SPOKANE RIVER BASIN MODEL PROJECT

Volume III - Verification Report

by

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ABSTRACT

Three existing mathematical models, capable of representing water quality in rivers and lakes, have been modified and adapted to the Spokane River Basin in Washington and Idaho. The resulting models were named the Steady-state Stream Model, the Dynamic Stream Model, and the Stratified Reservoir Model. They are capable of predicting water quality levels resulting from alternative basinwide wastewater management schemes, and are designed to assist EPA, State, and local planning organizations to evaluate water quality management strategies and to establish priorities and schedules for investments in abatement facilities in the basin.

Physical data and historical hydrologic, water quality and meteorologic data were collected, assessed and used for the model calibrations and verifications.

The modified models are all capable of simulating the behavior of various subsets of up to sixteen different water quality constituents. Sensitivity analyses were conducted with all three models to determine the relative importance of a number of individual model parameters.

The models were provided to the EPA as computer source card decks in FORTRAN IV language, with accompanying data decks. All development work on, and applications made with, these models were fully documented so as to permit their easy utilization and duplication of historical simulations by other potential users. A user's manual with a complete program listing was prepared for each model.

This report was submitted in fulfillment of Contract No. 68-01-0756 under the sponsorship of the Environmental Protection Agency.

The titles and identifying numbers of the final report volumes are:

Title	EPA Report No.
SPOKANE RIVER BASIN MODEL PROJECT Volume I - Final Report	_____ DOC __/74
SPOKANE RIVER BASIN MODEL PROJECT Volume II - Data Report	_____ DOC __/74
SPOKANE RIVER BASIN MODEL PROJECT Volume III - Verification Report	_____ DOC __/74
SPOKANE RIVER BASIN MODEL PROJECT Volume IV - User's Manual for Steady-state Stream Model	_____ DOC __/74
SPOKANE RIVER BASIN MODEL PROJECT Volume V - User's Manual for Dynamic Stream Model	_____ DOC __/74
SPOKANE RIVER BASIN MODEL PROJECT Volume VI - User's Manual for Stratified Reservoir Model	_____ DOC __/74

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SECTION I

INTRODUCTION

BACKGROUND

The Spokane River Basin Model Project, initiated on August 31, 1972, essentially consists of the modification and application of mathematical models for water quality to rivers and lakes in the Spokane River Basin in Washington and Idaho (see Figure 1).

The lakes to be modeled naturally divide the river system into five sub-areas. For the purposes of this project, these have been named River Regions, and numbered on Figure 2.

Three mathematical models are included. Both DOSAG (Texas Water Development Board) and the Receiving Water Module ("RECEIV") of the Storm Water Management Model (EPA) are to be applied to each of the five above mentioned river regions. The Deep Reservoir Model (EPA) is to be applied to Coeur d'Alene Lake, Long Lake, and if possible the Spokane River Arm of F. D. Roosevelt Lake.

The collection and assessment of the various data required by these models was completed with the Project Officer's acceptance of the Phase I Data Report. The Data Report also includes the selection and recommendation of simulation periods to be used for each lake or river region.

OBJECTIVES

The objectives of this verification report are to:

- report on the capabilities of the previously existing models
- itemize the results of the verification simulations
- record modifications to the models (i) necessary before their execution in Phase II, and (ii) desirable before their use in Phase III.

SCOPE OF PRESENT REPORT

This report documents the procedures used in, and results obtained from, verification executions of the three specified mathematical models simulating the prescribed rivers and lakes in the Spokane River Basin. It consists of two major sections.

Section II including the Appendices, describes the approach used and modifications to the models which were needed or suggested.

Section III itemizes and discusses the results of the verification simulations.

Since this report was a deliverable required during the earlier stages of the project, it was written in May 1973.

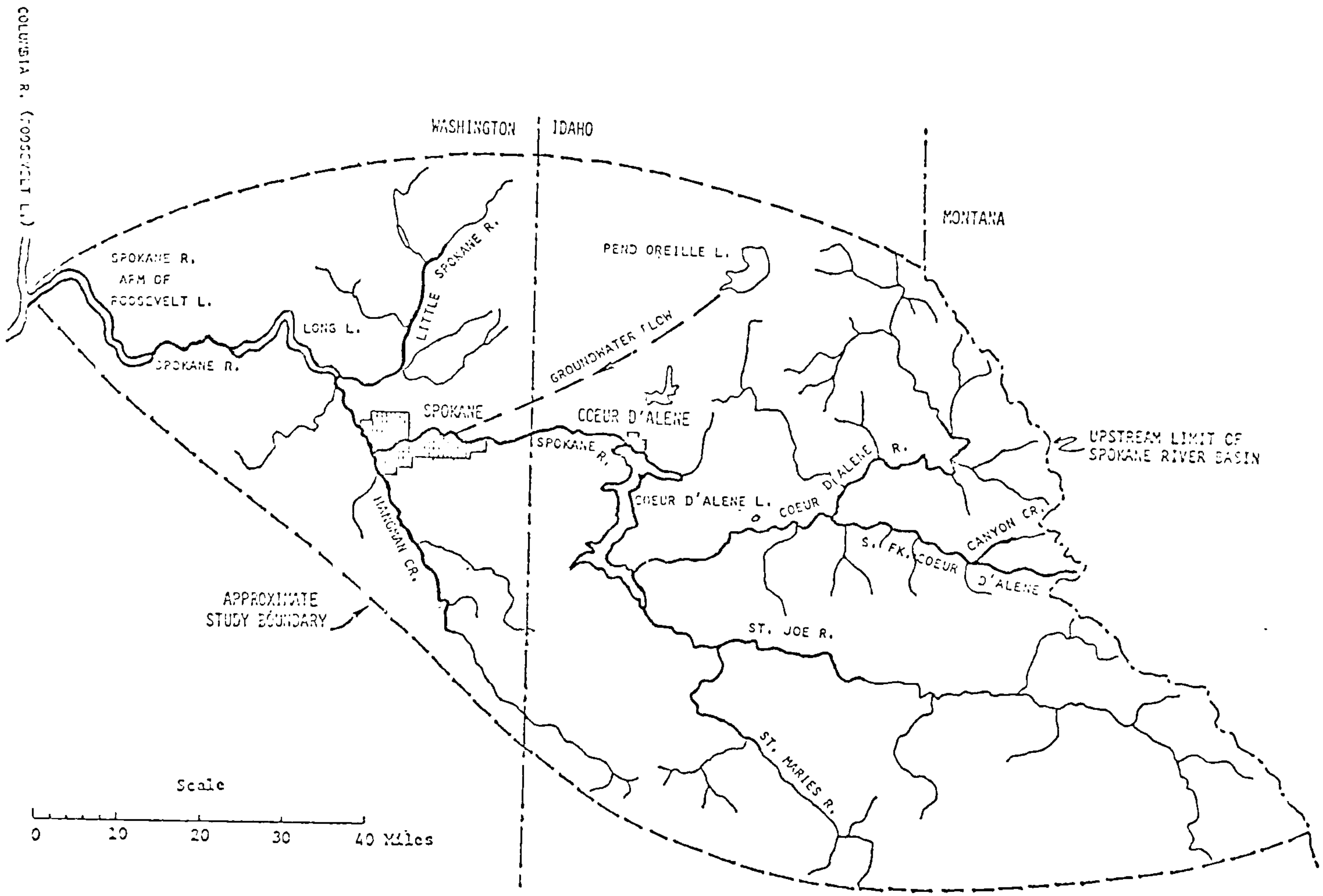
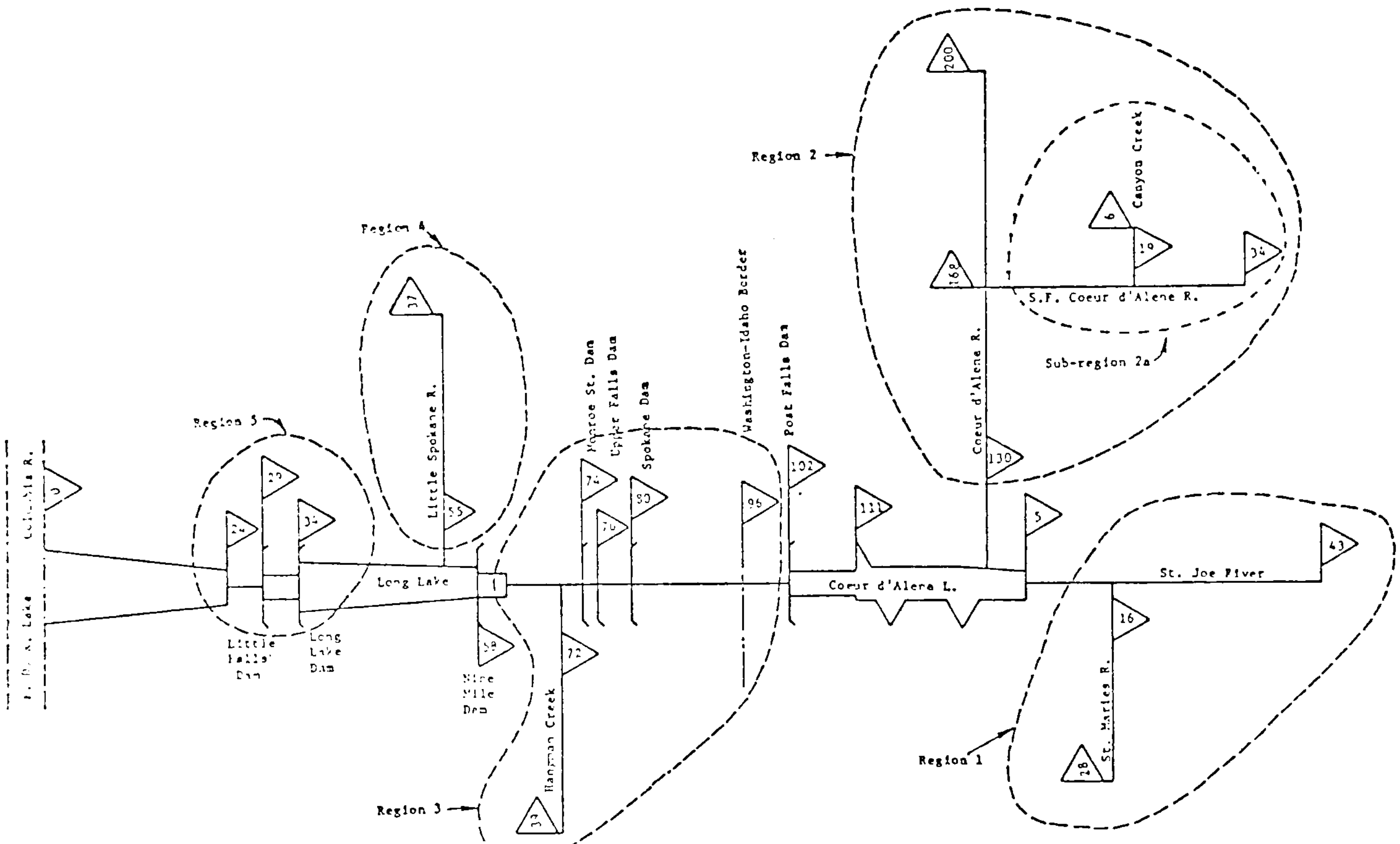


Figure 1. Spokane River Basin (portions to be modeled in bold).



River Region designations are approximate.

Legend

River Mileage

Dams

SCALE

0 10 20

Miles

FIGURE 2. LAYOUT OF SPOKANE RIVER SYSTEM

SECTION II

PROCEDURE

APPROACH

The Phase II version of DOSAG was verified by simulating BOD and DO in the five river regions. The Phase II version of RECEIV (Receiving Water Module of SWMM) was verified by simulating DO, BOD, and zinc in the five river regions.

Zinc was modeled as conservative and coliforms were not modeled at all, even though some observed coliform data were available. This was due to the shortage of coliform data and the fact that programming changes would have been needed in RECEIV to provide a different conversion factor and input and output format for coliforms on account of the different units required to describe them. No TDS data were available; and hence, TDS were not modeled.

For all runs the BOD decay coefficient was set at 0.2 DAY^{-1}. For all RECEIV runs, the reaeration coefficient was set at 1.0 DAY^{-1}.

The Phase II version of DRM was verified by simulating internal isotherms and discharge temperatures in Long Lake and Coeur d'Alene Lake.

Tables and brief explanations of the verification run results are included in Section III.

MODEL MODIFICATIONS

Article I of the contract specifies that program modifications made under Phase II shall be limited to those necessary to the Spokane River Basin, such as changes in DIMENSIONS, etc. However, SCI's experience with these models suggested that (a) they still contained basic errors, (b) some of the options they offered had not been tested, and (c) some of the types of applications made under this contract were new and untested ones for these models. Furthermore, large sections of the DRM code were non-general, and applicable to only one specific reservoir. All the significant modifications (other than those obviously needed, such as changes in DIMENSION, etc.) necessary to overcome the above mentioned difficulties, and thus enable execution of the 'as-delivered' model versions, are collected together under Class (i) modifications for each of the three Appendices.

Class (ii) modifications for each of the Appendices contains suggested further modifications desirable before the use of the models in Phase III.

SECTION III

RESULTS

DOSAG VERIFICATION

Tables, figures and brief discussions of the verification simulation results follow under separate sections for each River Region as defined in Figure 2.

In the tables, the units for concentrations are all given in units of mg/L; RM represents River Mile.

River Region 1: St. Joe - St. Maries (DOSAG)

The only observed data available for this region during July 16 - August 15, 1971, consist of coliform data and temperature data. A run was made, however, with the DO concentration in the headwaters set at 100% of saturation and the input temperature for the region set at 20.1° (see Table 1). At an elevation of 2150 feet and a temperature of 20.1°, the saturation level for DO is approximately 8.45 mg/L. Since the value of the reaeration coefficient, which is calculated in DOSAG as a function of velocity and depth, is such that DO levels remain near saturation, and since there is no BOD to decrease the DO level, the DO concentration remains at or near saturation throughout the region.

