Environmental & Water Quality Operational Studies

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REAERATION TESTS ENID LAKE OUTLET WORKS

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This study presents the results of gas transfer tests of the outlet structure at Enid Lake, Miss. Radioactive tracers, krypton-85 and tritium, were used to determine the gas transfer characteristics of the outlet structure. The sampling technique isolated the effects of the outlet conduit, the trajectory between the conduit and the tailwater, and the submerged portion of the stilling basin. Dissolved oxygen measurements were taken in the conduit in an attempt to supplement the radioactive tracer data.

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PREFACE

This analysis was conducted at the U. S. Army Engineer Waterways Experiment Station (WES), Hydraulics Laboratory (HL), from May 1978 to April 1980. This effort was conducted and this report was published within the Environmental and Water Quality Operational Studies (EWQOS) under the Environmental Laboratory (EL), WES.

Dr. J. L. Mahloch was Program Manager for EWQOS. Messrs. H. B. Simmons, Chief of the HL, and J. L. Grace, Jr., Chief of the Hydraulic Structures Division, directed the effort. Dr. John Harrison was Chief of EL. Mr. Charles H. Tate, Jr., conducted the study and prepared the text under the direct supervision of Dr. D. R. Smith, Chief of the Reservoir Water Quality Branch (Physical). Assistance in conducting the test and analyzing the tracer samples was provided by numerous HL personnel. Dr. E. C. Tsivoglou assisted in the investigation as a contractor and by consulting with the author on techniques and procedures.

The radioactive tracer tests at Enid Lake were coordinated with the Nuclear Regulatory Commission, the Division of Radiological Health of the Mississippi State Board of Health, and the Air and Water Pollution Control Commission. Permission to conduct the tests at Enid Lake was obtained from the District Engineer, Vicksburg District, U. S. Army Corps of Engineers, with the point of contact at the District office being Mr. Bob Palermo, Chief of the Reservoir Regulation Branch. Throughout the effort at Enid Lake, the local staff was extremely helpful with information and assistance.

Dr. Tsivoglou was placed under contract with WES to assist WES personnel in the performance of the 1978 Enid Lake tests and to provide the laboratory analysis of the tracer samples. In addition, Dr. Tsivoglou's radioactive materials license was used to conduct the 1978 tracer tests.

COL John L. Cannon, CE, and COL Nelson P. Conover, CE, were

Commanders and Directors of WES during this effort. Mr. Fred R. Brown was Technical Director.

This report should be cited as follows:

> Tate, C. H., Jr. 1982. "Reaeration Tests, Enid Lake Outlet Works," Technical Report E-82-2, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
cubic feet per second	0.02831685	cubic metres per second
feet	0.3048	metres
feet per second	0.3048	metres per second
miles (U. S. statute)	1.609347	kilometres

REAERATION TESTS, ENID LAKE OUTLET WORKS

PART I: INTRODUCTION

1. Properly designed hydraulic structures can enhance the quality of water released from lakes; conversely, improperly designed structures may release flow supersaturated with nitrogen or void of oxygen with possible adverse effects on the environment. As a result, the U. S. Army Corps of Engineers has found it imperative to acquire prototype and hydraulic model data from which existing predictive techniques can be evaluated and new or improved techniques developed for hydraulic structure design.

2. The U. S. Army Engineer Waterways Experiment Station (WES) has been evaluating methods of measuring the gas transfer that occurs in prototype structures and in physical hydraulic models. The information obtained will be used to determine model-to-prototype scale relations and to evaluate predictive techniques for gas transfer in hydraulic structures (Wilhelms and Smith 1981, and Smith et al., in publication).

3. As part of the above effort, measurements were made at Enid Lake using the radioactive gas tracer technique developed by Dr. E. C. Tsivoglou (Tsivoglou et al. 1965). This technique was selected based on measurement precision, dosing method, and previous use to evaluate reaeration in physical models. In 1977, the method was successfully demonstrated in a 1:20-scale spillway model by WES personnel and Dr. Tsivoglou (Wilhelms 1980). Techniques similar to those used in the model study were used at Enid Lake during August 1978 and February 1980. During September 1978, in situ dissolved oxygen (D.O.) levels were measured in the Enid outlet structure to supplement the tracer measurements.

Objectives

4. The objectives of this study were as follows:

   a. Obtain field data for comparison to model data and fo evaluating predictive techniques.

b. Demonstrate that the radioactive gas tracer technique can be applied to reservoir outlet works.

c. Determine the applicability of in situ D.O. measuring equipment for use in reservoir outlet structures.

Scope

5. This report addresses the field studies conducted at Enid Lake during the period 1978-1980 and the analysis of data obtained from those tests. Data from the various tests are presented in Appendixes A* and B.

Description of Prototype

6. Enid Lake is located on the Yocona River approximately 1/2 mile** east of Interstate 55 in north Mississippi (Figure 1). Although Enid is part of a comprehensive flood control plan for the Yazoo River Basin above the Mississippi River backwater area, it is used extensively for recreation. The dam is an earth-fill structure, 8400 ft long, with a crest elevation of 293.0 ft mean sea level (msl). From a 410-ft-wide base, the dam rises 85 ft to the crest which supports a two-lane asphalt paved road. The outlet structure is located near the north abutment. Two 8-ft-wide by 16-ft-high service gates regulate the release flow. Each gate releases flow into an 11-ft-inside diameter (ID) concrete conduit which passes through the base of the dam and discharges into one side of the stilling basin. The spillway is located in the north abutment and designed to pass excessive flood flows without endangering the dam (Figure 2).

Procedure

7. The release flow was dosed upstream of the Enid Lake outlet

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* E. C. Tsivoglou, Letter Report to Charles H. Tate, Jr., 1 September 1978.

