cooling water passes though the plant. The results of these studies will then be used to evaluate the potential for impact on aquatic life in the reservoir.

To achieve the first objective of defining the extent and duration of the redistribution of DO, the DO in the vicinity of SQN must be evaluated in terms of the overall DO regime in Chickamauga Reservoir, especially since Watts Bar Nuclear Plant (WBN) is expected to be coming online in the next few years and will discharge into the upper end of Chickamauga. Therefore, a two-dimensional model of DO in Chickamauga Reservoir will be developed to enable the evaluation of the effects of both WBN and SQN in terms of overall reservoir DO dynamics. The model

will allow prediction of plant-induced effects on DO outside the diffuser mixing zone for reservoir conditions other than those encountered during field sampling. However, since the model covers the entire reservoir (roughly 60 river miles), it will only predict far-field plant effects, i.e., beyond the 1500 foot mixing zone downstream of the diffuser.

Near-field effects (i.e., within the mixing zone), including the effect of the underwater dam on diffuser mixing, are much more difficult to accurately model, due to the complex hydrodynamic regime encountered in this relatively small volume of water. Due to certain rather intractable mathematical problems involved with modeling the near-field effects, our investigation of the mechanics of the diffuser/underwater dam mixing process (the second objective of this study) will mainly focus on field studies under a variety of hydrologic and plant operating conditions. Some limited modeling using idealized flow assumptions may be utilized to aid in the investigation if practicable.

To achieve the third objective of evaluating the plant's impact on DO in the cooling water passing through the plant, continuous online DO monitors will be set up to monitor DO levels at the intake skimmer wall, at the inflow to the diffuser pond, and at the outflow from the diffuser pond to the diffuser pipe.

Section II presents more detail on the modeling, Section III presents further detail on the field studies to be conducted to calibrate the model, Section IV presents further details on the field studies to be conducted to investigate the role of the underwater dam in the diffuser/underwater dam mixing process, Section V further discusses the in-plant DO monitoring, and Section VI summarizes the reporting schedule for this project.

II. RESERVOIR WATER QUALITY MODELING

A two-dimensional reservoir water quality model will be developed to evaluate the effects of SQN heat load on DO patterns in Chickamauga Reservoir. Except for some important modifications, the model will be similar to that developed previously for Pickwick, Fort Loudoun, Cherokee, Boone, and Normandy Reservoirs.

The primary objective of this model will be to provide information on the extent, frequency, and duration of plant-induced effects on reservoir DO outside the diffuser mixing zone for reservoir conditions other than those encountered during the sampling program. The results of the model will help fill spatial and temporal gaps in field data, but more importantly they will be used to estimate plant effects for different hydrologic years (high, low, and normal flows).

A secondary benefit of the model is that it will provide a tool for future analysis of the combined effects of SQN and WBN on patterns of DO and temperature when units of both plants are placed on line. Other reservoir conditions that can be varied in the model besides hydrology include multiple heat loads, meteorology, and inflow quality (DO, temperature, etc.) at inflow locations. The model will therefore be available for reservoir-wide consideration of issues other than just DO, such as cooling water supply, thermal compliance, and management strategies that may require special operations at Watts Bar and Chickamauga Dams.

Plant heat load can affect reservoir water quality by (1) physically redistributing DO with diffuser-induced mixing, and (2) altering the rates of temperature-dependent biochemical processes that affect DO.

Simulation of the physical redistribution of DO due to the diffuser will require modification of an existing diffuser plume model and incorporation into the reservoir water quality model. The plume model will determine entrainment of ambient water along the path of the buoyant diffuser plume and will be used to provide loadings of water quality constituents into appropriate volume elements of the reservoir water quality model. However, only far-field plant effects (beyond the mixing zone, i.e., 1500 feet downstream of the diffuser) will be simulated because the diffuser mixing zone is smaller than the limit of resolution of the water quality model and its simplified hydrodynamic

formulations. The model will provide valuable information on recovery of DO downstream of the mixing zone with full accounting for interaction with other DO processes.