For the August 16 - September 16, 1971 period, DO data and temperature data are available. The input temperature for this period is 20.5° and the resultant saturation level of DO is approximately 8.35 mg/L (see Table 2). The fact that the observed values of DO are higher indicates that the regionwide input temperature is probably too high.

River Region 2: Coeur d'Alene (DOSAG)

Extensive observed DO, BOD and temperature data are available for both August and September, 1969 for this region. In general, the observed values of DO are higher throughout the region in September than in August, while the observed values of BOD are lower in the South Fork and higher in the main stem in September. Small sewers enter the river system at three locations, and there is extensive leaching and seeping from various mining operations along the South Fork of the Coeur d'Alene River.

For the August simulation, DO concentrations were set at approximately 8 mg/L throughout the system and BOD concentrations were set at approximately 1 mg/L. BOD and DO concentrations in the sewers were set at 200 mg/L and 1.0 mg/L respectively. The temperature for August was input at 19 degrees. As can be seen from Table 3 and Figures 3 and 4, the DO stays near saturation at about 8.5 mg/L while the BOD stays near 1 mg/L except in the vicinity of the outfalls.

TABLE 1.

DOSAG VERIFICATION (PHASE II)

RIVER REGION 1 (ST. JOE - ST. MARIES)

JULY 16 - AUGUST 15, 1971

	RM*	DO OBS	DO MOD
ST. JOE	42.9		8.44
	33.5		8.44
	31.1		8.44
	24.5		8.44
	15.7		8.44
	15.4		8.44
	15.0		8.44
	10.0		8.44
	0.7		8.44
ST. MAR	27.8		8.44
	14.8		8.44
	12.0		8.44
	10.0		8.44
	3.9		8.44

*River Mile

TABLE 2

DOSAG VERIFICATION (PHASE II)

RIVER REGION 1 (ST. JOE - ST. MARIES)

AUGUST 16 - SEPTEMBER 16, 1971

		DO	
	RM	OBS	MOD
ST. JOE	42.9	9.5	8.37
	33.5	9.2	8.37
	31.1	9.7	8.37
	24.5		8.37
	15.7		8.37
	15.4	9.0	8.37
	15.0	9.6	8.37
	10.0	9.4	8.37
	0.7	9.4	8.37
ST. MAR	27.8	10.0	8.37
	14.8		8.37
	12.0	9.5	8.37
	10.0		8.37
	3.9		8.37

TABLE 3

DOSAG VERIFICATION (PHASE II)

RIVER REGION 2 (COEUR D'ALENE)

AUGUST 1969

		DO		BOD	
	RM	OBS	MOD	OBS	MOD
COEUR D'ALENE RIVER	138	7.5	8.40	1.3	1.30
	145	7.6	8.42	1.0	1.29
	148	7.6	8.46	0.85	1.26
	154	8.3	8.51	1.3	1.20
	160	8.3	8.54	1.0	1.10
	166	8.5	8.53	1.0	1.18
	168	8.6	8.54		0.786
	170	7.6	8.53	0.9	0.792
	177	8.1	8.52	1.0	0.762
	182	8.3	8.56	1.0	0.741
	188	8.0	8.56	1.0	0.762
	194	8.2	8.50	0.8	0.741
S. FORK	1	8.2	8.49	1.7	2.27
	4	7.9	8.49	3.1	2.34
	6	7.9	8.47	0.9	2.39
	7	8.2	8.48	1.4	1.85
	10	8.0	8.48	3.7	1.89
	12	8.2	8.53	1.7	2.44
	15	8.7	8.56	2.9	0.883
	17	7.8	8.56	1.7	0.890
	18	7.9	8.56	1.75	0.894
	22	8.0	8.58	1.3	0.915

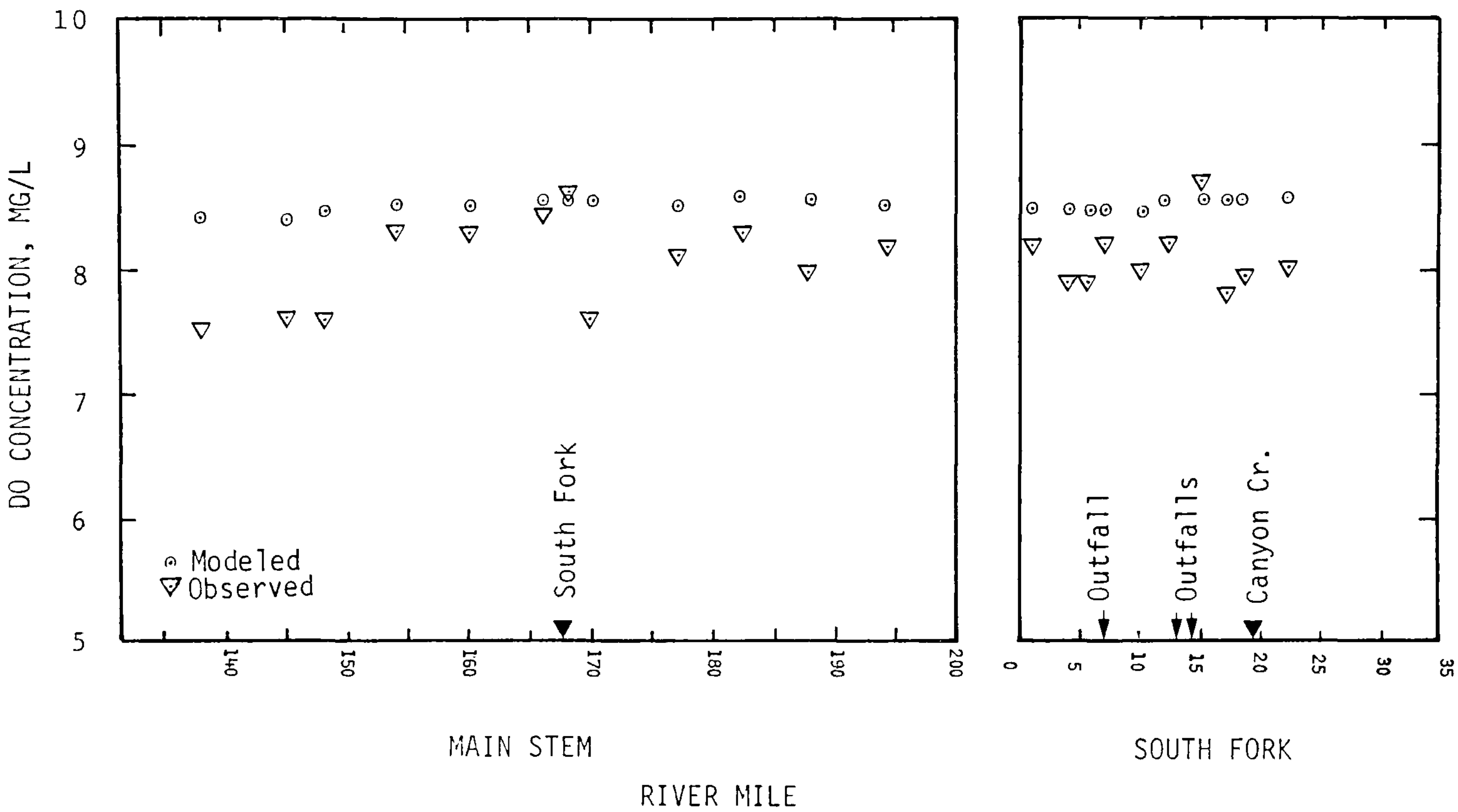


FIGURE 3. DOSAG VERIFICATION FOR DO ON RIVER REGION 2, AUGUST 1969

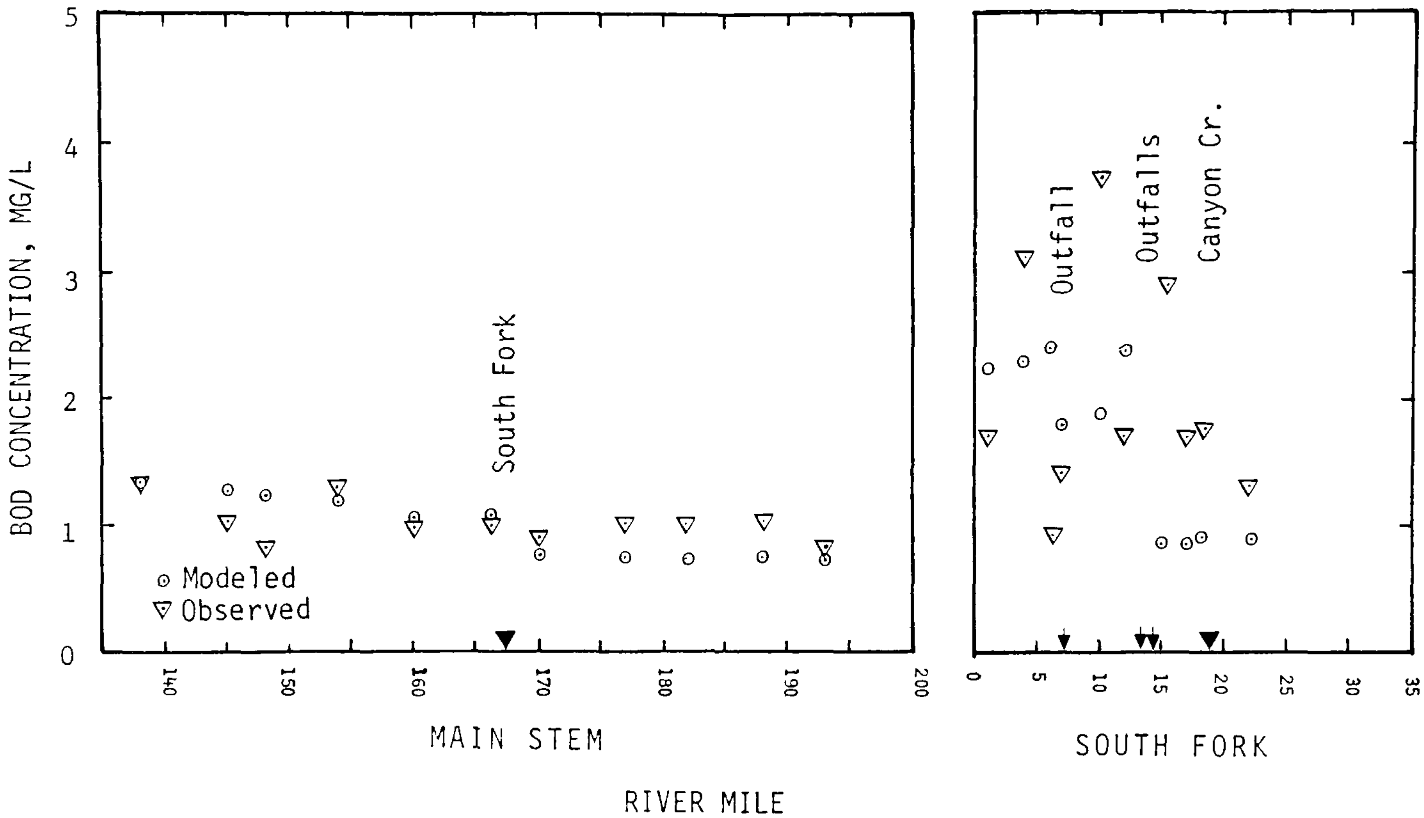


FIGURE 4. DOSAG VERIFICATION FOR BOD ON RIVER REGION 2, AUGUST 1969

For the September simulation, DO concentrations were set at approximately 9.5 mg/L throughout the system and BOD concentrations were set at approximately 1.5 mg/L. The BOD concentration in the sewers was set at 75 mg/L. The temperature for September was input at 17 degrees. The resulting values match the observed values very well (see Table 4 and Figures 5 and 6) with the exception of DO in the upper reaches of the South Fork. This descrepancy is probably due to the fact that the temperature of these upper reaches was less than 17 degrees; and, thus, the DO concentration level there was greater than 9 mg/L.

River Region 3: Upper Spokane (DOSAG)

Sparse DO and temperature data are available for both August and September 1969 for this region. Small diversions from the river occur at two locations, and there is considerable groundwater flow into the system throughout the region.

For August the region temperature was set at 21.1 degrees and the DO level in the main inflow (below Post Falls Dam) was set at 85% of saturation. DO in the groundwater inflow was set at 7 mg/L. The resulting DO concentration (see Table 5) agrees with the observed values in the upper part of the Spokane River, but is too high in the downstream part. This is perhaps caused by the large groundwater inflow which may have a DO concentration less than the 7 mg/L which was used. Reactions which consume DO, such as BOD decay, are also taking place, although no observed data is available. Also, the value of the reaeration coefficient, which is calculated as a function of depth and velocity, may not be suitable for this area of the region.

For September the region temperature was set at 17 degrees and the DO level in the main inflow was set at 90% of saturation. The DO level in the groundwater was left at 7 mg/L. Results similar to the August results were obtained (see Table 6).

River Region 4: Little Spokane (DOSAG)

Observed DO, BOD, and temperature data are available for July 11 - August 10, 1968 for this region. Observed DO and temperature data are available for August 11 - September 10, 1968. There is considerable groundwater flow into the region.