** A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

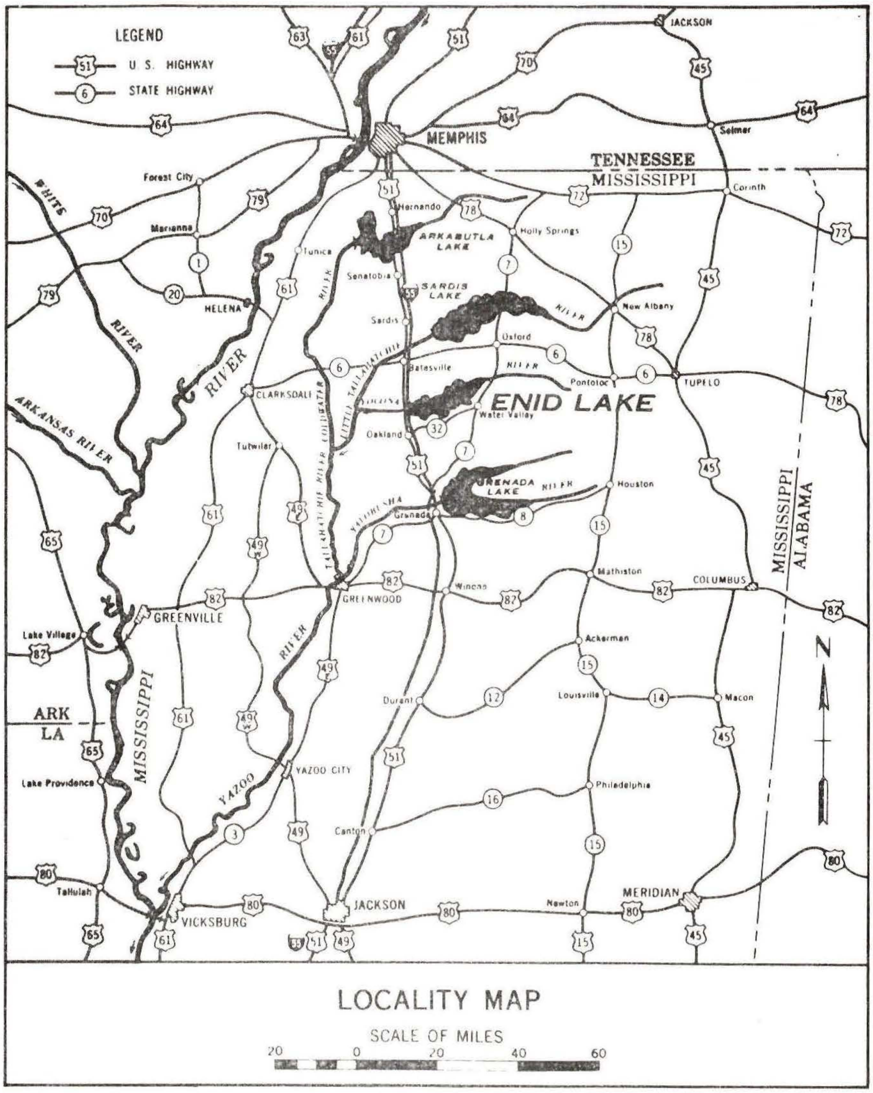

Figure 1. Locality map

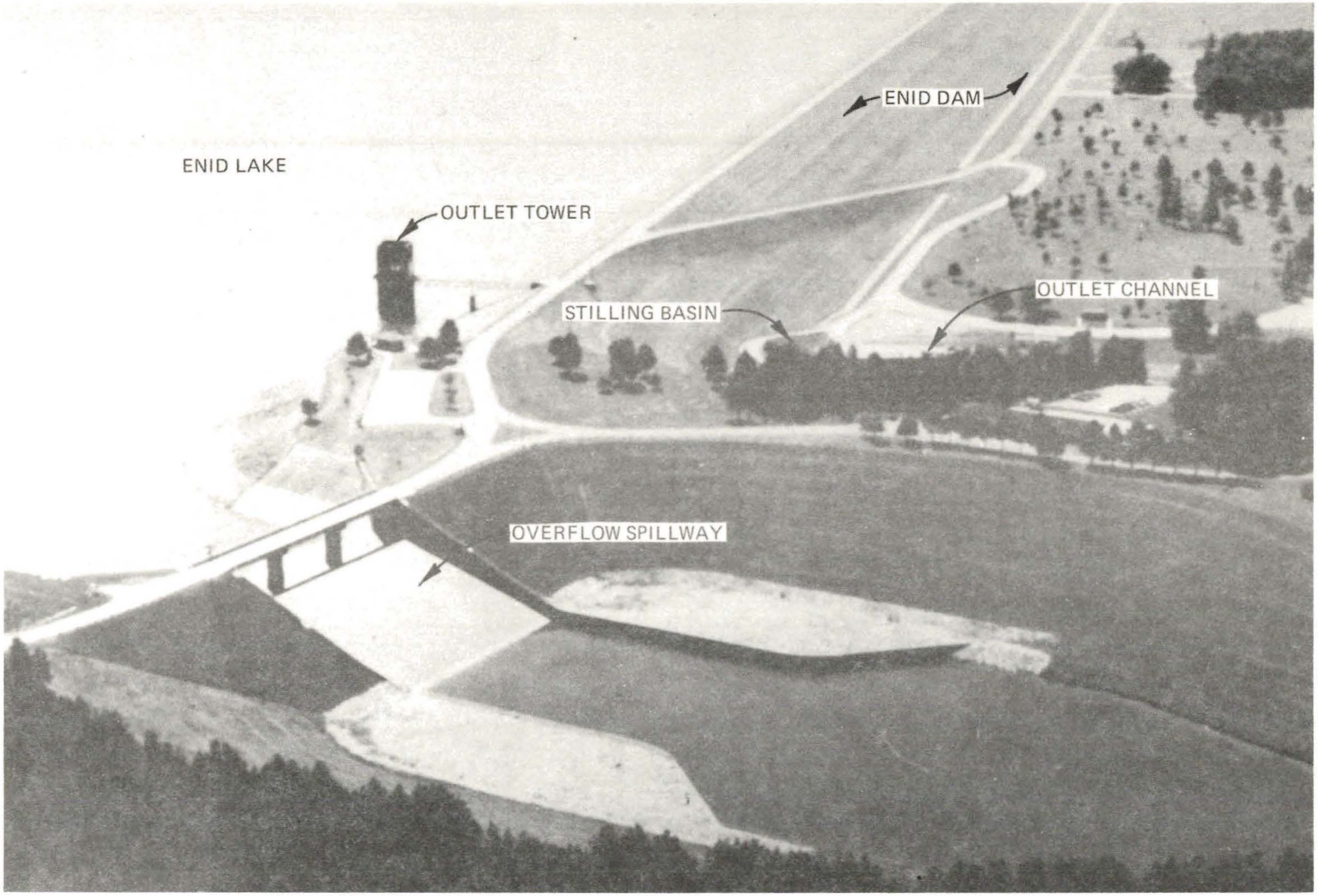

Figure 2. Overview of Enid Lake outlet structures

structure with a point dose containing three tracing elements, two of which are radioactive. Dissolved krypton-85 (Kr-85) gas is used to measure the gas transfer between the water and the atmosphere. The efflux of Kr-85 from the water can be related to the influx of atmospheric gases to the water due to the physical properties of the flow. Tritium (H-3) as tritiated water molecules is the other radioactive tracer and is used to measure the dispersion of the dose. The ratio of the radioactive tracers in the collected samples is used to determine the gas transfer rate in the test section. This transfer rate indicates the potential dissolved gas levels based upon the rate of mass transfer in the two-phase flow regime under study. Chemical and biological reactions may cause the actual dissolved gas levels to vary from the potential levels indicated by the inert tracers. Rhodamine-wt dye is the third tracing element and is used to indicate the presence of radioactive tracers at the sample stations. Additional information on the tracer technique can be found in Tsivoglou, McClanahan, and Sanders (1972).