Modeled reservoir processes affecting DO include inflow replenishment, surface reaeration, algal photosynthesis and respiration, organic decay, oxidation of ammonia, and sediment oxygen demand (SOD). Temperature-dependence is included for each of these processes. Plant effects will be deduced by comparing simulations with and without plant operation. The model will thus allow assessment of the relative rates of major processes affecting the DO balance in the reservoir, and will allow ranking of the significance of the plant heat load relative to other reservoir processes.

It is important to consider all processes affecting DO to identify the full range of effects of the heat load, both positive and negative. For example, the lower surface DO that occurs during redistribution of water by the diffuser combined with warmer temperatures due to plant heat may actually increase aeration of the water column through more rapid surface exchange and subsequent mixing, thereby offsetting any temperature-induced increase in DO consumption by oxygen-demanding processes. Therefore, even though the plant heat load decreases surface DO concentrations, the rate of improvement in overall DO mass in the downstream direction may in fact be greater with the heat load than without it. Such issues can be addressed with the model.

Modifications to the existing model that will be required for this project include: (a) adding the diffuser plume submodel, (b) accounting for the physical barrier imposed by the underwater dam, (c) separation of main reservoir flow-through volumes from adjacent embayment volumes, and (d) accounting for additional photosynthesis and respiration of aquatic weeds. Major tasks to complete the modeling effort can be summarized as: (1) development of basic model geometry; (2) development of inputs for hydrology, meteorology, and inflow quality; (3) model modifications; (4) reduction of field data for calibration; (5) initial calibration on 1985-86 data; (6) verification on 1987-88 data; (7) sensitivity simulations to assess relative importance of DO processes; (8) simulation of different hydrologic regimes, and (9) presentation and reporting of results.

III. Field Studies for Model Calibration

To investigate the effect of the SQN diffuser discharge on the overall DO regime in Chickamauga Reservoir, it is essential that the plant be operating. However, valuable background information required to calibrate the reservoir model can be obtained when the plant is pumping water through the system without adding significant heat. Since SQN is currently not operating and its restart date is uncertain, instream monitoring for model calibration should begin April 1, 1987, regardless of whether the plant is operational.

Frequent and consistent monitoring at a number of stations both upstream and downstream of the plant is required to adequately calibrate the model. Also, it is necessary to monitor under the full range of reservoir conditions under which the plant might discharge. Therefore, a two year regular monitoring program, supplemented by intensive diurnal studies to determine the variation in DO levels over a 48-hour period, is proposed. Also, SOD studies are recommended because SOD has been an important factor in modeling DO in other TVA reservoirs.

A. Regular Monitoring

The regular monitoring program is summarized in Table 1. Monitoring of 19 river mile locations (or 32 sampling stations when different horizontal locations are taken into account) throughout Chickamauga is proposed. Since plant operation is not expected until late summer at the earliest, the 1987 monitoring program will be mainly aimed at collection of data for initial calibration of the model without plant heat input. Biweekly monitoring will be conducted from April 1, 1987 to March 31, 1988. Assuming that at least one SQN unit will be operating at close to full capacity by April 1, 1988, more intensive weekly monitoring to evaluate the plant's impact on DO is planned for April 1, 1988 to October 31, 1988.

Hydrolab profiles of temperature, DO, pH, and conductivity will be run at each station, and nutrient samples will be collected so that the effect of algal photosynthesis on DO can be modeled. Also, samples for fluorometric analysis will be collected to provide corroboration of the effects of diffuser mixing.