For the July 11 - August 10 run, the input temperature was 14.6 degrees. The DO level in the headwater inflow was set at 94% of saturation. The DO level of Deadman Creek (which has a flow approximately equal to that of the Little Spokane River above their junction) was set to 9 mg/L. The DO concentration of the groundwater (which triples the Little Spokane

TABLE 4

DOSAG VERIFICATION (PHASE II)

RIVER REGION 2 (COEUR D'ALENE)

SEPTEMBER 1969

		DO		BOD	
	RM	OBS	MOD	OBS	MOD
COEUR D'ALENE RIVER	138		8.78		1.38
	145	9.0	8.80	1.6	1.35
	148	9.5	8.83	1.6	1.29
	154	9.3	8.88	1.4	1.21
	160	8.9	8.91	1.2	1.07
	166	9.2	8.91	1.2	1.15
	168		8.94		0.914
	170	8.8	8.94	0.6	0.921
	177	8.8	8.94	0.5	0.762
	182	9.3	8.93	1.7	0.741
	188	8.9	8.94	1.0	0.759
	194	9.1	8.89	1.0	0.743
S. FORK	1	8.6	8.92	1.1	1.88
	4	8.7	8.94	1.6	1.91
	6	9.3	8.97	1.3	1.95
	7	10.2	8.99	1.8	1.71
	10	7.9	8.99	1.9	1.73
	12	10.3	8.94	1.7	1.92
	15	10.2	8.96	1.5	1.25
	17	10.0	8.96	1.7	1.25
	18	9.8	8.97	1.4	1.26
	22	9.5	8.95	1.3	1.38

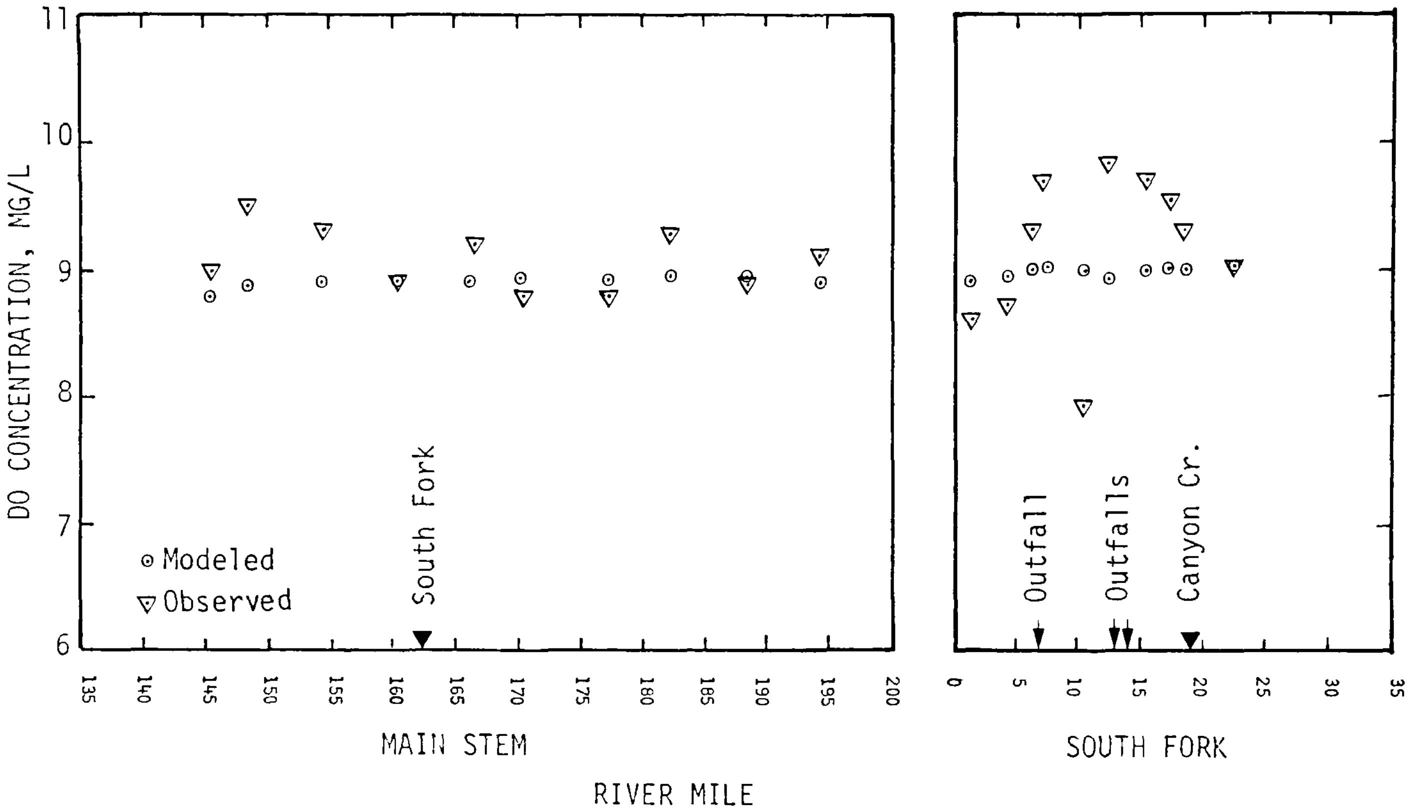


FIGURE 5. DOSAG VERIFICATION FOR DO ON RIVER REGION 2, SEPTEMBER 1969

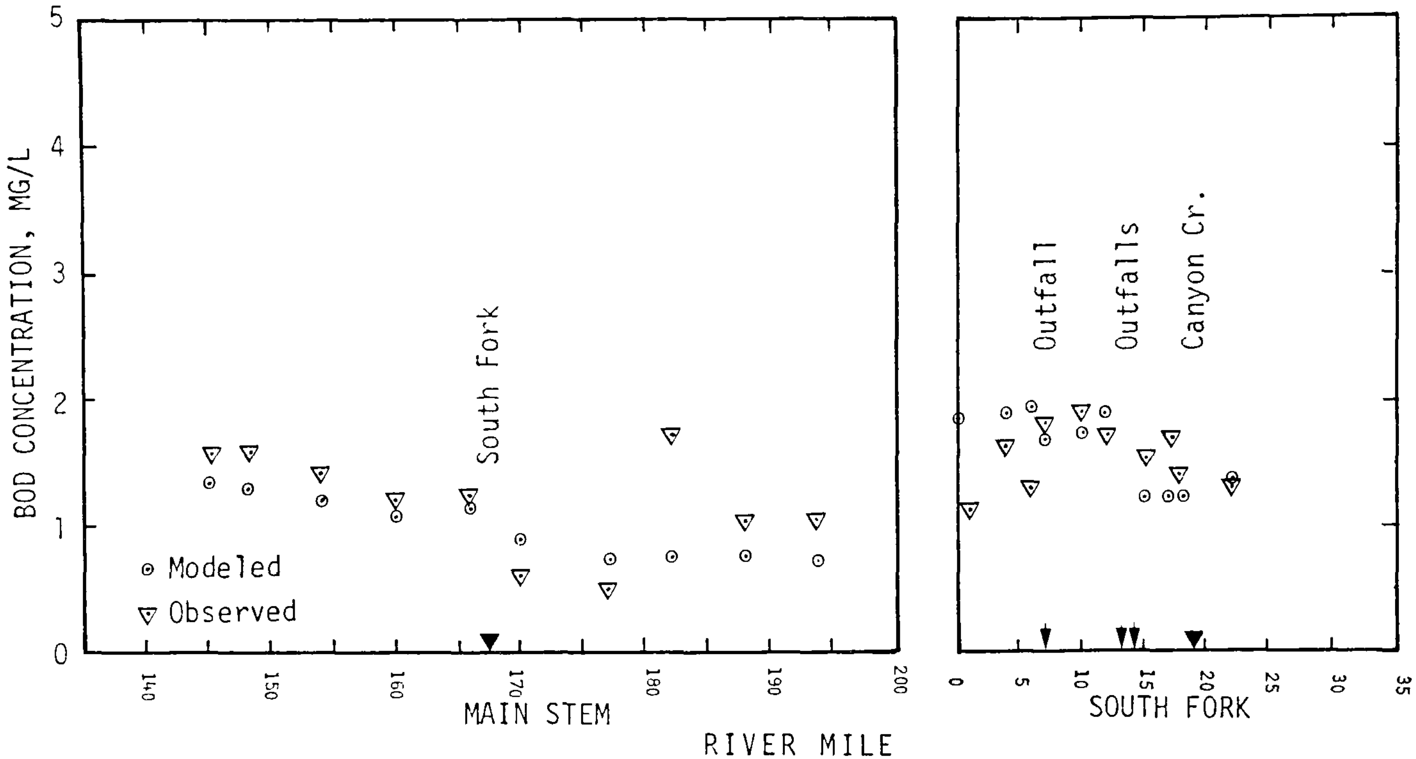


FIGURE 6. DOSAG VERIFICATION FOR BOD ON RIVER REGION 2, SEPTEMBER 1969

TABLE 5

DOSAG VERIFICATION (PHASE II)

RIVER REGION 3 (UPPER SPOKANE)

AUGUST 1969

	RM	DO OBS	DO MOD
SPOKANE RIVER	110.7		7.18
	106.6		7.68
	102.1		8.00
	101.8	8.2	8.03
	98.7	8.1	8.13
	96.4		8.19
	93.9	8.0	8.22
	88.7		8.11
	84.8		8.04
	80.2		8.04
	77.9		8.03
	76.2		8.02
	74.2		8.01
	72.9		8.02
	72.4		7.93
	64.2		7.97
	58.1		8.02
	56.7	7.4	8.04
HANGMAN CR.	39.0		7.17
	32.9		8.33
	20.2		8.36
	14.5		8.36
	0.8		8.36

TABLE 6

DOSAG VERIFICATION (PHASE II)

RIVER REGION 3 (UPPER SPOKANE)

SEPTEMBER 1969

	RM	DO OBS	DO MOD
SPOKANE RIVER	110.7		8.22
	106.6		8.49
	102.1		8.71
	101.8	8.8	8.73
	98.7	8.8	8.81
	96.4		8.87
	93.9		8.90
	88.7		8.86
	84.8		8.78
	80.2		8.77
	77.9		8.76
	76.2		8.73
	74.2		8.73
	72.9		8.72
	72.4		8.62
	64.2		8.64
	58.1		8.70
	56.7	7.7	8.71
HANGMAN CR.	39.0		8.43
	32.9		9.07
	20.2		9.09
	14.5		9.09
	0.8		9.09

flow between RM11 and RM4) was set at 7 mg/L. The headwater BOD level was set at 0.8 mg/L. All other BOD concentrations were set at 0.6 mg/L. As can be seen from Table 7, the DO concentration is driven toward saturation by reaeration and diluted toward 7 mg/L by the groundwater flow. The BOD values agree fairly well with the observed values.

For the August 11 - September 10 run, the input temperature was 14.1 degrees, all BOD concentrations were zero, and the DO level of Deadman Creek was set at 9.5 mg/L. Groundwater DO remained at 7 mg/L. A DO profile similar to the July 11 - August 10 run was obtained (see Table 8).

River Region 5: Lower Spokane (DOSAG)

Only one observed value of DO is available for this region during each of the months of August and September, 1971. No BOD data are available.

For August, the input temperature was set at 20.1 degrees and the DO level of the inflow was set at 54% of saturation. Simulation results are presented in Table 9.

For September, the input temperature was set at 17.1 degrees and the DO level of the inflow was set at 54% of saturation. Simulation results are presented in Table 10.

SWMM (RECEIV) VERIFICATION

Tables, figures and brief discussions of the verification simulation results follow under separate sections for each River Region as defined in Figure 2.

River Region 1: St. Joe - St. Maries (RECEIV)

The only observed data available for this region during July 16 - August 15, 1971 consist of coliform data and temperature data. Since RECEIV simulates neither of these quantities (see Section II), the region was not modeled for this period.

For the August 16 - September 16, 1971 period, DO data and temperature data are available, and for this period the DO-BOD constituent was simulated, with all BOD levels set to zero. The reaeration coefficient K_2 was set to keep DO levels near saturation and DO saturation was set at 10 mg/L. The initial concentrations of the various junctions were set at values close to the observed data, and DO concentrations of junction inflows were set accordingly. Simulation results are presented in Table 11.

TABLE 7

DOSAG VERIFICATION (PHASE II)

RIVER REGION 4 (LITTLE SPOKANE)

JULY 11 - AUGUST 10, 1968

	DO		BOD	
RM	OBS	MOD	OBS	MOD
37.6		9.14		0.80
34.6		9.49		0.79
32.9	9.7	9.51	0.6	0.78
31.0	10.4	9.51	0.7	0.77
21.3		9.51		0.73
13.5	9.9	9.51	0.9	0.70
13.1		9.23		0.64
11.4	9.4	9.40	0.6	0.63
10.8	8.8	8.30	0.6	0.61
7.9	8.6	8.53	0.6	0.61
3.9	8.7	9.24	0.7	0.60
0.1	9.8	9.42	0.4	0.59

TABLE 8

DOSAG VERIFICATION (PHASE II)

RIVER REGION 4 (LITTLE SPOKANE)

AUGUST 11 - SEPTEMBER 10, 1968

	DO	
RM	OBS	MOD
37.6		9.14
34.6		9.54
32.9	9.8	9.59
31.0	10.6	9.62
21.3		9.62
13.5	9.4	9.62
13.1		9.55
11.4	9.6	9.58
10.8	9.8	8.41
7.9	8.2	8.49
3.9	8.6	9.16
0.1	8.6	9.40

TABLE 9

DOSAG VERIFICATION (PHASE II)

RIVER REGION 5 (LOWER SPOKANE)

AUGUST 1971

	DO	
RM	OBS	MOD
33.9	4.6	4.61
31.8		4.79
28.2		4.98
24.0		5.36

TABLE 10

DOSAG VERIFICATION (PHASE II)

RIVER REGION 5 (LOWER SPOKANE)

SEPTEMBER 1971

	DO	
RM	OBS	MOD
33.9	4.8	4.99
31.8		5.16
28.2		5.32
24.0		5.64

TABLE 11

RECEIV VERIFICATION (PHASE II)

RIVER REGION 1 (ST. JOE - ST. MARIES)

AUGUST 16 - SEPTEMBER 16, 1971

		DO	
	RM	OBS	MOD
ST. JOE	42.9	9.5	9.58
	33.5	9.2	9.70
	31.1	9.7	9.70
	24.5		9.77
	15.7		9.84
	15.4	9.0	9.84
	15.0	9.6	9.84
	10.0	9.4	9.86
	0.7	9.4	9.87
ST. MAR	27.8	10.0	10.0
	14.8		10.0
	12.0	9.5	9.95
	10.0		9.95
	3.9		9.94

River Region 2: Coeur d'Alene (RECEIV)

Extensive observed data for DO, BOD, zinc and temperature are available for this region for both August and September, 1969.