8. The four sampling stations for the tracer tests were located at the emergency gate slot, the outlet portal, the entrance to the tailwater, and middepth over the end sill (Figure 3).

9. The release flow entering the outlet structure was sampled at station 1. Uneven flow distribution upstream of the service gate coupled with point dosing operations necessitated sampling across the width of the intake. The samples from station 1 were used to verify the tracer ratios in the dose since the flow had not been exposed to the atmosphere.

10. Sample flow was drawn from the bottom of the conduit at station 2 and, using the tracer concentration ratios from this location and the initial dose concentration ratios, the gas transfer in the conduit was determined.

11. Sampling station 3 was located near the middle of the outlet transition between the conduit outlet portal and the stilling basin. The invert of the outlet transition of the outlet works at Enid Lake is stepped rather than the smooth parabolic trajectory typical of most reservoir outlet works. The intake for sampling station 3 was located

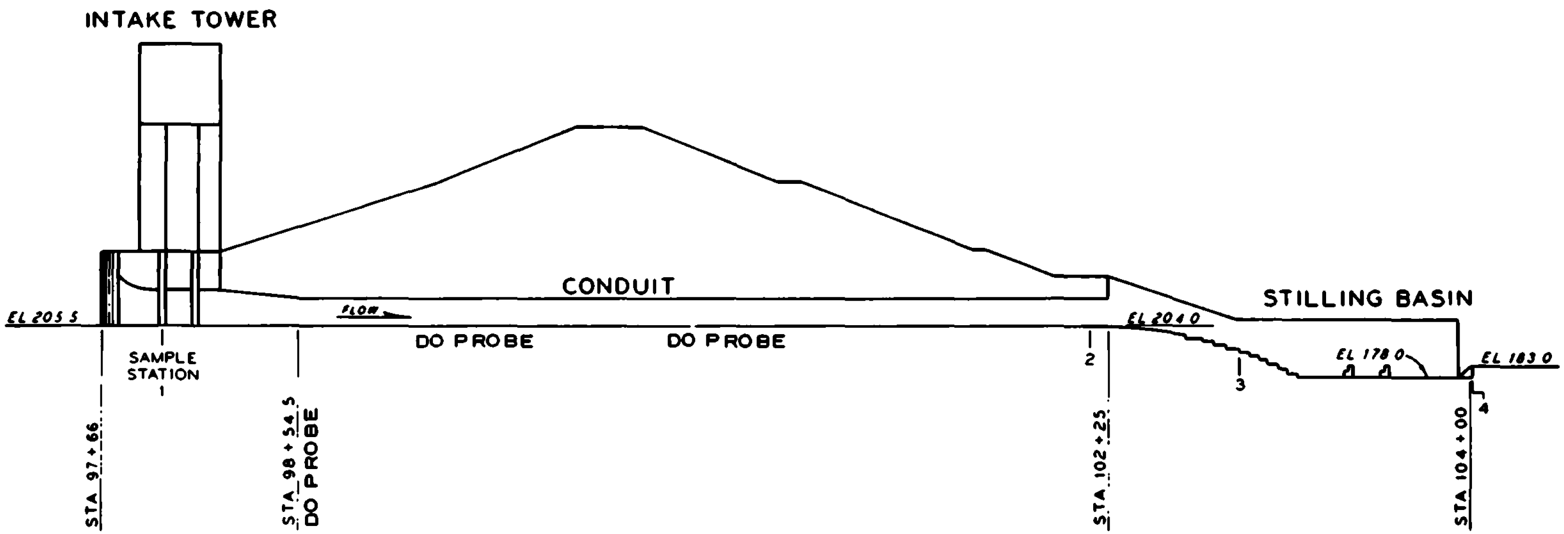

Figure 3. Enid Dam outlet structure sampling stations

on one of the steps just below the tailwater at the toe of the hydraulic jump. Thus the effect of a portion of the stepped trajectory could be isolated from the total effect of the stilling basin.