The selection of the river mile locations listed in Table 1 was in part based on the historical data base. The upper four Tennessee River stations (i.e., TRMs 529.9, 518.0, 506.6, and 496.5) are historically well established as part of the WBN preoperational monitoring program. TRM 529.9 is just below Watts Bar Dam and upstream of WBN. TRM 518.0 is a middle station between 529.9 and 506.6. TRMs 506.6 and 496.5, along with Hiwassee River Miles (HRM) 7.4 and 20.0, allow the assessment of the influence of the Hiwassee River on Chickamauga Reservoir, since the Hiwassee enters at TRM 499.43. TRMs 490.5, 484.1, 483.4, and 478.2 are historically well established as part of the SQN preoperational and operational monitoring program. TRM 484.1 is just upstream from the diffuser, which is located at 483.65, and 483.4 is right at the edge of the diffuser mixing zone (1500 feet downstream of the diffuser.) TRM 478.2 is the downstream effects monitoring station in the SQN operational monitoring program.

TRM 484.7 is at the SQN intake and 471.1 is just upstream from Chickamauga Dam. The remaining intermediate stations were chosen at even half mile to three mile increments from the edge of the mixing zone (483.4) in order to more precisely define the extent of the DO redistribution.

B. Diurnal Studies (to be conducted in 1988 when SQN is operational). While the seasonal monitoring program outlined above should provide valuable information on the DO levels and associated parameters under a variety of flow and temperature conditions, it will only provide information on instantaneous DO levels under daytime conditions. To investigate DO levels over longer time periods, under no flow conditions, and during the night, two 48-hour diurnal studies will be conducted, one in the spring and one in the late summer, when at least one SQN unit is operating. These studies will be coordinated with dam operations to assure that at least two periods of zero flow can be monitored during each diurnal survey. Hydrolab profiles will be run every four hours (except during no flow conditions every two hours) over the two-day period at the following river mile locations: 484.7, 484.1, 483.7 (just up from the underwater dam), 483.65, 483.4, 482.9, 482.4, 481.4, 480.4, and 478.2. Profiles will generally be run at the same horizontal locations as in the seasonal monitoring program (i.e., three horizontal locations in the near-field and one middle location further downstream). However, the final decision on the exact monitoring locations will need to be made in the field, since it is desired to track the diffuser plume as closely as possible. Therefore, communication between field crews and field engineering expertise will be essential during these surveys.

In addition to the Hydrolab profiles, one set of nutrient samples (see Table 1, footnote c for the list of parameters) will be collected at mid-depth at the mid-channel sampling locations (i.e., 10 samples at beginning and 10 at end), and one set of fluorometry samples will be collected at the beginning and end of each survey at all sampling locations. (It is not anticipated that there will be sufficient time to collect any other data during the surveys, since 20-30 Hydrolab profiles will be run every 2-4 hours.)

In addition to providing data on the far-field DO effects, the diurnal studies should also provide further insight into the mechanics of the diffuser/underwater dam mixing process, since intensive monitoring in the near-field will be conducted. The data from the diurnal studies, in conjunction with the special studies described in section IV to investigate the role of the underwater dam, should enable a better understanding of the mixing process to be developed.

C. Sediment Oxygen Demand (SOD) Studies

The SOD must be taken into account to effectively model DO in Chickamauga. To accurately measure this parameter, it is recommended that a minimum of six river mile locations be sampled. Scuba divers would collect 20-30 cores from each longitudinal location and SOD would be determined in the Water Quality Branch (WQB) Unit Operations Laboratory (UOL). The WQB-UOL has considerable experience in running SODs in the laboratory and the

results obtained therein correlate well with EPA's *in situ* method. Exact river miles for SOD sampling would be determined by looking at plots of sediment deposition in the reservoir and sampling sites would be chosen to represent areas where the most sediment (and hence most potential oxygen demand) exists. It is expected that the SOD samples would be collected and run during the summer of 1987. Since SODs for only two sampling stations can be run at one time, and since the SOD run must begin within 24 hours of sample collection, sediment core samples will need to be collected on three separate sampling trips. Each SOD run (including sampling) requires about three weeks, therefore, about nine weeks would be required to conduct the six SOD tests. The SOD results would be used to calibrate the DO model for the reservoir.