Initial conditions similar to those used by DOSAG (see DOSAG VERIFICATION) with regard to DO and BOD were input and the saturation value of DO was set at 8.3 mg/L for the August simulation. In addition, zinc levels of approximately 2 mg/L were input for Canyon Creek and the zinc concentration of the inflow in Junction 11 (representing the discharge of a zinc processing plant) was set at 125 mg/L. Good agreement with the observed data was obtained (see Table 12 and Figures 7 through 9).

For September, the DO saturation level was set at 9.3 mg/L, the zinc plant inflow concentration for zinc was set at 250 mg/L, and the sewage BOD levels were reduced (as with DOSAG). Good agreement with the observed data was again obtained (see Table 13 and Figures 10 through 12).

River Region 3: Upper Spokane (RECEIV)

Sparce observed DO, zinc, and temperature data are available for August and September, 1969, for this region. Small diversions from the river occur at two locations and there is considerable groundwater flow into the system throughout the region.

For August, the DO saturation level was set at 8.2 mg/L and the DO level of the groundwater inflow was set at 7.0 mg/L. The zinc level was set at 0.15 mg/L in the main inflow (below Post Falls Dam). The results agree with the observed data reasonably well (see Table 14), except for DO in the lower reaches of the Spokane River where the simulated value is higher than the observed data. This may be due to unmodeled DO consumption, such as BOD decay, or the input reaeration coefficient may not be realistic for this area of the region.

For September, the DO saturation level was set at 9.0 mg/L and the zinc level in the main inflow was set at 0.19 mg/L. The DO concentration of the groundwater was left at 7.0 mg/L. Results similar to the August results were obtained (see Table 15).

River Region 4: Little Spokane (RECEIV)

Observed DO, BOD, and temperature data are available for July 11 - August 10, 1968, for this region. Observed DO and temperature data are available for August 11 - September 10, 1968. There is considerable groundwater flow into the region.

For the July 11 - August 10 run, the DO saturation level was set at 9.8 mg/L. The DO level in the headwater inflow and in Deadman Creek was set at 9.8 mg/L. The DO level in the groundwater inflow was set at 7.5 mg/L.

TABLE 12

RECEIV VERIFICATION (PHASE II)

RIVER REGION 2 (COEUR D'ALENE)

AUGUST 1969

		DO		BOD		ZINC	
	RM	OBS	MOD	OBS	MOD	OBS	MOD
COEUR D'ALENE RIVER	138	7.5	8.10	1.3	1.15	2.6	2.03
	145	7.6	8.11	1.0	1.30	1.8	1.96
	148	7.6	8.11	0.85	1.30	1.65	1.96
	154	8.3	8.13	1.3	1.45	4.7	1.91
	160	8.3	8.16	1.0	1.39	4.7	1.90
	166	8.5	8.23	1.0	1.16	1.9	1.89
	168	8.6	8.26		1.21	0	0
	170	7.6	8.28	0.9	0.81	0	0
	177	8.1	8.30	1.0	0.83	0	0
	182	8.3	8.30	1.0	0.85	0	0
	188	8.0	8.30	1.0	0.91	0	0
	194	8.2	8.30	0.8	0.93	0	0
S. FORK	1	8.2	8.26	1.7	1.21	5.1	1.88
	4	7.9	8.30	3.1	2.46	6.65	6.64
	6	7.9	8.30	0.9	2.54	0.5	0.59
	7	8.2	8.30	1.4	2.54	0.3	0.59
	10	8.0	8.27	3.7	2.69	0.3	0.66
	12	8.2	8.30	1.7	2.46	0.6	0.66
	15	8.7	8.26	2.9	3.04	0.65	1.01
	17	7.8	8.26	1.7	3.04	0.8	1.01
	18	7.9	8.30	1.75	1.41	1.0	1.05
	22	8.0	8.30	1.3	1.43	0	0

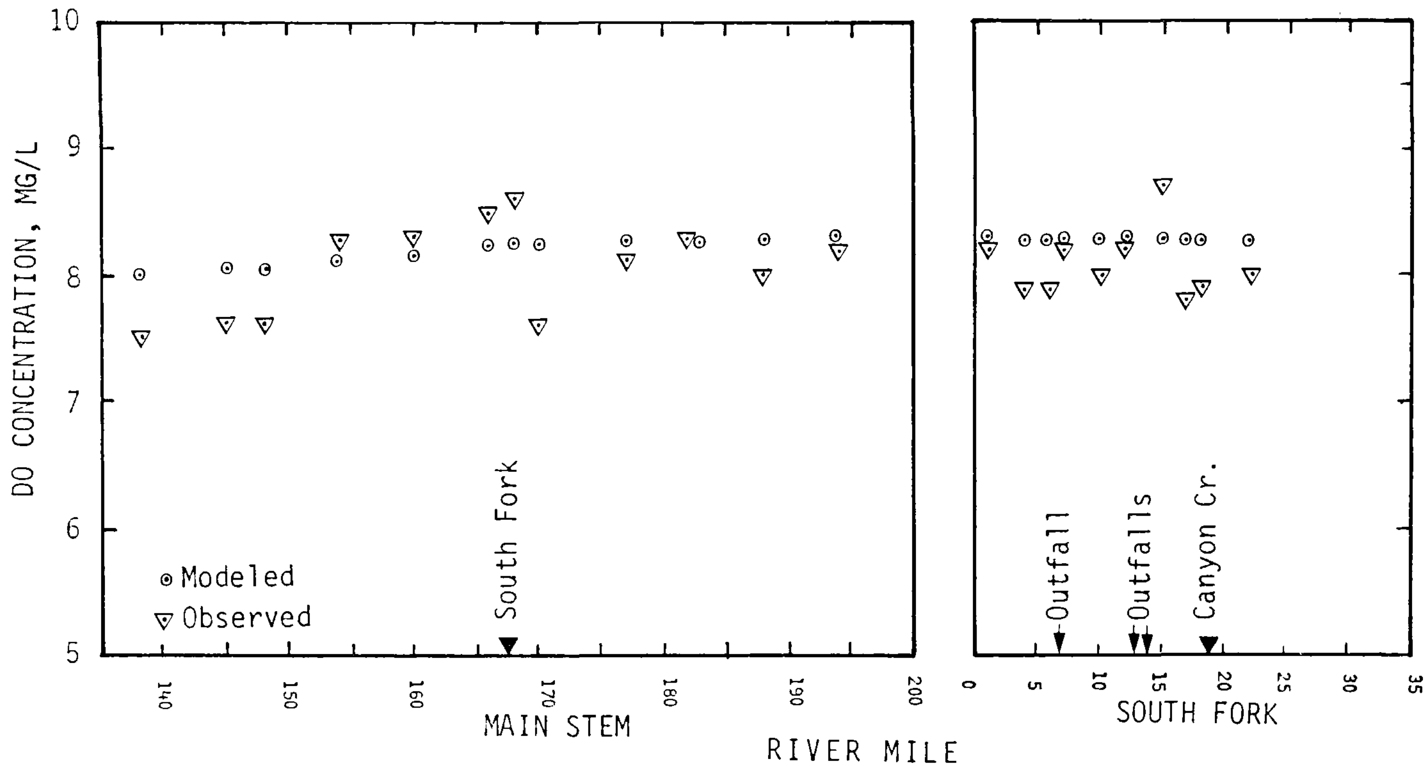


FIGURE 7. RECEIV VERIFICATION FOR DO ON RIVER REGION 2, AUGUST 1969

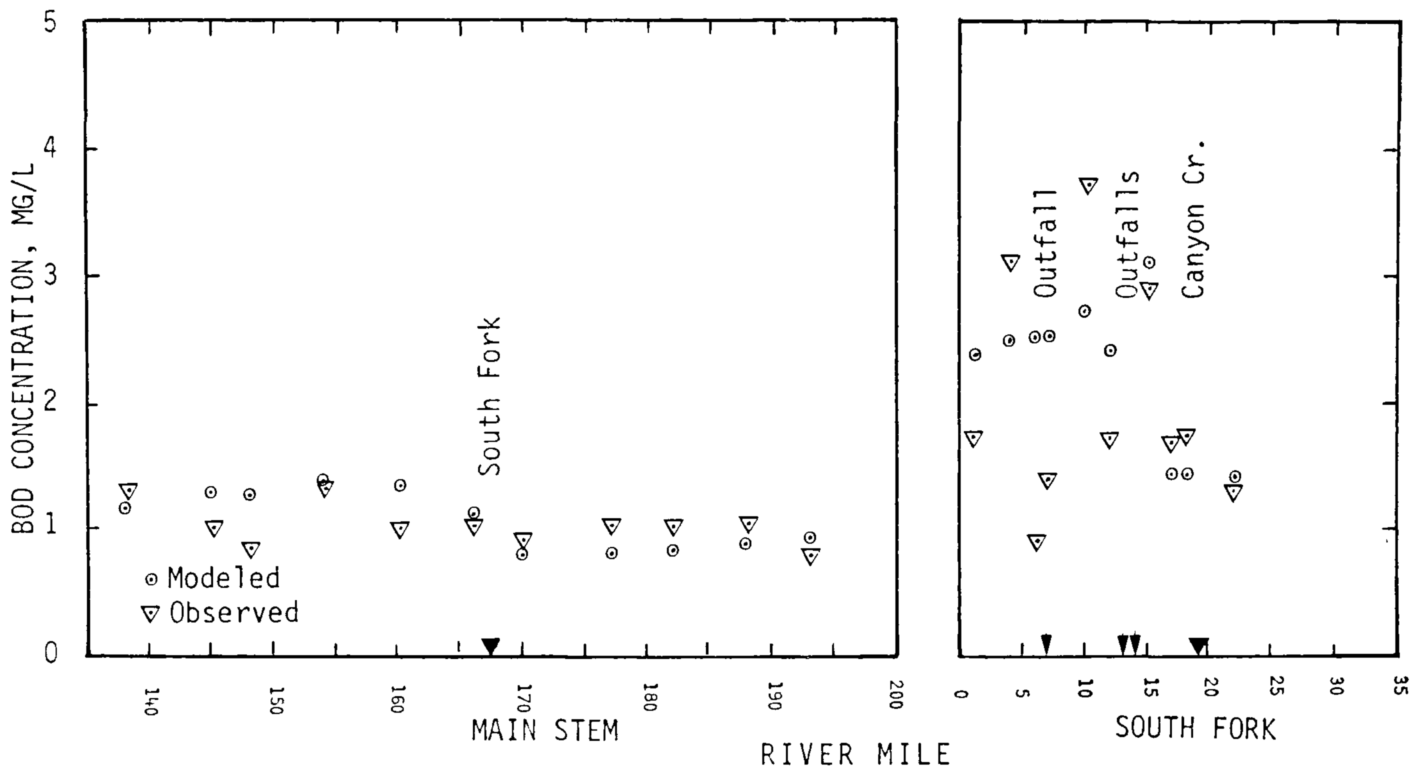


FIGURE 8. RECEIV VERIFICATION FOR BOD ON RIVER REGION 2, AUGUST 1969

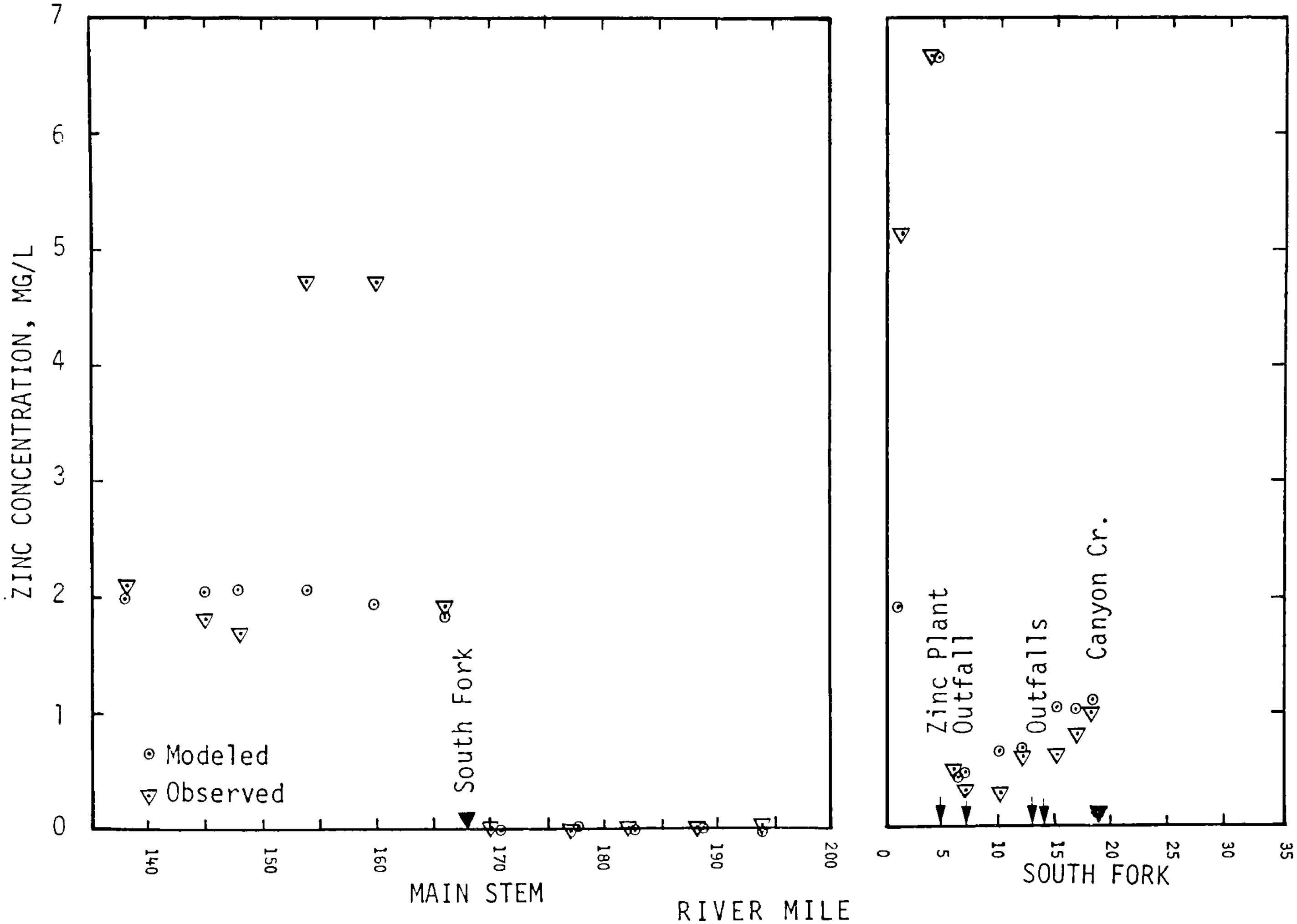


FIGURE 9. RECEIV VERIFICATION FOR ZINC ON RIVER REGION 2, AUGUST 1969

TABLE 13

RECEIV VERIFICATION (PHASE II)