12. The intake at sampling station 4 was located at middepth over the end sill of the stilling basin and in the main portion of the flow. Tracer ratios from this station coupled with the initial dose ratio were used to determine the total gas transfer due to the reservoir outlet structure.

13. D.O. probes were placed in the conduit 40, 100, and 220 ft downstream of the service gate. A D.O. probe was also placed at the end sill of the stilling basin. D.O. levels were monitored at these locations for flows of 50, 100, 150, and 200 cfs. These probes were mounted such that they were constantly in the flow. Previous study indicated that the probes performed acceptably during short periods of immersion in high velocity flow (Hart and Wilhelms 1977). The generalized selective withdrawal model SELECT (Bohan and Grace 1973) was used to predict the D.O. concentration entering the outlet structure. This model is used to calculate the vertical velocity profile for density-stratified flow in the lake and predict release values based on in-lake profiles and lake geometry. SELECT was calibrated for Enid Lake in that the effective port centerline elevation was determined using temperatures observed at the D.O. sampling location 40 ft downstream of the service gate.

Results

14. Results of the tracer tests are summarized in Appendix A. Sometime between test A and test B, the intake for sampling station 3 separated from the mounting, and sample flow was collected from an unknown location. Samples collected at this station were not used in the analysis of the subsequent tests. The amount of the tracer gas entering the test section that is lost to the atmosphere is relatable to the D.O. uptake by the relation described in Appendix A.

Individual test section results

15. Figure 4 illustrates the average Kr-85 gas loss per test section. For doses A through D (100 cfs), an average of 65.1 percent of the tracer gas entering the test section was lost between sampling stations 1 and 2. Approximately 77.9 percent of the tracer gas present at station 2 was lost to the atmosphere between sampling stations 2 and 3. In contrast only 8.9 percent of the tracer present at station 3 was lost to the atmosphere between stations 3 and 4.

16. Figure 5 illustrates the D.O. deficit potentially satisfied between sampling stations by reaeration. These values are based on separate tracer and D.O. measurements for a release of 100 cfs. The gas transfer between the service gate (station 1) and the first D.O. probe (40 ft from the service gate) was determined from D.O. measurements. This indicates the minimum amount of reaeration that occurs in this test reach.

17. Figure 5 indicates that for the 100 cfs flow the majority of the gas transfer occurs between the service gate and the downstream end of the transition section, and between the end of the conduit and the tailwater. Both of these areas are highly aerated. Below the service gate a high velocity flow exists which transitions from 0.1 ft deep to approximately 1.0 ft deep. At 100 cfs the reach between the conduit and the tailwater is essentially a series of 2-ft-high cascades. The remaining test reaches contain relatively tranquil flow which is not visibly aerated.

Cumulative results

18. The total tracer gas loss during flow through the structure for doses A through D (100 cfs) averaged 92.3 percent. Doses E and F (200 cfs) had an average total tracer gas loss of 88.2 percent. Two tests conducted with an 800 cfs discharge had an average total tracer gas loss of 84.1 percent. The initial D.O. deficits potentially satisfied with flows of 100, 200, and 800 cfs were 95.4, 92.4, and 89.1 percent, respectively. These results indicate that for Enid structure and the range of flows tested, the D.O. deficits satisfied by reaeration decreased with increased flow rates.

