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WATER QUALITY STUDY: MIDDLE SNAKE RIVER

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PORTLAND, OREGON

WATER QUALITY STUDY:
MIDDLE SNAKE RIVER

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INTRODUCTION

Background

The water quality of the Middle Snake River is of vital concern to both State and Federal agencies. The reach from Weiser, Idaho to the river's mouth has in the past several years been the subject of several studies and investigations relative to water quality and uses. The use of particular interest is the anadromous fisheries of the Snake and its major tributaries, such as the Salmon River.

A water quality study was initiated in July 1968 to gather data in support of Department of the Interior testimony presented before the Federal Power Commission license application hearings on High Mountain Sheep Dam. Unusually heavy rainfall during August 1968 required a supplemental field survey in August 1969. This follow-up survey was further justified by Secretary Hickel's request for a moratorium on project construction in the Snake during which more studies were to be undertaken.

This report includes the data from the above mentioned surveys as well as data from the Federal Water Pollution Control Administration (FWPCA) Pollution Surveillance Branch, Northwest Regional Office, the U.S. Geological Survey, and the Bureau of Commercial Fisheries.

Authority

Section 5 of the Federal Water Pollution Control Act, as amended, authorizes the Secretary of Interior to conduct ". . .studies relating to the causes, control, and prevention of water pollution."

Scope

Study Area

The study area, illustrated in Figure 1, included the reach of the Snake River from Weiser, Idaho (River Mile 351.6) to the mouth of the Clearwater River at Lewiston, Idaho (River Mile 139.3). The main emphasis of the study, shown as the shaded area in Figure 1, was concentrated in the reach from the Brownlee Reservoir log boom (River Mile 285.2) to Wild Sheep Creek Rapids (River Mile 241.4) below Hells Canyon Dam.

Study Time

The study consisted of two phases. The first phase involved the installation of three continuous dissolved oxygen (D.O.) and temperature recorders for a three-month period commencing in July of 1968. The second phase involved four one-week surveys, one each during the months of August, September, and October 1968 and August 1969.