RIVER REGION 2 (COEUR D'ALENE)

SEPTEMBER 1969

		DO		BOD		ZINC	
	RM	OBS	MOD	OBS	MOD	OBS	MOD
COEUR D'ALENE RIVER	138		9.01		1.57	2.6	4.06
	145	9.0	9.04	1.6	1.71	4.1	4.00
	148	9.5	9.04	1.6	1.71	3.1	4.00
	154	9.3	9.09	1.4	1.36	3.0	3.97
	160	8.9	9.12	1.2	1.31	6.0	3.97
	166	9.2	9.17	1.2	1.07	4.7	3.94
	168		9.19		0.99		3.94
	170	8.8	9.19	0.6	0.79	0	0
	177	8.8	9.20	0.5	0.82	0	0
	182	9.3	9.20	1.7	0.84	0	0
	188	8.9	9.23	1.0	0.90	0	0
	194	9.1	9.24	1.0	0.92	0	0
S. FORK	1	8.6	9.19	1.1	0.99	15.0	3.94
	4	8.7	9.26	1.6	1.65	14.0	14.50
	6	9.3	9.30	1.3	1.69	2.0	2.07
	7	10.2	9.30	1.8	1.69	2.0	2.07
	10	7.9	9.28	1.9	1.73	1.2	2.08
	12	10.3	9.30	1.7	1.63	1.5	2.08
	15	10.2	9.24	1.5	1.75	1.8	2.12
	17	10.0	9.24	1.7	1.75	2.8	2.12
	18	9.8	9.28	1.4	1.41	1.5	2.13
	22	9.5	9.30	1.3	1.42	0.1	0

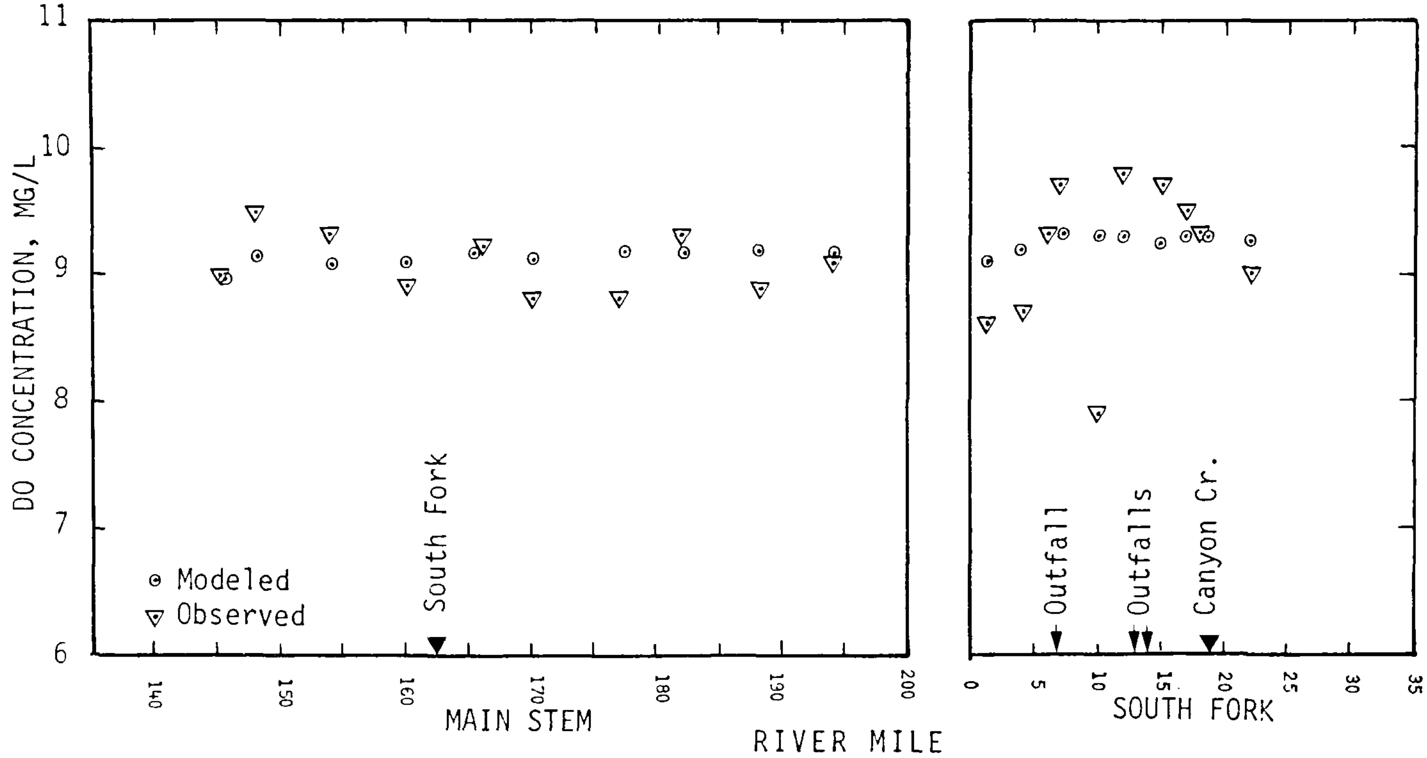


FIGURE 10. RECEIV VERIFICATION FOR DO ON RIVER REGION 2, SEPTEMBER 1969

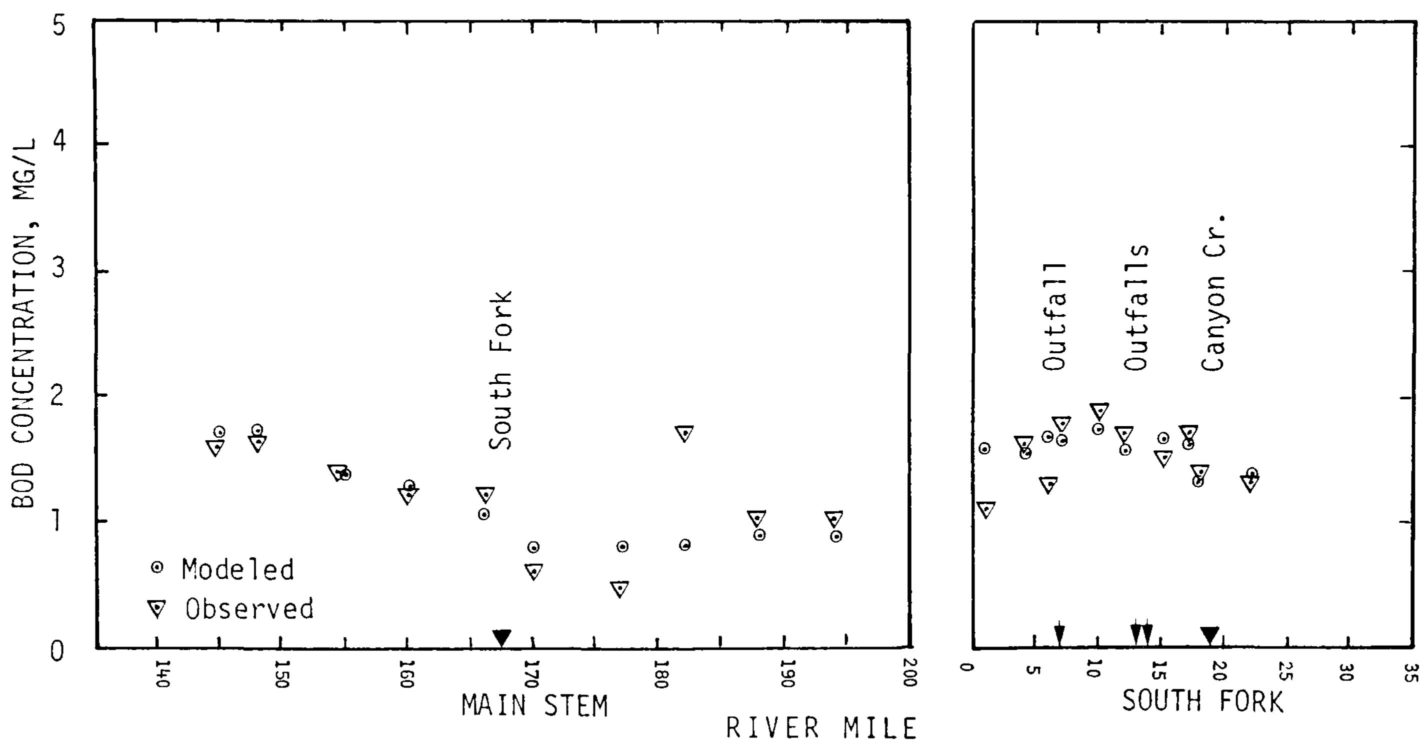


FIGURE 11. RECEIV VERIFICATION FOR BOD ON RIVER REGION 2, SEPTEMBER 1969

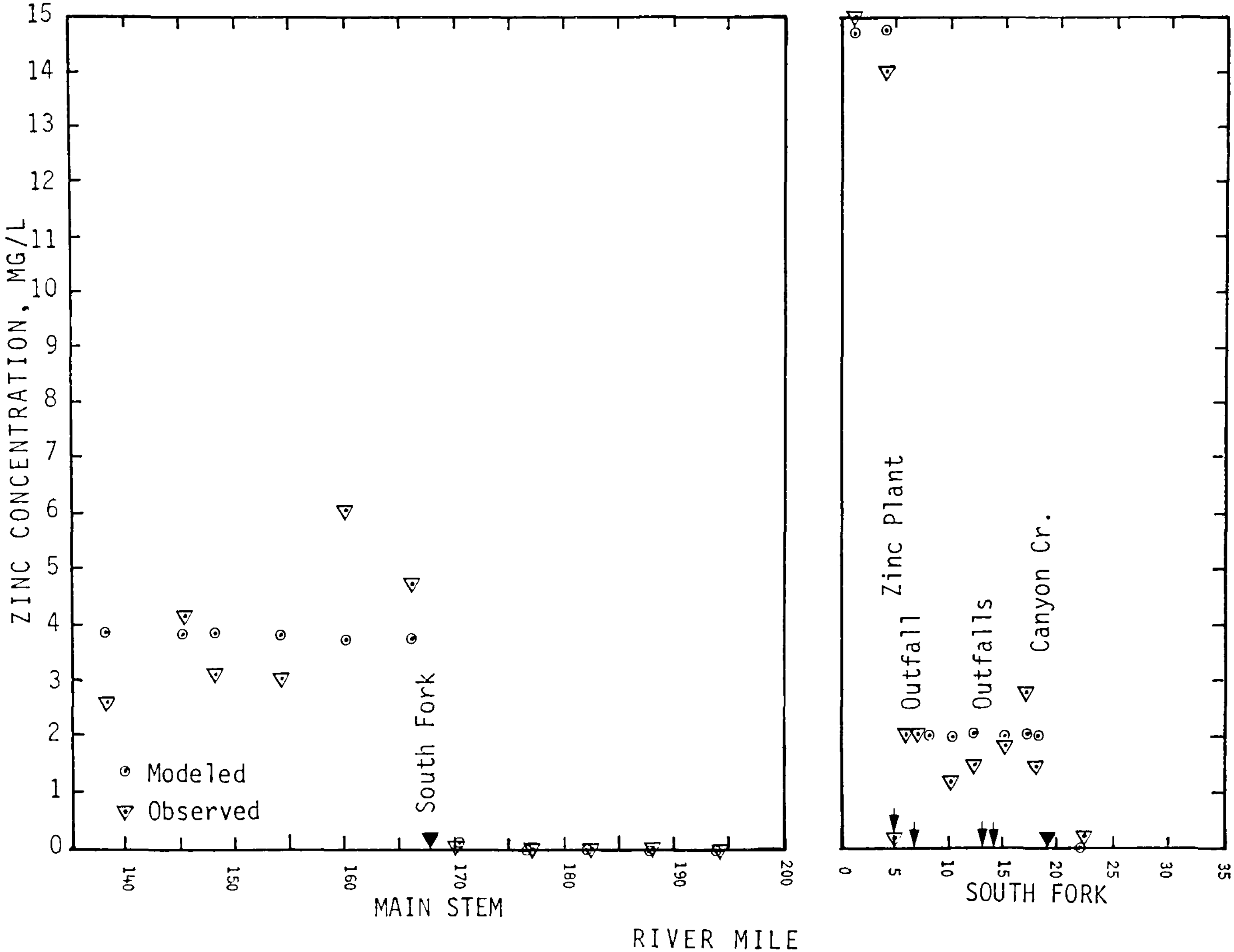


FIGURE 12. RECEIV VERIFICATION FOR ZINC ON RIVER REGION 2, SEPTEMBER 1969

TABLE 14

RECEIV VERIFICATION (PHASE II)