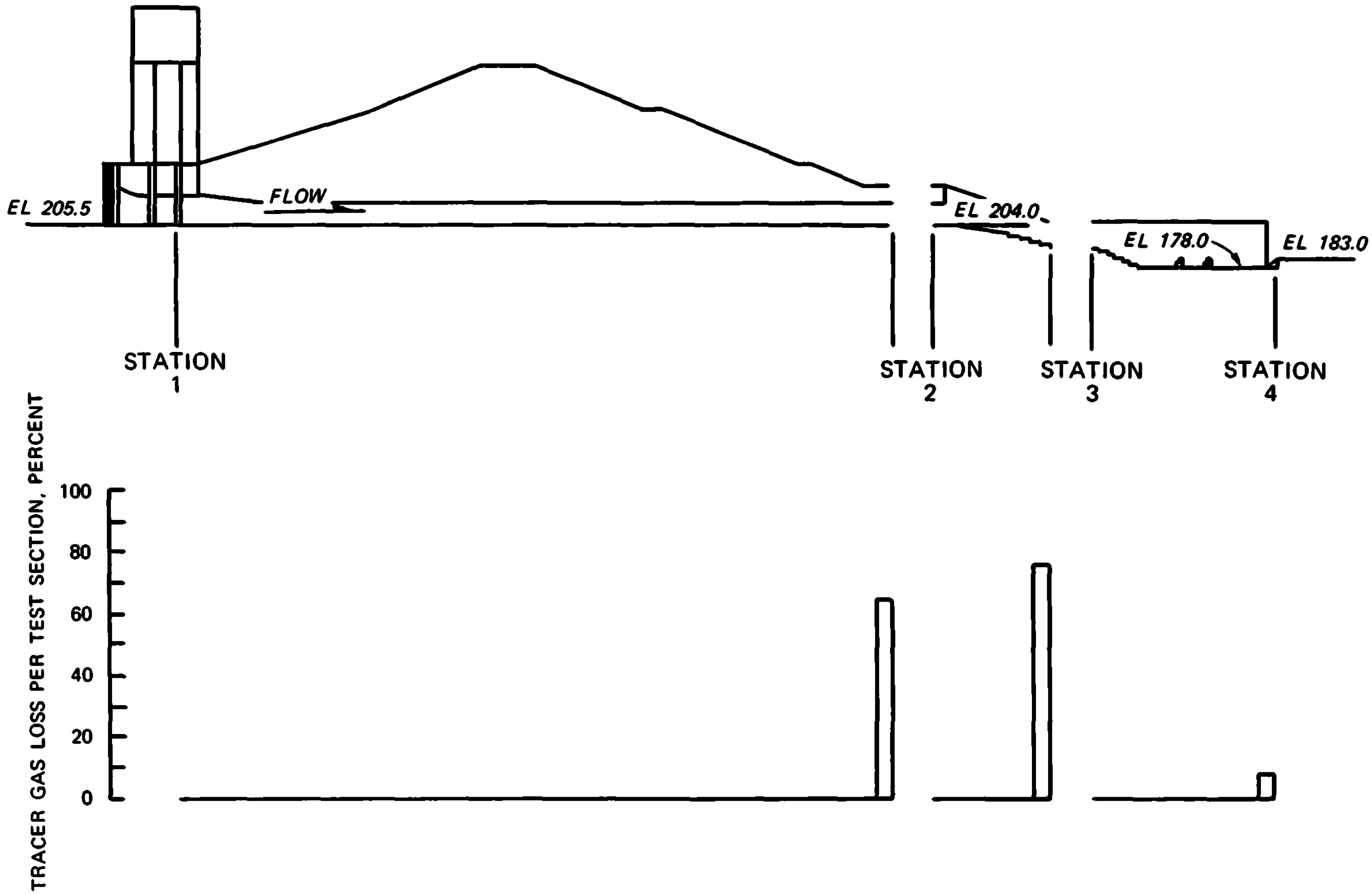

Figure 4. Tracer gas loss per test section

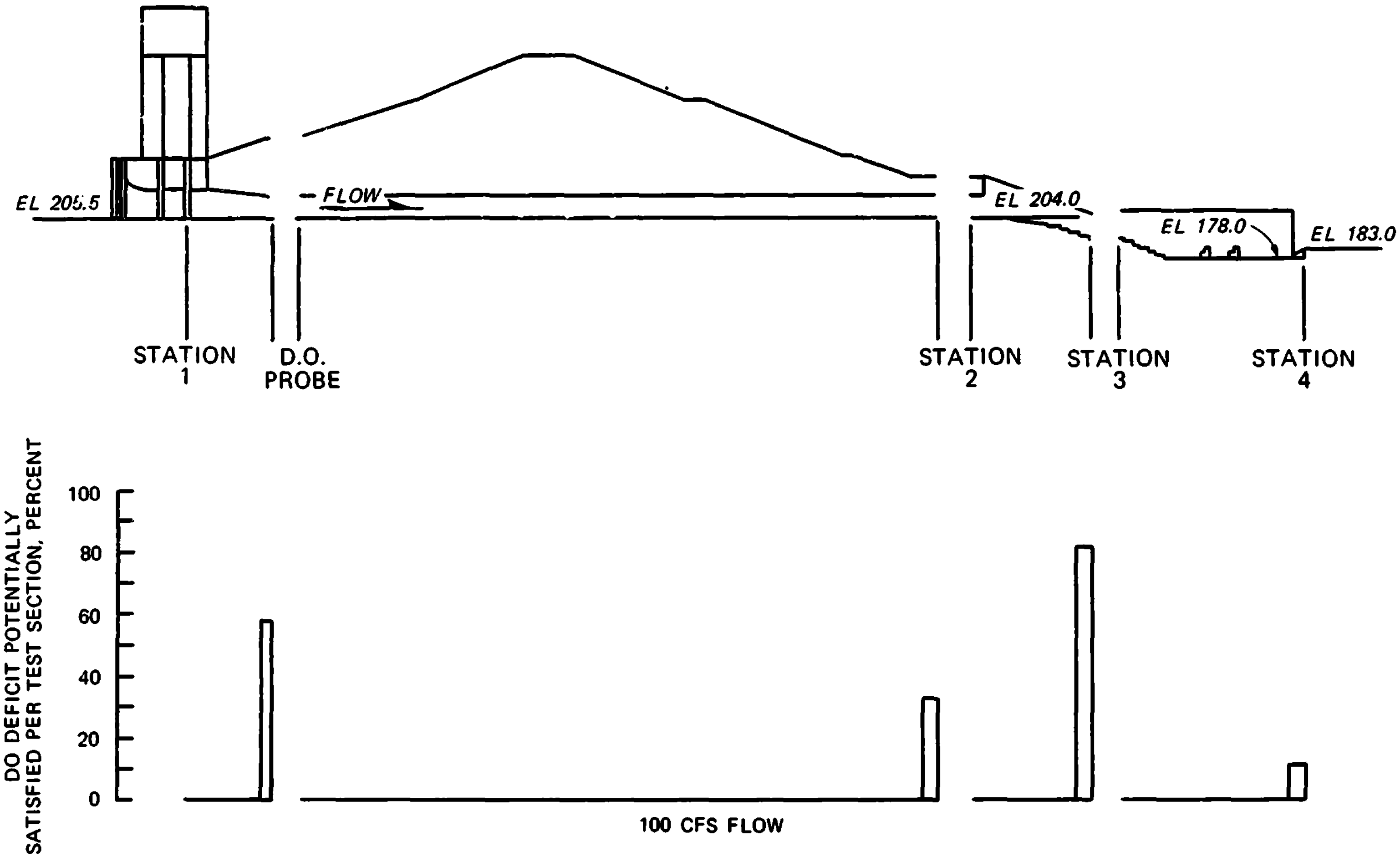

Figure 5. D.O. deficit potentially satisfied per test section

19. The cumulative effect of reaeration through the outlet structure for the 100 cfs flow rate is shown in Figure 6. Observed D.O. values near the middle of the conduit and at the end sill are included for comparison. The D.O. data suggest that part of the oxygen added to the release flow by reaeration was rapidly lost to an unidentified sink.