IV. Underwater Dam Mixing Studies

To better understand the role of the underwater dam (UD) in the diffuser/UD mixing process, the effect of the UD on DO mixing will be investigated with the diffuser shut down so that the effect of the dam can be isolated. Two types of studies will be used to elucidate the UD mixing effect: DO profiles surveys upstream and downstream from the dam under different hydrologic conditions, and a more complex dye tracer study which will entail DO and velocity profiles as well as dye concentration profiles. All of these surveys will entail profiles in the middle of the main channel at the following river mile locations: 483.8, 483.7 (UD), 483.65 (diffuser), 483.55, 483.45, and 483.40 (edge

of mixing zone). In the dye study, dye will be injected near the bottom of the river at TRM 483.9 (0.2 mile or about 1000 feet upstream from the UD).

A series of six DO profile surveys are planned to enable the evaluation of the effect of the UD on mixing under a variety of hydrologic conditions. The more detailed dye tracer study will enable a more direct assessment of the vertical mixing in the vicinity of the UD. To avoid conflict with plant operation, these studies will be conducted during FY 87. The results of these studies, in combination with the diurnal studies discussed above in III.B., should provide a much clearer understanding of the role of the UD in the diffuser/UD mixing process.

V. In-Plant DO Monitoring

As discussed in Section I of this workplan, in-plant monitoring of the intake and discharge DO will be conducted to determine if the plant is having any effect on DO levels in the diffuser discharge. Monitoring will be conducted both with and without the plant heat load. Continuous online DO monitors will be setup to monitor DO at the intake skimmer wall, at the inflow to the diffuser pond, and at the outflow from the diffuser pond to the diffuser pipe. Monitoring will begin when the DO level in the discharge from Watts Bar Dam (monitored weekly during spring and summer) first falls below 5.0 mg/L. Monitoring will continue until a firm conclusion regarding the plant's impact (or lack of impact) on DO without heat load can be determined. Monitoring will also be

conducted during this time period in 1988 unless SQN comes back online for a long enough time to determine if the plant's heat load is impacting DO during 1987. Thus it is currently planned to conduct this monitoring from May 1, 1987 to September 30, 1987 and May 1, 1988 to September 30, 1988.

VI. Reporting Schedule

Interim status reports will be prepared and submitted to the State on October 31, 1987 and October 31, 1988. The final report analyzing the results of the field surveys, the results of the water quality modeling, and evaluating the potential for impact on aquatic life will be prepared and submitted to the State by July 1, 1989 (assuming SQN operation by April 1, 1988). Table 2 summarizes the planned schedule for this project.

Table 1

Chickamauga Reservoir Dissolved Oxygen Study
Regular Monitoring Program

TRM	Number of Horizontal Locations[b]	Nutrient Sampling[c]	Fluorometry Sampling[d]
529.9	1	Yes	Yes
518.0	1	Yes	No
506.6	1	Yes	Yes
HRM[a] 7.4	1	Yes	No
HRM 20.0	1	Yes	No
496.5	1	Yes	Yes
490.5	1	No	Yes
484.7	3	Yes	Yes
484.1	4	Yes	Yes
483.4	3	Yes	Yes
482.9	3	No	Yes
482.4	3	Yes	Yes
481.4	3	No	Yes
480.4	1	Yes	Yes
479.4	1	No	Yes
478.2	1	Yes	Yes
475.4	1	No	Yes
473.4	1	No	Yes
471.1	1	Yes	Yes

a. From April 1, 1987, through March 31, 1988, field sampling will be conducted once every two weeks. From April 1, 1988 to October 31, 1988, sampling will be conducted weekly.

b. Hydrolab profiles (DO, temperature, pH, and conductivity) and Secchi disc readings will be run at all river miles. Hydrolab readings will be taken at depths of 0.3, 1.0, 1.5, 3.0 meters . . . to bottom. The profiles and Secchi disc measurements will be made at the center of the main channel for those river miles marked for one horizontal location, and at locations evenly spaced across the river for those river miles marked for three or four horizontal locations.