RIVER REGION 3 (UPPER SPOKANE)

AUGUST 1969

	RM	DO OBS	DO MOD	ZINC OBS	ZINC MOD
SPOKANE RIVER	110.7		8.2		0.150
	106.6		8.2		0.150
	102.1		8.2		0.150
	101.8	8.2	8.2	0.150	0.150
	98.7	8.1	8.2	0.145	0.150
	96.4		8.2		0.150
	93.9	8.0	8.2	0.200	0.150
	88.7		7.98		0.115
	84.8		7.99		0.111
	80.2		8.03		0.104
	77.9		8.03		0.104
	76.2		8.03		0.091
	74.2		7.96		0.091
	72.9		7.98		0.091
	72.4		7.98		0.091
	64.2		7.84		0.084
	58.1		7.96		0.083
	56.7	7.4	7.96	0.080	0.083
HANGMAN CR.	39.0		7.33		0
	32.9		7.58		0
	20.2		7.69		0
	14.5		7.78		0
	0.8		7.98		0

TABLE 15

RECEIV VERIFICATION (PHASE II)

RIVER REGION 3 (UPPER SPOKANE)

SEPTEMBER 1969

		DO		ZINC	
	RM	OBS	MOD	OBS	MOD
SPOKANE RIVER	110.7		8.87		0.190
	106.6		8.87		0.190
	102.1		8.93		0.190
	101.8	8.8	8.93	0.190	0.190
	98.7	8.8	8.94	0.190	0.190
	96.4		8.95		0.190
	93.9		8.95		0.190
	88.7		8.71		0.159
	84.8		8.73		0.158
	80.2		8.80		0.154
	77.9		8.80		0.154
	76.2		8.80		0.146
	74.2		8.77		0.146
	72.9		8.79		0.145
	72.4		8.79		0.145
	64.2		8.63		0.137
	58.1		8.63		0.137
	56.7	7.7	8.74	0.140	0.137
HANGMAN CR.	39.0		7.53		0
	32.9		7.96		0
	20.2		8.14		0
	14.5		8.30		0
	0.8		8.42		0

Input BOD concentrations were approximately 0.7 mg/L except for the groundwater BOD which was input as 0.55 mg/L. As can be seen from Table 16, the DO level stays near saturation until the groundwater flow enters the river (between RM11 and RM4) and reduces it to approximately 8.2 mg/L. A better match to the observed data could probably be obtained by increasing the DO level in the groundwater or by increasing the reaeration coefficient.

For the August 11 - September 10 run, the DO saturation level was set at 9.5 mg/L. All BOD levels were set to zero. Other concentrations remained the same. A DO profile similar to the July 11 - August 10 run was obtained (see Table 17).

River Region 5: Lower Spokane (RECEIV)

For each of the months of August and September, 1971, one observed value of DO and one observed value of zinc are all that is available.

For September, the DO saturation level was set at 7.5 mg/L and the DO concentration of the inflow was set at 4.6 mg/L. All zinc concentrations were set at .04 mg/L. Simulation results are reported in Table 18.

Because of the great similarity of the August and September data, an August run was not made.

TABLE 16

RECEIV VERIFICATION (PHASE II)

RIVER REGION 4 (LITTLE SPOKANE)

JULY 11 - AUGUST 10, 1968

	DO		BOD	
RM	OBS	MOD	OBS	MOD
37.6		9.8		0.69
34.6		9.8		0.67
32.9	9.7	9.8	0.6	0.67
31.0	10.4	9.8	0.7	0.65
21.3		9.7		0.60
13.5	9.9	9.8	0.9	0.73
13.1		9.8		0.73
11.4	9.4	8.3	0.6	0.60
10.8	8.8	8.3	0.6	0.60
7.9	8.6	8.1	0.6	0.58
3.9	8.7	8.2	0.7	0.58
0.1	9.8	8.3	0.4	0.56

TABLE 17

RECEIV VERIFICATION (PHASE II)

RIVER REGION 4 (LITTLE SPOKANE)

AUGUST 11 - SEPTEMBER 10, 1968

	DO	
RM	OBS	MOD
37.6		9.5
34.6		9.5
32.9	9.8	9.5
31.0	10.6	9.5
21.3		9.5
13.5	9.4	9.4
13.1		9.4
11.4	9.6	8.3
10.8	9.8	8.3
7.9	8.2	8.1
3.9	8.6	8.2
0.1	8.6	8.3

TABLE 18

RECEIV VERIFICATION (PHASE II)

RIVER REGION 5 (LOWER SPOKANE)

SEPTEMBER 1971

	DO		ZINC	
RM	OBS	MOD	OBS	MOD
33.9	4.8	4.78	0.04	0.04
31.8		5.09		0.04
28.2		5.53		0.04
24.0		5.84		0.04

DRM VERIFICATION

This section presents brief discussions with tables and figures, where appropriate, of the verification simulation results obtained from applications of the Deep Reservoir Model to both Long Lake and Coeur d'Alene Lake (see Figures 1 and 2).

Long Lake (DRM)

Considerable temperature data are available for Long Lake for June - November, 1971. The lake inflow rates and inflow temperatures were estimated using measurements from USGS gaging stations 4225, 4260 and 4310. Outflow rates and outflow temperatures were determined from USGS gaging station 4330. Meteorologic data from the City of Spokane were used. The lake was modeled as an inverted trapezoid 22 miles long, 32 meters deep, and with the bottom width equal to .01 times the top width. This results in a full volume of 3.19×10^8 cubic meters and a maximum surface area of 1.98×10^7 square meters Based on available data, all of these values appear reasonable. The lake was assumed to be completely mixed at a temperature of 12 degrees on June 1.

The simulation indicated that Long Lake "turned over" during the first week of September, 1971. Simulation results are compared with observed data in Table 19 and Figures 13 through 20; the comparison in general is very good.

Coeur d'Alene Lake (DRM)

Surface temperature data are available on only four days during June - November, 1971 for Coeur d'Alene Lake. No outflow or inflow temperatures are available. The lake inflow rates were estimated using measurements from USGS gaging station 4135, 4145, and 4149. Outflow was determined from USGS gaging station 4190. Inflow temperatures were estimated from surface temperature data. Meteorologic data from the city of Spokane were used. The lake was modeled as being 22 miles long and 25 meters deep, with a full volume of 1.5×10^9 cubic meters and a maximum surface area of 1.77×10^8 square meters. The full volume value was roughly estimated from available data for the top ten feet only. The lake was assumed to be completely mixed at a temperature of 14 degrees on June 1.

The simulation indicates that Coeur d'Alene Lake "turned over" about September 15th. Simulation results are compared with the observed data in Table 20.

TABLE 19

DRM VERIFICATION (PHASE II)

LONG LAKE, 1971

Date	Depth(m)	Lake Temp. (°C) OBS	Lake Temp. (°C) MOD	Outflow Temp. (°C) OBS	Outflow Temp. (°C) MOD
June 1	0	12.0	12.2	12.9	12.0
June 13	0	13.7	14.1	14.1	13.5
June 22	0	17.1	18.9		16.0
July 8	0	14.8	16.3		16.0
July 11	0	15.8	16.1	16.4	16.0
July 25	0	20.2	21.2	19.4	18.8
July 27	1	23.6	21.7		19.2
	12	17.0	17.2		
	15	16.7	16.5		
	21	15.5	16.1		
August 1	0	21.0	22.6	20.2	19.9
August 10	1	25.8	22.6		20.5
	6	20.9	21.6		
	12	19.8	19.1		
	14	19.0	18.3		
	24	16.0	16.7		
August 15	0	19.5	21.0	20.0	20.3
August 18	1	23.4	20.0		19.9
	6	21.0	20.0		
	12	19.5	19.3		
	24	16.0	17.1		
August 23	1	21.4	19.2		19.2
	6	20.4	19.2		
	12	19.0	19.2		
	14	18.5	18.8		
	21	15.5	17.6		

(continued)

TABLE 19 (CONTINUED)

Date	Depth(m)	Lake Temp. (°C) OBS	Lake Temp. (°C) MOD	Outflow Temp. (°C) OBS	Outflow Temp. (°C) MOD
August 24	0	20.6	19.3		19.2
September 1	1	18.9	18.9		19.1
	6	18.8	18.9		
	12	19.3	18.9		
	14	18.0	18.8		
	15	19.5	18.7		
	21	17.2	18.1		
	30	16.5	17.9		
September 6	0	16.8	17.9	17.5	18.0
September 15	1	17.6	16.8		16.9
	6	17.3	16.8		
	12	16.8	16.8		
	15	17.0	16.8		
	21	16.5	16.8		
	30	16.0	16.8		
September 19	0	14.4	16.2	16.7	16.2
September 21	1	16.7	15.7		15.8
	12	13.5	15.8		
	14	17.0	15.8		
	15	15.4	15.8		
September 22	6	14.5	15.8		15.8
October 5	0	14.1	14.1		14.0
October 19	0	10.0	11.3		11.5
October 27	0	8.6	9.2		9.4
November 3	0	7.5	7.4		7.5

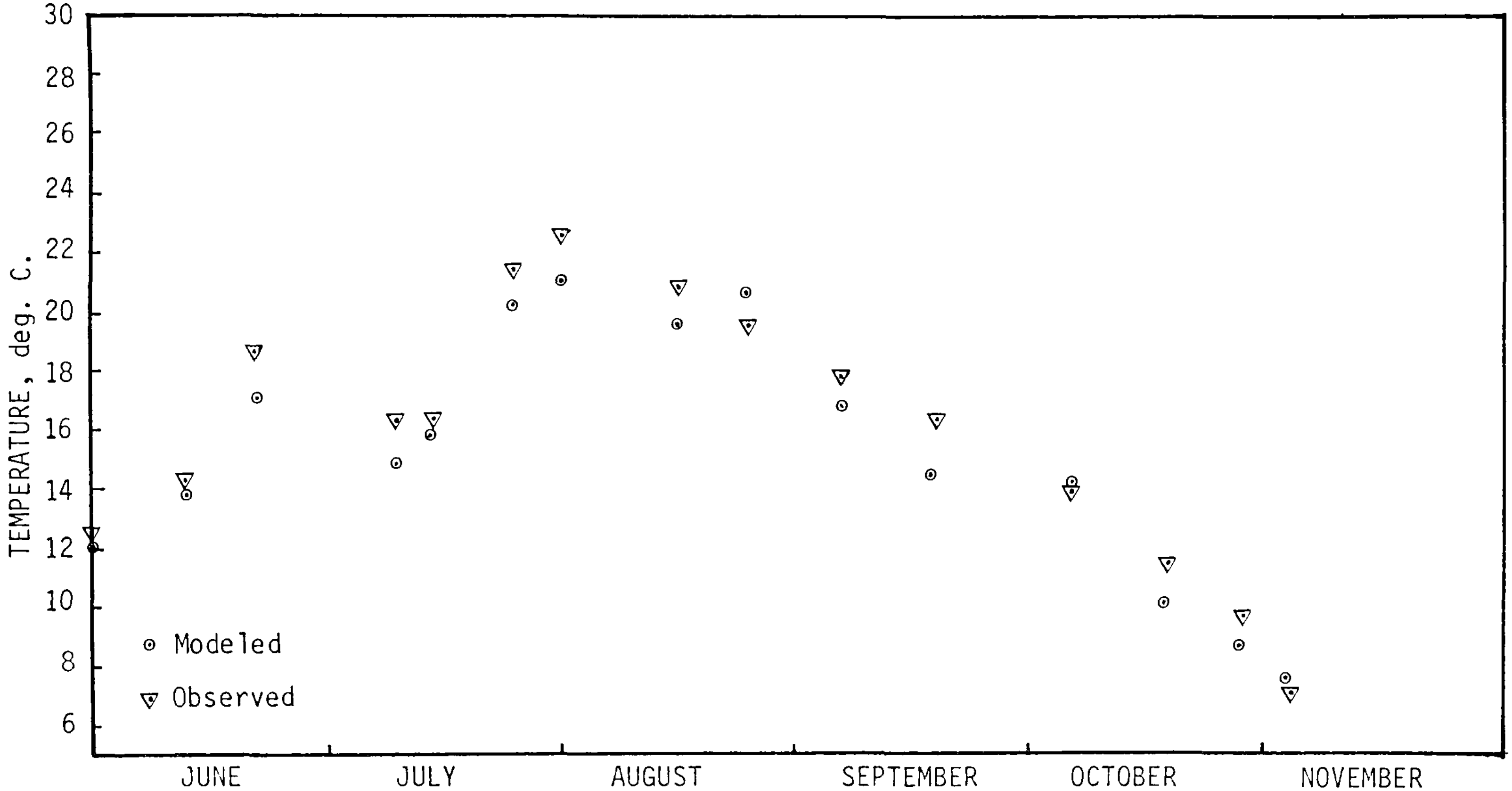


FIGURE 13. DRM VERIFICATION FOR TEMPERATURE IN LONG LAKE, 1971 (SURFACE)