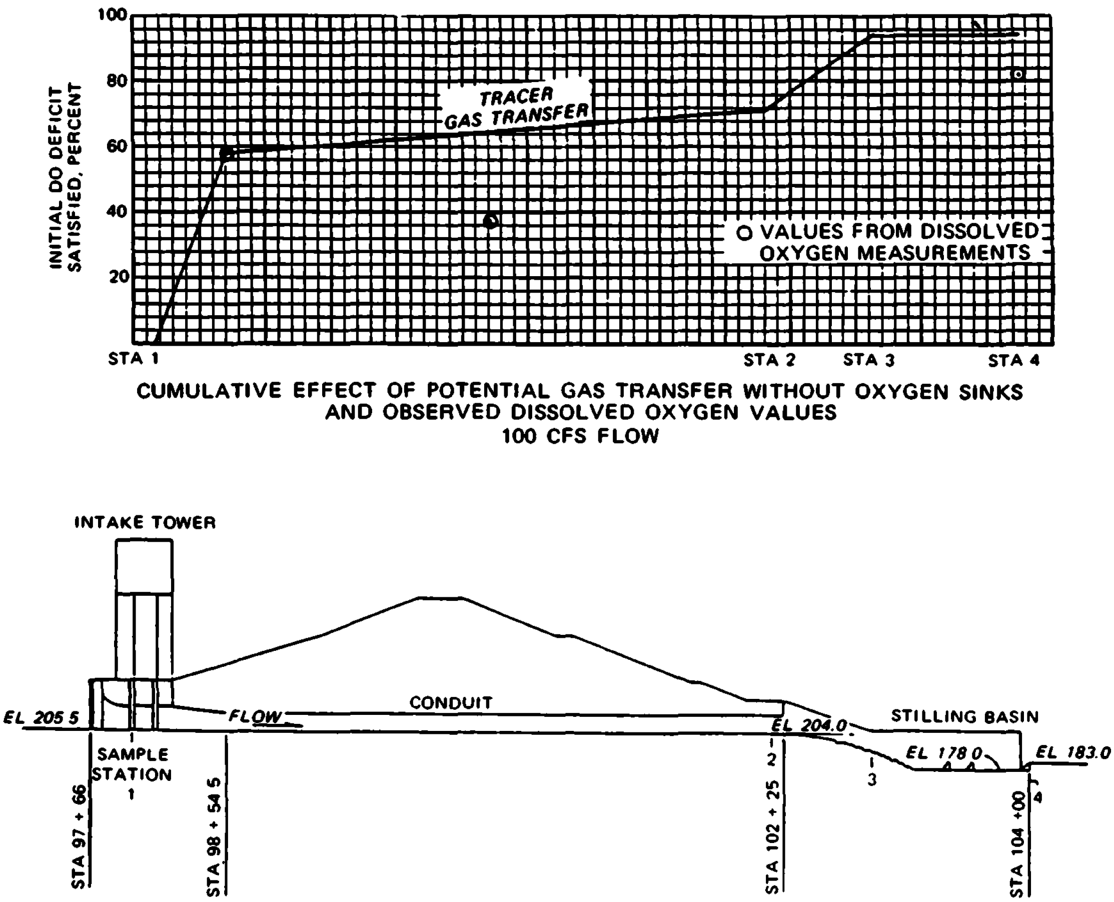

Figure 6. Cumulative effect of gas transfer, Enid Dam outlet structure

PART II: CONCLUSIONS AND DISCUSSION

20. A data base has been established relative to the reaeration or gas transfer characteristics of the Enid Lake outlet works and in a subsequent study this will be compared to the results of model tests. The results of the prototype study have been used in comparing predictive techniques for reaeration in prototype structures using gross characteristics (Wilhelms and Smith 1981). By locating the sampling stations at selected points in the structure, the individual effects of different flow regimes throughout the outlet works were isolated. The isolation of the effects of various flow regimes on gas transfer characteristics allows each regime to be analyzed separately. This will be valuable in the subsequent comparison of model-prototype relations. After scaling relations are investigated, the results of the Enid Lake studies can be used to predict gas transfer characteristics in similar structures and flow regimes. In the interim the radioactive tracer technique demonstrated in this study can be used to determine the gas transfer characteristics of other hydraulic structures. The technique may not be feasible for flows significantly greater than 1000 cfs due to the concentration of radioactive tracers required to dose the release flow. Because of this safety consideration, structures such as large overflow spillways and hydropower plants will require individual analysis to determine the applicability of the tracer technique.

21. If possible, both in situ D.O. measurements and radioactive tracer tests should be conducted to determine total site-specific gas transfer characteristics and release D.O. concentrations. The radioactive tracer technique indicates the transfer of oxygen from the atmosphere to the water. This, however, is not necessarily a good indicator of the final D.O. concentration because it does not reflect the depletion of D.O. as a result of oxygen sinks. If oxygen sinks exist in the release flow with rapid reaction rates compared to the transit time through the structure, then the released D.O. concentrations may be less than anticipated from the total gas transfer characteristics. This condition is indicated in Figure 6 where the observed D.O. concentrations

near the middle of the conduit and at the end sill are significantly less than those indicated by the conservative tracer tests. Because of the presence of H_2S, chemical oxidation in the release flow appears to be the reason for the discrepancy in the predicted versus observed D.O. concentrations in the Enid Lake outlet works. The presence and concentrations of oxygen sinks such as H_2S, iron, or manganese are site- and season-specific and should be considered when making realistic D.O. predictions for releases from hydraulic structures. Oxidation of H_2S occurs rapidly and the effect of this reaction on D.O. levels may be measurable within the outlet works. Similar reactions (e.g., for iron, manganese, etc.) generally occur at a slower rate and the effects on the D.O. concentrations would be measurable downstream of the outlet structure rather than in the outlet structure. In spite of the presence of a rapidly reacting oxygen sink the outlet structure ultimately satisfied over 80 percent of the initial D.O. deficit and removed some of the oxygen demand of the released water.