c. Nutrient sampling will be conducted monthly during the entire sampling program at the indicated stations at the middle of the main channel. The samples will be collected at surface, mid-depth, and one meter off the bottom. Nutrient analyses will include the following parameters: NO_2 plus NO_3-N, NH_3 + NH_4-N, organic N, total phosphorus, dissolved phosphorus, ortho-P, long-term BOD (2, 5, 10, 15, and 20 days), turbidity, total suspended solids (TSS), volatile suspended solids (VSS), total organic carbon (TOC), and total alkalinity.

d. Fluorometry samples for analyses of chlorophyll fluorescence will be collected at mid-channel only during all surveys from the same depths that hydrolab measurements are taken. Fluorescence response index will be determined on each sample using treatment with DCMU. An appropriate portion of every tenth sample will be acetone-extracted for spectrophotometric determination of chlorophylls.

e. HRM = Hiwassee River Mile.

Table 2

Preliminary Schedule Assuming One Unit
Sequoyah Nuclear Plant Operation
by April 1, 1988

Activity	Beginning Date	Completion Date
Regular Monitoring	April 1, 1987	October 31, 1988
Diurnal Studies	May 1, 1988	September 30, 1988
Underwater Dam Studies	May 1, 1987	September 30, 1987
SOD Sample Collection	June 1, 1987	August 31, 1987
Interim Reports to State		October 31, 1987 October 31, 1988
In-Plant Monitoring	April 1, 1987	September 30, 1988
Laboratory Analysis	April 1, 1987	November 30, 1988
Data Verification & Storage	May 1, 1987	December 31, 1988
Water Quality Modeling	February 1, 1987	January 31, 1989
Data Analysis and Draft Final Report Preparation	January 1, 1989	April 30, 1989
Internal TVA Review	May 1, 1989	May 31, 1989
Final Report Preparation	June 1, 1989	June 30, 1989
Final Report Submission to State		July 1, 1989

Chickamauga Reservoir Dissolved Oxygen Monitoring Program

Cost Estimate Assuming Plant Operation by April 1, 1988
(all figures are $K)

Organization (Activity)	FY 87	FY 88	FY 89	Total
Field Operations-East				
Regular Monitoring	38	105	14	157
Diurnal Studies	-	27	-	27
Underwater Dam Mixing Studies	13	-	-	13
SOD Sample Collection	6	-	-	6
In-Plant Monitoring	24	24	-	48
Fluorometry (Regular Monitoring)	26	78	10	114
Fluorometry (Diurnal Studies)	-	5	-	5
Total $ Field Operations-East	107	239	24	370
Laboratory Branch				
Regular Surveys				
Nutrients	46	92	8	146
Chlorophyll	7	19	2	28
Diurnal Surveys	-	9	-	9
Total $ Laboratory Branch	53	120	10	183
Data Services Branch				
Data Verification, Storage, and Retrieval	8	20	15	43
Engineering Laboratory				
Modeling	35	35	30	100
Underwater Dam Mixing Studies	17	-	-	17
Total $ Engineering Laboratory	52	35	30	117
Fisheries & Aquatic Ecology Branch				
Planning and Management	15	10	-	25
Report Preparation	-	10	20	30
Total $ Fisheries & Aquatic Ecology Branch	15	20	20	55
Water Quality Branch				
SOD Studies	15	-	-	15
Project Management	25	40	15	80
Report Preparation	-	10	35	45
Total $ Water Quality Branch	40	50	50	140
Total Direct Dollars	275	484	149	908
Estimated Overheads[a]	92	161	50	303
Total Dollars	367	645	199	1211

a. Direct dollars are believed to be accurate but indirect expenses vary from year to year and from organization to organization. Therefore, the overhead figures should be considered rough estimates.