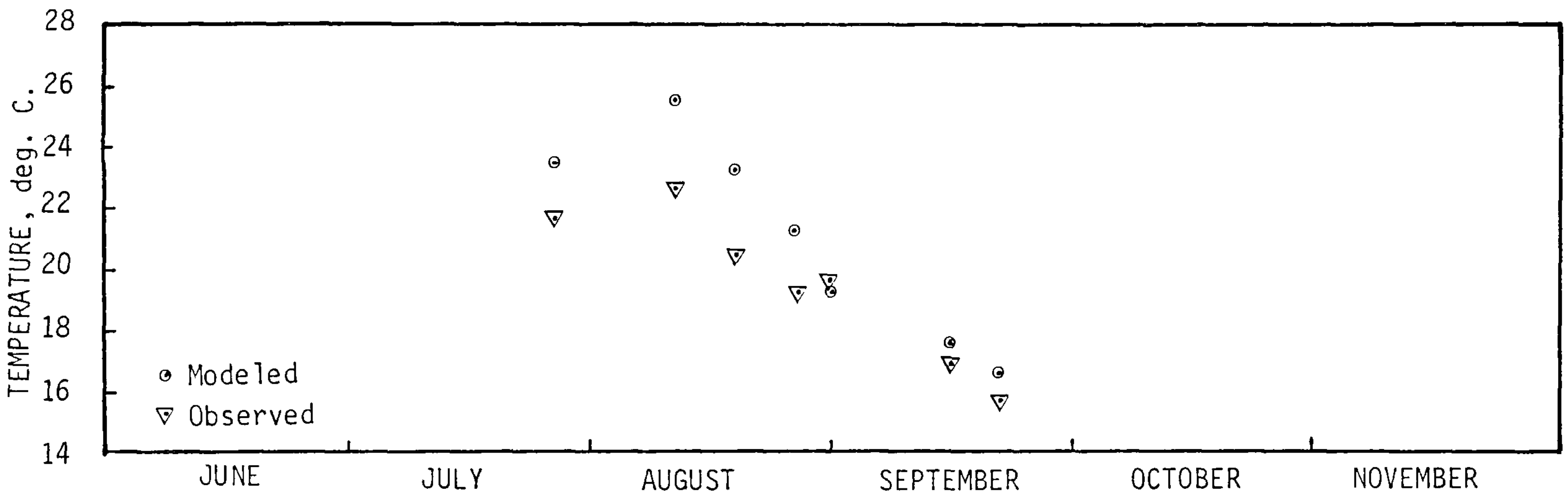


FIGURE 14. DRM VERIFICATION FOR TEMPERATURE IN LONG LAKE, 1971 (1 METER DEPTH)

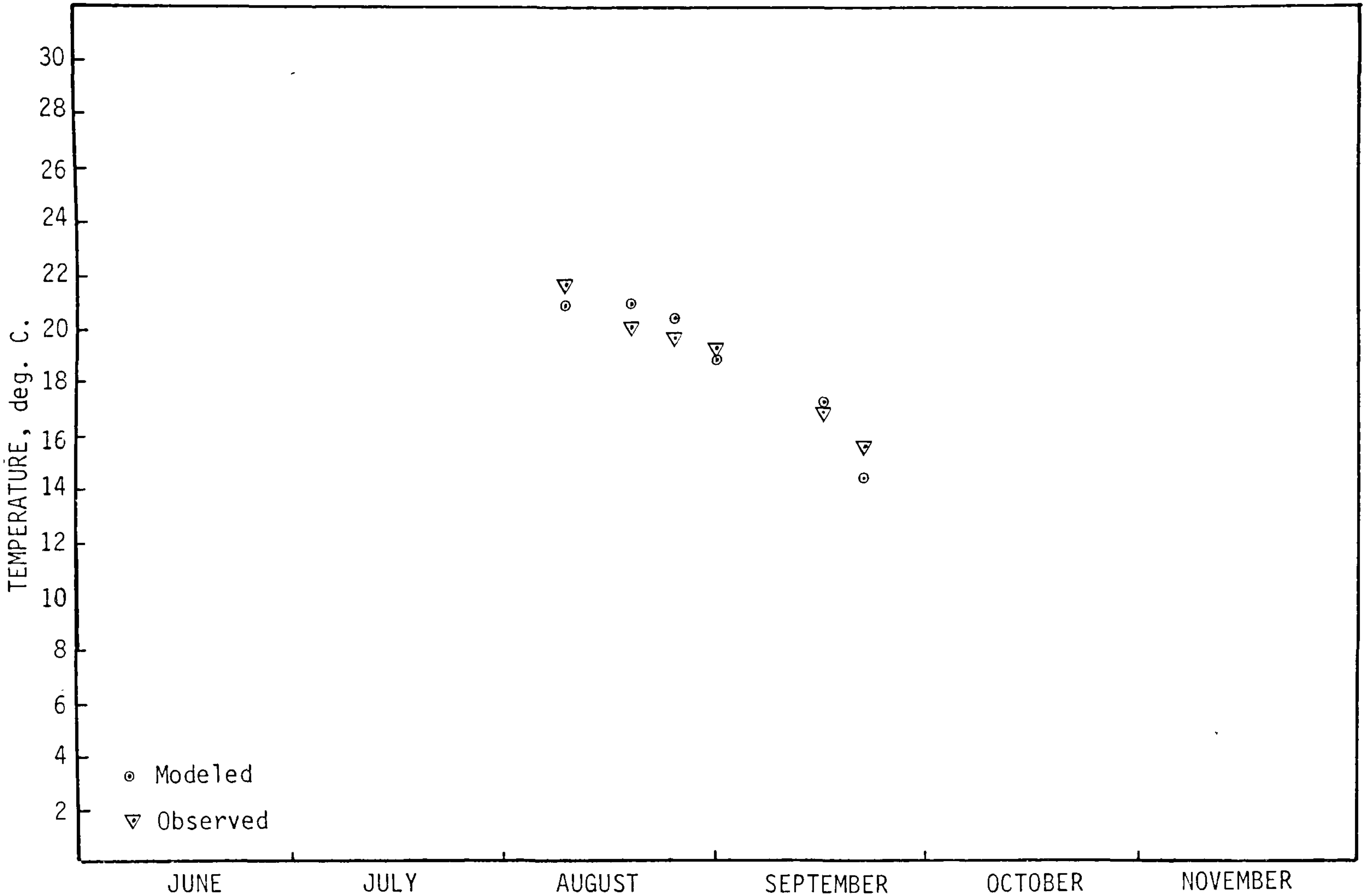


FIGURE 15. DRM VERIFICATION FOR TEMPERATURE IN LONG LAKE, 1971 (6 METER DEPTH)

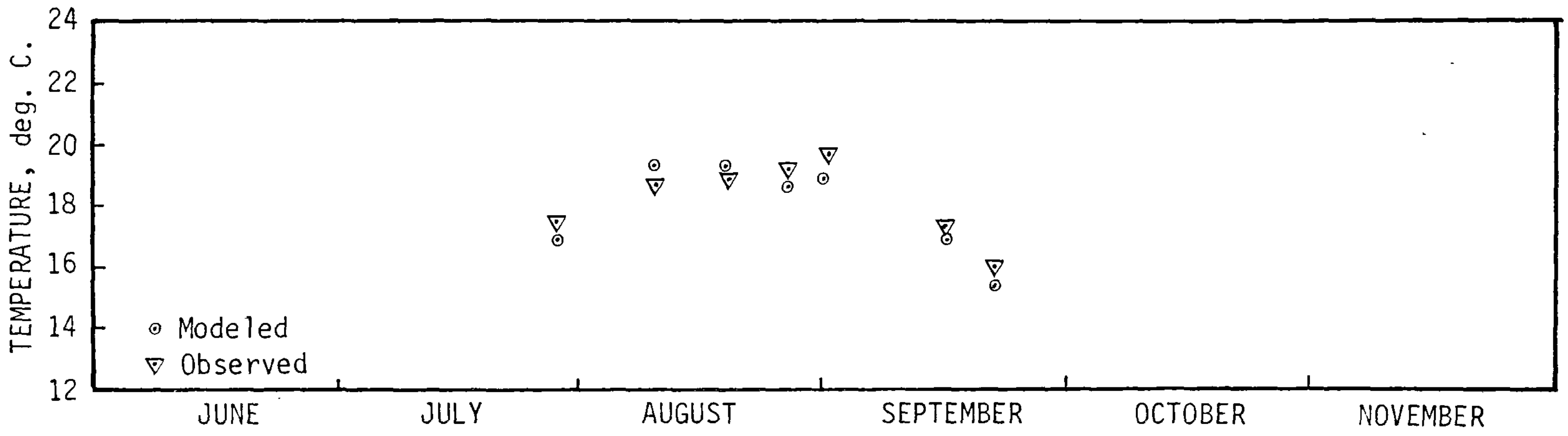


FIGURE 16. DRM VERIFICATION FOR TEMPERATURE IN LONG LAKE, 1971 (14 METERS DEPTH)

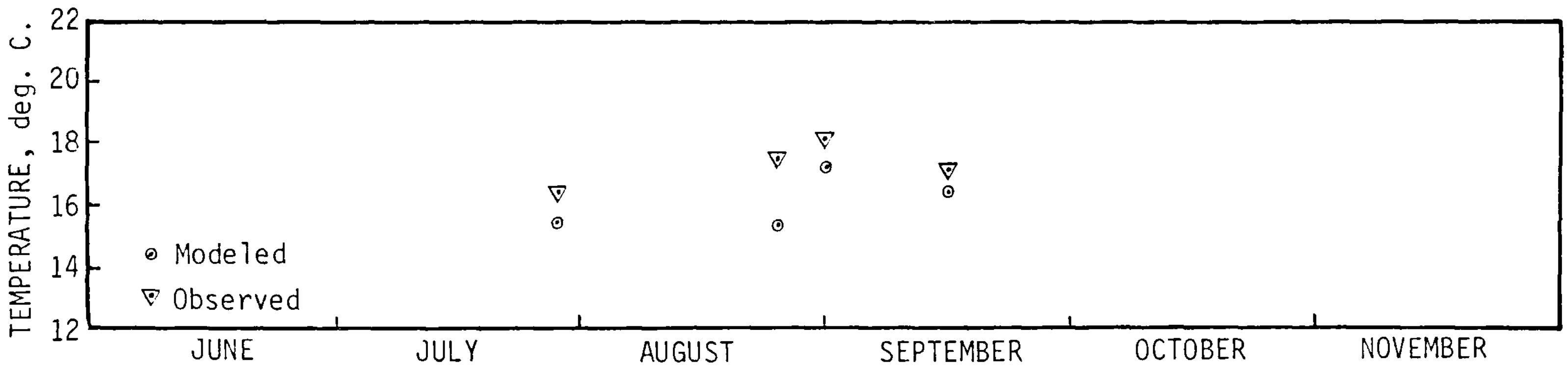


FIGURE 17. DRM VERIFICATION FOR TEMPERATURE IN LONG LAKE, 1971 (21 METERS DEPTH)

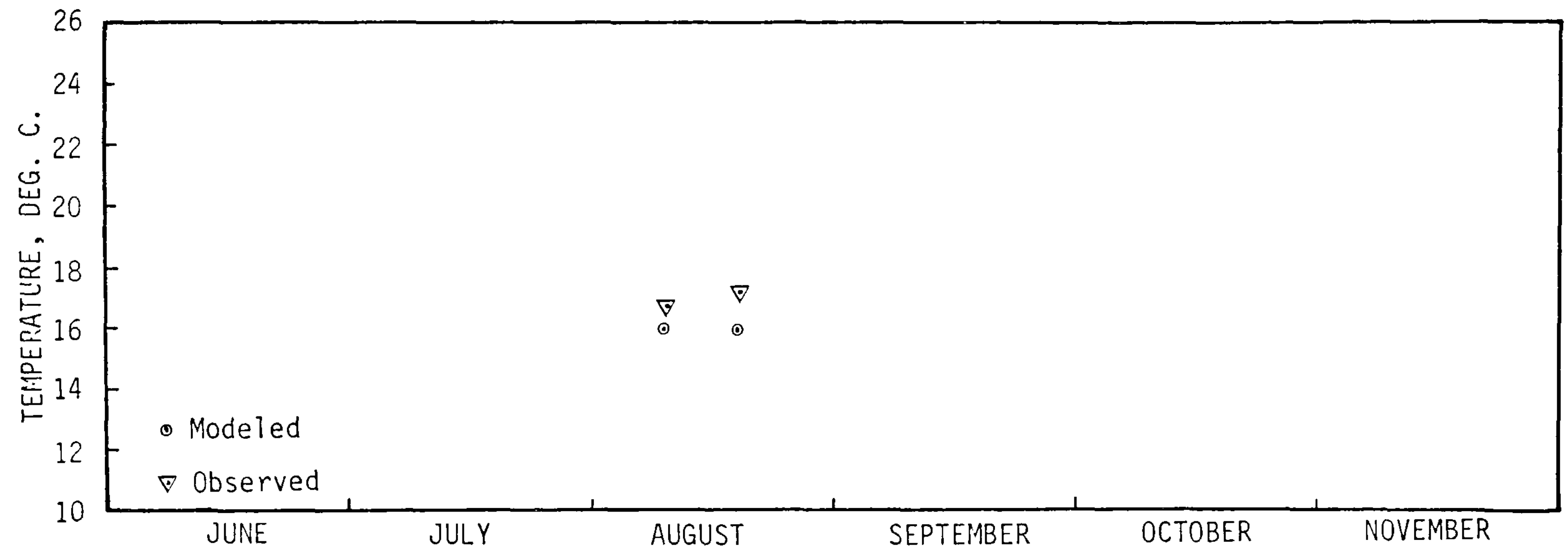


FIGURE 18. DRM VERIFICATION FOR TEMPERATURE IN LONG LAKE, 1971 (24 METERS DEPTH)