22. Significant amounts of oxygen were added to the flow released from Enid Lake, resulting in high D.O. concentrations at the downstream end of the outlet structure. This occurred in spite of oxygen sinks active within the outlet works. Slower reacting oxygen demands can reduce the D.O. concentration as the flow progresses downstream (Metcalf and Eddy, Inc. 1972). If such a D.O. sag does occur below an outlet structure, the reaeration in the structure can reduce the duration or intensity or both. The reaeration which occurs within the outlet structure significantly improves the quality of the flow released from the lake.

23. The in situ D.O. probes used in the investigation did not perform acceptably in that water was forced into the electrical connection between the probe and the cable. When this occurred, the meter reading would go off scale. Modification of this connection would permit reaeration studies based on measurement of D.O. uptake at structures if rapid D.O. depletion does not exist. Studies using this technique should be economical and could be conducted by trained personnel.

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APPENDIX A

RADIOACTIVE TRACER MEASUREMENTS AT ENID LAKE

By

Dr. E. C. Tsivoglou

8/31/78

ENID LAKE TRACER STUDY

STUDY PERIOD: August 20-25, 1978

TRACER DOSE SUMMARY:

Dose	Krypton-85 curies	Tritium curies	Dose Ratio
A	0.80	0.50	1.600
B	0.80	0.50	1.600
C	0.80	0.50	1.600
D	0.80	0.50	1.600
E	1.52	1.00	1.520
F	1.52	1.00	1.520
Totals:	6.24	4.00	

ENID LAKE

SUMMARY OF RESULTS

Dose	Flow cfs	Percent Loss of Tracer Gas Between Indicated Stations (1 - 2)	(1 - 3)	(1 - 4)	(2 - 3)	(2 - 4)	(3 - 4)
A	100	66.3	92.0	92.7	76.2	78.3	8.9
B	100	nd*	92.4	92.1	nd	nd	-3.3
C	100	64.3	92.4	92.2	78.6	78.1	-2.4
D	100	64.6	92.5	92.0	78.7	77.3	-6.6
	Mean:	65.1	92.3	92.3	77.8	77.9	-0.9
E	200	nd	88.0	87.6	nd	nd	-3.5
F	200	nd	88.5	88.7	nd	nd	1.3
	Mean:	nd	88.3	88.2	nd	nd	-1.1
Feb 1980							
G	800	nd	nd	84.9 (2)	nd	nd	nd
H	800	nd	nd	82.8	nd	nd	nd
	Mean:	nd	nd	84.1	nd	nd	nd

* Not determined.

KRYPTON:OXYGEN RELATIONSHIPS

From

$$R_2 = R_1 e^{-K_{kr} t} \qquad \text{where } R = \text{Kr-85:H-3 ratio}$$

and

$$D_2 = D_1 e^{-K_{ox} t} \qquad \text{where } D = \text{D.O. deficit}$$

and

$$K_{kr} = 0.83 K_{ox}$$

it follows that

$$\ln \frac{D_2}{D1} = \frac{\ln \frac{R_2}{R_1}}{0.83} \tag{1}$$

at a specific temperature, and in a system where there is no significant D.O. source or sink except reaeration.

Under such circumstances, it is not necessary to evaluate the reaction rate coefficients, K_{kr} and K_{ox} , in order to predict the downstream D.O. from the observed tracer data and the upstream D.O. Equation 1 is sufficient.

<u>Examples</u>:

Reach (1-2) $(R_2/R_1)_{ave} = (1 - 0.651) = 0.349$

and $D_2 = (0.281) \times D_1$

or, 72 percent of the D.O. deficit present at station 1 will be satisfied at station 2, the end of the conduit, at the prevailing temperature in the study and 100 cfs.

Reach (1-4) $(R_2/R_1)_{avg} = (1 - 0.923) = 0.077$

and $D_2 = (0.046) \times D_1$

ENID LAKE TRACER STUDY

FINAL CALIBRATIONS

Tritium efficiency = e_H = 0.1005 + 1.1784 × 10^{-6} × (AES)

Kr-85 spillover = Sp = 0.0566 - 2.2000 × 10^{-7} × (AES)

Total Kr-85 counts = ΣKr = 35,600 + 0.220 × (AES)

From analysis of station 1 data:

Krypton efficiency = e_{Kr} = 0.2559 + 1.5835 × 10^{-6} × (AES)

SAMPLE BACKGROUND*

Red Channel:	149.89
Green Channel:	226.89

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* Determined from the sample taken for Doses A and B.

DATA SUMMARY - DOSE A

Station Number	Sample Number	Mean 10-Min Count Red	Mean 10-Min Count Green	Kr-85:H-3 Ratio Sample	Kr-85:H-3 Ratio Station Mean	Gas Fraction Remaining	Gas Fraction Lost
1	ns*	--	--	--	1.600**	1.000	0.000
2	1	8,831	8,329	0.515			
	2	7,875	7,864	0.554	0.539	0.337	0.663
	4	6,896	6,915	0.548			
3	3	2,956	872	0.123			
	4	3,493	1,022	0.128	0.128	0.080	0.920
	5	3,393	1,031	0.133			
4	11	2,440	736	0.119			
	12	2,424	733	0.120	0.117	0.073	0.927
	13	2,451	703	0.111			

* This station not sampled.
** Dose ratio determined at Georgia Tech.

DATA SUMMARY - DOSE B

Station Number	Sample Number	Mean 10-Min Count Red	Mean 10-Min Count Green	Kr-85:H-3 Ratio Sample	Kr-85:H-3 Ratio Station Mean	Gas Fraction Remaining	Gas Fraction Lost
1	ns*	--	--	--	1.600**	1.000	0.000
2	ns†	--	--	--	--	--	--
3	2	3,214	913	0.120			
	3	3,294	947	0.123	0.122	0.076	0.924
	4	3,163	921	0.124			
4	1	5,073	1,366	0.124			
	2	4,958	1,402	0.131	0.126	0.079	0.921
	3	4,880	1,317	0.124			

* This station not sampled.
** Dose ratio determined at Georgia Tech.
† Sample counts all near background; station deleted.