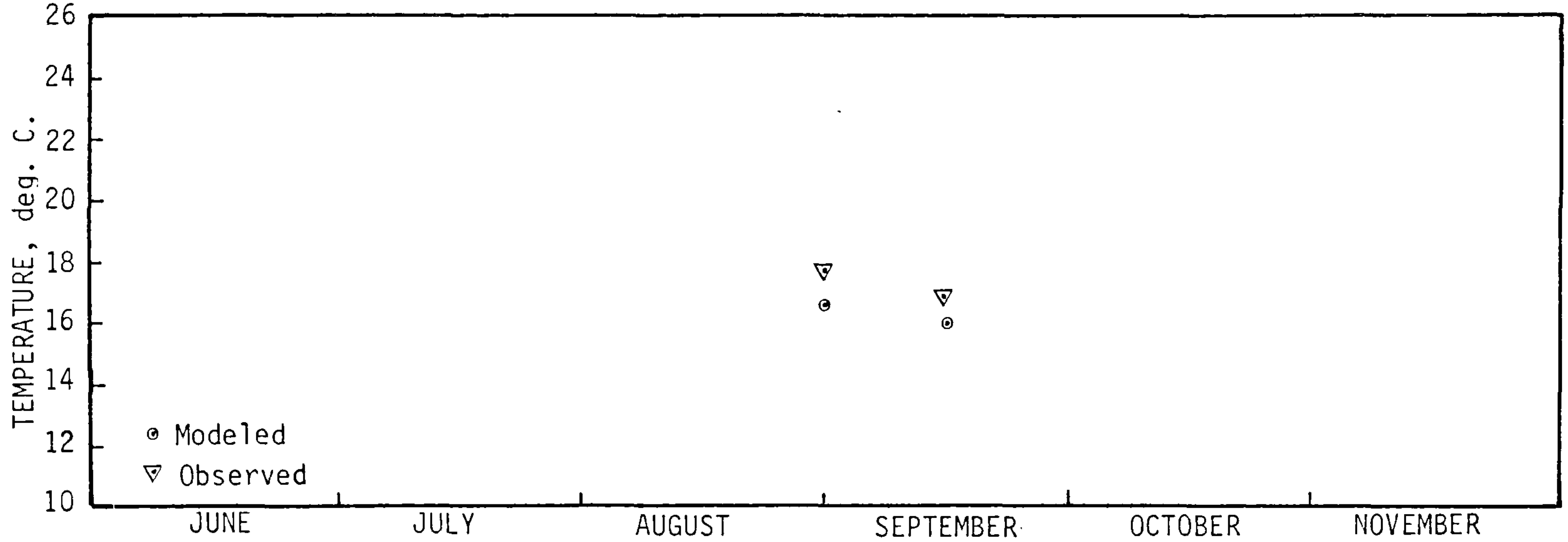


FIGURE 19. DRM VERIFICATION FOR TEMPERATURE IN LONG LAKE, 1971 (30 METERS DEPTH)

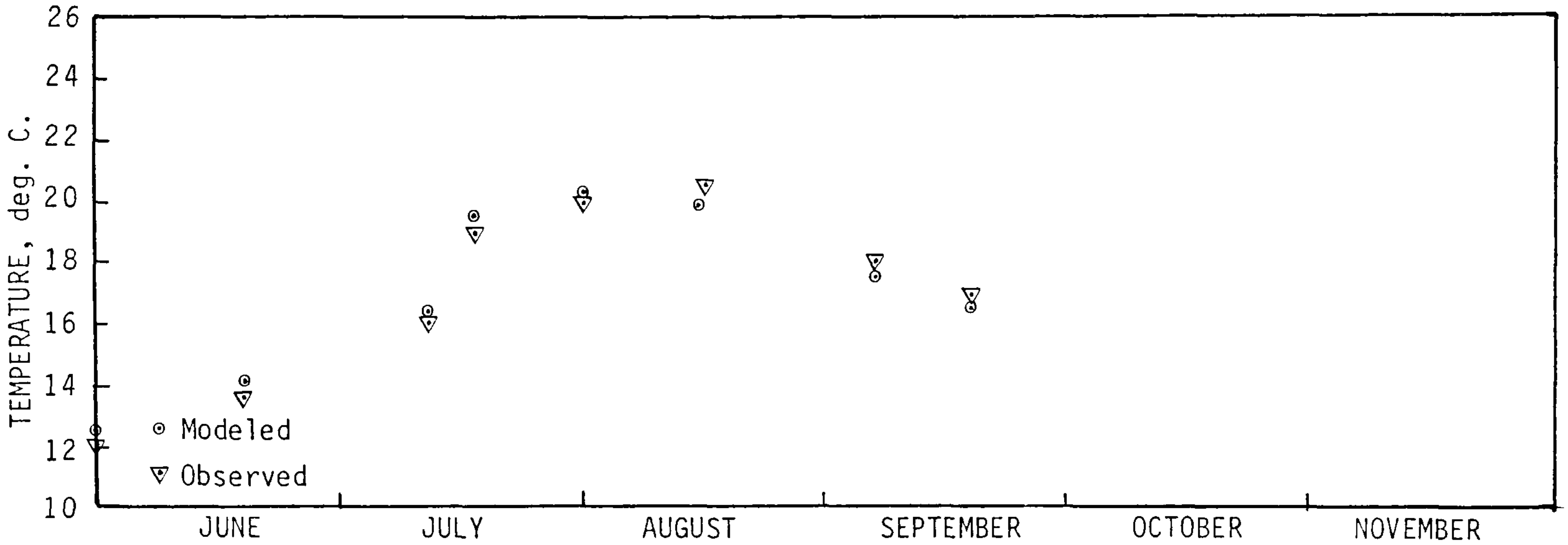


FIGURE 20. DRM VERIFICATION FOR TEMPERATURE IN LONG LAKE, 1971 (OUTFLOW)

TABLE 20

DRM VERIFICATION (PHASE II)

COEUR D'ALENE LAKE, 1971

Date	Depth (m)	Lake Temp. (°C) OBS	Lake Temp. (°C) MOD	Outflow Temp. (°C) OBS	Outflow Temp. (°C) MOD
June 16	0	16.0	15.6		15.1
July 14	0	19.0	20.1		17.8
August 20	0	24.0	19.7		20.1
August 27	0	21.8	20.6		19.9

SECTION IV

DELIVERABLES

The deliverables required from Phase II of this contract are a Verification Report (this document) and source and data decks for all the verified models.

The following three source decks (in level G FORTRAN IV language, executable on the IBM 370/155 system), and 20 data decks corresponding to the verification runs described in Section III are being separately supplied to the Project Officer.

Source Deck	Data Deck (for the indicated Source Deck) Region	Period
DOSAG	RR1	July - August 1971
	RR1	August - September 1971
	RR2	August 1969
	RR2	September 1969
	RR3	August 1969
	RR3	September 1969
	RR4	July - August 1968
	RR4	August - September 1968
	RR5	August 1971
	RR5	September 1971
RECEIV	RR1	August - September 1971
	RR2	August 1969
	RR2	September 1969
	RR3	August 1969
	RR3	September 1969
	RR4	July - August 1968
	RR4	August - September 1968
	RR5	September 1971
DRM	Long Lake	June - November 1971
	Coeur d'Alene Lake	June - November 1971

APPENDIX A

MODIFICATIONS TO DOSAG

APPENDIX A

MODIFICATIONS TO DOSAG

Class (ii): Desirable before use in Phase III

Modification D1.

Purpose:

To enable DOSAG to handle a region with no junctions (branching points) directly, i.e., without the need for dummy tributaries, etc.

Description:

When there are no junctions included, the section of the code which reads in the File D data is skipped.

Modification D2.

Purpose:

To facilitate use of program.

Description:

Default values were added for K_1 and for the exponents and coefficients of flow used to calculate depth and velocity.

Modification D3.

Purpose:

To facilitate use of program.

Description:

Only reaches with non-zero lateral inflow need to be input to file F-2.

Modification D4.

Purpose:

To facilitate interpretation of output results.

Description:

A plotting capability (subroutines PLTSET, PLOT) was added to plot constituent concentration versus reach.

APPENDIX B

MODIFICATIONS TO SWMM (RECEIV)

APPENDIX B

MODIFICATIONS TO SWMM (RECEIV)

Class (i): Necessary to execute Phase II model

Modification R1.

Purpose:

To enable RECEIV to simulate shallow, steep, non-tidal river reaches (particularly in River Region 2).

Description:

(a) For the non-tidal case, the check for a dry junction (negative depth) at the integration half step was removed.

(b) For the non-tidal case, the junction volumes written on disk for use by the quality portion of the program were made consistent with the channel volumes, i.e., if the channel volumes are known, the junction volumes are also known (neglecting overlap, which will be small for river applications).

Modification R2.

Purpose:

To correct quality errors in SWMM subroutine LOOPQL.

Description:

The error found by SCI in subroutine LOOPQL is the same error documented by Bob Shubinski of WRE in his letter of November 10, 1972 to Mr. Torno of EPA, and subsequently supplied to SCI, on February 27, 1973. SCI recommends changing only the statement labeled 288 in LOOPQL from

```
288  C(J,KC)=C(J,KC)+(MADD(J,KC)/VOL(J))*DELTQ
     to
288  C(J,KC)=(1.-QIN(J)*DELTQ/VOL(J))*C(J,KC)+(MADD(J,KC)/VOL(J))*DELTQ
```

This results, in effect, in the same new statement 288 as that suggested by WRE in their letter.

The remainder of the changes proposed by WRE prevent the above-mentioned correction from being made at the downstream boundary junction (where J = JGW). Since in the non-tidal case the program sets QIN(JGW) equal to zero, no matter what value is input, the correction is not required at the boundary junction, and the additional WRE changes are satisfactory. They appear not to be necessary, however, since statement 288 as recommended above, produces correct results whether QIN(J) is zero or not.

Modification R3.

Purpose:

To prevent possible storage of unwanted plot data in an invalid core address.

Description:

The array JPLT in common is not initialized. If the input value of NPLT is zero, i.e., if no plots of junction surface elevations are required, an IBM "error 240" may occur, depending on what random value is in JPLT(1). The following fix is recommended.

Insert the following after card SWFL203 in subroutine SWFLOW.

```
IF(NPLT.EQ.0) GO TO 350
```

Insert the following after card SWFL522 in subroutine SWFLOW.

```
IF(NPLT.EQ.0) GO TO 1040.
```

Class (ii): Desirable before use in Phase III

Modification R5.

Purpose:

To facilitate use of the program.

Description:

(a) Channel length is input in miles, not feet.

(b) Constituent concentrations of inflows are input in mg/L, not lbs/day.

(c) Junction surface area and depth are calculated internally instead of being input (in steady-state case only).

(d) Input channel depth is actual depth, not distance from datum plane to channel bottom.

(e) Convergence checks were added to subroutines SWFLOW and SWQUAL to terminate integration if convergence is reached before the input stop time is reached (in steady-state case only).

(f) Average daily values of channel flow and velocity are calculated and printed for each channel.

(g) The capability was added to write the hydrodynamic data onto tape for the single day (initially unknown) on which hydrodynamic convergence occurred, as determined by item (e) above. (Note: previously, if only one day's data were required to be written on tape, as for the case of steady-state in which the quality model SWQUAL would use the same day's data repetitively, this data had to be for the initially prescribed stop date.)

Modification R6.

Purpose:

To provide better hydrodynamic convergence, reduce input preparation and run time.

Description:

As an optional alternative to prescribing Manning's n values for each river reach, compute these from the channel configurations and initially prescribed flow conditions. (This results in consistency in the energy losses amongst the various reaches, whence more rapid convergence in steeper streams.)

APPENDIX C

MODIFICATIONS TO DRM

APPENDIX C

MODIFICATIONS TO DRM

Class (i): Necessary to execute Phase II model

Modification L1.

Purpose:

To enable the as-delivered model version to be applied to other cases than Dworshak Reservoir/Libby Dam.

Description:

Generalize the code and documentation, supplement poor documentation, including the following:

(a) Numerous hard-wired values were changed to be input variables. Among the values generalized were first and last day of run, fitting coefficients, tape (disk) units used for interfacing, lake surface elevation, lake bottom elevation, dam outlet elevations, and the number of outlets.

(b) An option was added to allow an outlet to always be at the lake surface, i.e., to simulate a spillway.

Modification L2.

Purpose:

To prevent referencing data from an invalid core address.

Description:

The variable NUME has not been initialized when subroutine SUBC is called. This may also cause an IBM "error 240". The following fix is recommended.

Change the 5th line after statement lable 105 in subroutine SUBC from

```
IF(T(NUME)-T(1).GT. .1)   IMIX = NUME
                    to
IF(T(MAXE)-T(1).GT .1)    IMIX = MAXE
```

Class (ii): Desirable before use in Phase III

Modification L3.

Purpose:

To facilitate the use of the program.

Description:

(a) The three separate subprograms BAL, MIPP, and TSIP were integrated into one program.

(b) The format of the input cards defining inflow, outflow, and inflow temperatures was changed so that the quantities are input grouped together by day number, instead of being input separately in blocks to match the months being simulated.

(c) The initial temperature is printed for each level of the lake in the output.

(d) Automatic interpolation is done if the temperature history of the lake inflow is incomplete.

(e) An option to apply a factor and a bias (representing groundwater flow) to the inflow was added.

SELECTED WATER RESOURCES ABSTRACTS

INPUT TRANSACTION FORM

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Spokane River Basin Model Project

October, 1974

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Systems Contról, Inc.
Palo Alto, California

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Environmental Protection Agency

Set of six volumes: Volume I - Final Report, Volume II - Data Report, Volume III - Verification Report, Volume IV - User's Manual for Steady-state Stream Model, Volume V - User's Manual for Dynamic Stream Model, Volume VI - User's Manual for Stratified Reservoir Model.

Three existing mathematical models, capable of representing water quality in rivers and lakes, have been modified and adapted to the Spokane River Basin in Washington and Idaho. The resulting models were named the Steady-state Stream Model, the Dynamic Stream Model, and the Stratified Reservoir Model. They are capable of predicting water quality levels resulting from alternative basinwide wastewater management schemes, and are designed to assist EPA, State, and local planning organizations to evaluate water quality management strategies and to establish priorities and schedules for investments in abatement facilities in the basin. Physical data and historical hydrologic, water quality and meteorologic data were collected, assessed and used for the model calibrations and verifications. The modified models are all capable of simulating the behavior of various subsets of up to sixteen different water quality constituents. Sensitivity analyses were conducted with all three models to determine the relative importance of a number of individual model parameters. The models were provided to the EPA as computer source card decks in FORTRAN IV language, with accompanying data decks. All development work on, and applications made with, these models were fully documented so as to permit their easy utilization and duplication of historical simulations by other potential users. A user's manual with a complete program listing was prepared for each model.

Send To:

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