DATA SUMMARY - DOSE C

Station Number	Sample Number	Mean 10-Min Count Red	Mean 10-Min Count Green	Kr-85:H-3 Ratio Sample	Kr-85:H-3 Ratio Station Mean	Gas Fraction Remaining	Gas Fraction Lost
1	3	181,272	427,924	1.377			
	4	207,366	543,249	1.544	1.530	1.000	0.000
	5	131,825	369,635	1.668			
2	2	54,195	56,173	0.573			
	3	51,225	49,113	0.528	0.546	0.357	0.643
	4	43,940	42,849	0.537			
3	2	2,247	681	0.116			
	3	2,908	844	0.120	0.117	0.076	0.924
	4	2,682	772	0.115			
4	2	4,887	1,244	0.115			
	3	3,478	949	0.116	0.120	0.078	0.922
	4	1,736	607	0.128			

DATA SUMMARY - DOSE D

Station Number	Sample Number	Mean 10-Min Count Red	Mean 10-Min Count Green	Kr-85:H-3 Ratio Sample	Kr-85:H-3 Ratio Station Mean	Gas Fraction Remaining	Gas Fraction Lost
1	6	98,066	259,521	1.566			
	7	93,901	262,703	1.667	1.672	1.000	0.000
	8	90,819	269,952	1.783			
2	1	137,245	147,173	0.594			
	2	98,934	104,712	0.588	0.593	0.354	0.646
	3	52,594	56,669	0.596			
3	2	2,899	877	0.127			
	3	2,915	871	0.125	0.126	0.075	0.925
	4	2,411	760	0.126			
4	3	4,708	1,427	0.141			
	4	4,207	1,180	0.126	0.134	0.080	0.920
	5	2,996	944	0.135			

DATA SUMMARY - DOSE E

Station Number	Sample Number	Mean 10-Min Count Red	Mean 10-Min Count Green	Kr-85:H-3 Ratio Sample	Kr-85:H-3 Ratio Station Mean	Gas Fraction Remaining	Gas Fraction Lost
1	--	--	--	--	1.520*	1.000	0.000
2	ns**	--	--	--	--	--	--
3	4	2,384	1,061	0.201			
	5	3,390	1,315	0.181			
	6	3,514	1,400	0.188	0.182	0.120	0.880
	7	3,590	1,324	0.172			
	8	3,405	1,255	0.169			
4	2	4,106	1,704	0.201			
	3	4,039	1,678	0.201			
	4	3,404	1,385	0.191	0.188	0.124	0.876
	6	3,333	1,273	0.177			
	7	3,390	1,263	0.172			

* Dose ration determined at Georgia Tech.
** This station not sampled.

DATA SUMMARY - DOSE F

Station Number	Sample Number	Mean 10-Min Count Red	Mean 10-Min Count Green	Kr-85:H-3 Ratio Sample	Kr-85:H-3 Ratio Station Mean	Gas Fraction Remaining	Gas Fraction Lost
1	ns*	--	--	--	1.520**	1.000	0.000
2	ns	--	--	--	--	--	--
3	4	3,272	1,211	0.170			
	5	4,228	1,598	0.181			
	6	4,269	1,533	0.170	0.174	0.115	0.885
	7	4,138	1,500	0.172			
	8	4,251	1,592	0.180			
4	4	5,751	2,046	0.175			
	5	4,748	1,641	0.166			
	6	4,408	1,580	0.171	0.172	0.113	0.887
	7	3,892	1,456	0.177			
	8	3,159	1,188	0.172			

* This station not sampled.
** Dose ratio determined at Georgia Tech.

APPENDIX B

DISSOLVED OXYGEN MEASUREMENTS
ENID LAKE

SURFACE ELEVATION: 248.91 FT MSL

Depth, meters	Temperature, °C	D.O., mg/ℓ	Oxidation-Reduction Potential
Surface	26.6	7.5	+180
1	26.5	7.2	+180
2	26.5	7.15	+180
3	26.4	7.1	+184
4	26.4	7.05	+189
5	26.2	6.9	+190
6	25.5	5.2	+205
7	25.3	5.1	+209
8	25.2	4.8	+210
9	25.1	4.4	+210
10	24.0	1.1	+190
11	23.5	0.75	+64
12	21.0	0.6	-100
13	19.0	0.45	-155

Station	Temperature, °C	D.O., mg/ℓ	Oxidation-Reduction Potential
Q = 50 cfs			
Service Gate + 40 ft	21.8	7.6	--
Service Gate + 100 ft	22.2	9.2	--
Service Gate + 220 ft	22.0	9.6	--
End Sill	22.1	7.4	-70

Station	Temperature, °C	D.O., mg/ℓ	Oxidation-Reduction Potential
Q = 100 cfs			
Service Gate + 40 ft	22.0	5.5	--
Service Gate + 100 ft	--	--	--
Service Gate + 220 ft	22.6	3.8	--
End Sill	22.5	7.5	-80
Q = 150 cfs			
Service Gate + 40 ft	22.2	5.3	--
Service Gate + 100 ft	--	--	--
Service Gate + 220 ft	22.9	4.7	--
End Sill	22.8	7.75	-85
Q = 200 cfs			
Service Gate + 40 ft	22.0	5.0	--
Service Gate + 100 ft	--	--	--
Service Gate + 220 ft	--	--	--
End Sill	23.0	7.8	-80
Predicted Values Flow, cfs			
50	21.87	0.71	-19.75
100	22.11	0.83	+0.15
150	22.33	0.97	17.15
200	22.54	1.15	33.23

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Tate, Charles H.
Reaeration tests, Enid Lake outlet works / by Charles H. Tate, Jr. (Hydraulics Laboratory, U.S. Army Engineer Waterways Experiment Station). -- Vicksburg, Miss. : The Station ; Springfield, Va. : available from NTIS, 1982.
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At head of title: Environmental & Water Quality Operational Studies.
Bibliography: p. 18.

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