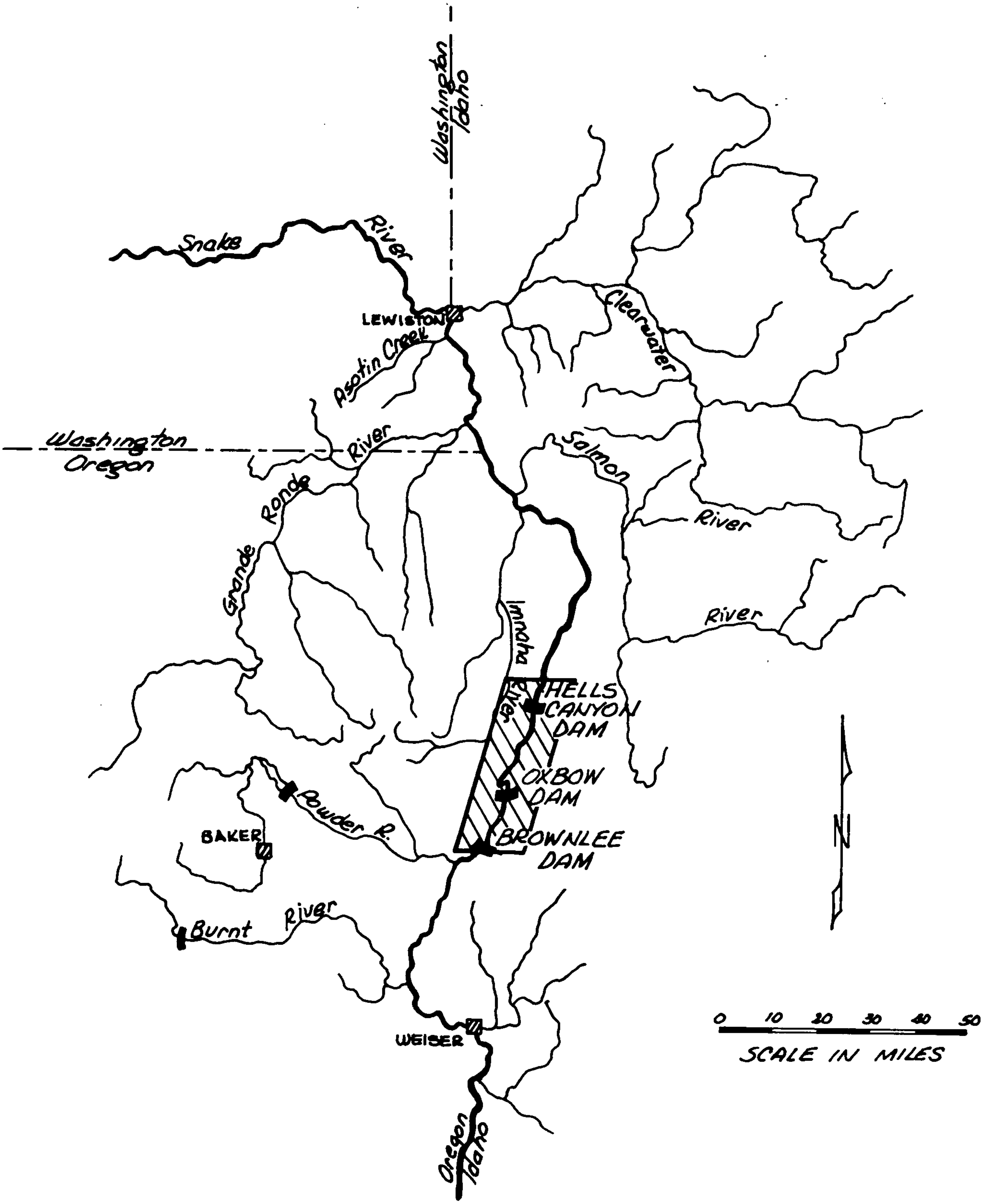

FIGURE 1 Middle Snake River Study Area

Objectives

The objectives of the study were to define the existing water quality conditions of the Middle Snake River and to determine the overall effects of the three individual Idaho Power Company projects (Brownlee, Oxbow, and Hells Canyon) upon water quality.

Acknowledgments

The assistance and cooperation of the Idaho Power Company is gratefully acknowledged.

SUMMARY

Findings

1. A 34 to 38 percent reduction in dissolved oxygen concentrations was measured between inflow and outflow in Brownlee Reservoir compared with essentially no change in either Oxbow or Hells Canyon Reservoirs.

2. Measured dissolved oxygen levels from Brownlee Dam to Wild Sheep Creek Rapids below Hells Canyon Dam were below criteria of applicable water quality standards except where algal activity was high. During the summer months the major portion of water in Oxbow and Hells Canyon Reservoirs had a D.O. concentration ranging from 5 to 6 milligrams per liter (mg/l).

3. The increase in dissolved oxygen measured in the river below Hells Canyon Dam was small, ranging from 0.9 to 1.4 mg/l in a six-mile reach.

4. Temperatures in each of the three reservoirs during the summer months were uniform to a depth of approximately 150 feet. A thermocline exists in Hells Canyon Reservoir below which the dissolved oxygen measured was zero.

5. When looking at average annual temperatures, less than a 1^{o} C. change was noted between inflow and outflow in any of the three reservoirs.

6. Significant algal concentrations were noted in all three reservoirs.

7. A decrease in turbidity, total phosphorus, and total kjeldahl nitrogen concentrations was measured between inflow and outflow in Brownlee Reservoir with no apparent change between inflow and outflow in Oxbow and Hells Canyon Reservoirs.

8. Essentially no change in either orthophosphate or ammonia nitrogen concentrations was measured between inflow and outflow of the three reservoirs.

9. Moderately high sulfate levels ranging from 12 to 60 mg/1 exist throughout the study area with conversion to hydrogen sulfide gas in areas with zero dissolved oxygen.

10. Spillage at the three dams during the high spring flows of 1969 resulted in dissolved nitrogen concentrations as high as 135 percent.

Conclusions

1. The reduction in dissolved oxygen between inflow and outflow in Brownlee Reservoir is due to a combination of organic solids which settle out, creating an oxygen-consuming benthic load, and the decomposition of dissolved and suspended organics.

2. Reaeration in the 6 miles below Hells Canyon Dam is limited as the travel time is short and only a small percentage of the flow is exposed at the surface.

3. The total phosphorus and total kjeldahl nitrogen removed in Brownlee Reservoir were in solids which settled out.

4. The discharge of waters from below the thermocline in Brownlee and Hells Canyon Reservoirs is potentially toxic to fish because these waters contain hydrogen sulfide and ammonia.

5. The amount of dissolved nitrogen added through spilling is a function of the flow and the depth of plunge in the pool.

6. Water supersaturated with dissolved nitrogen returns to equilibrium very slowly in impoundments.

STUDY AREA DESCRIPTION

The area considered in this study is a 213-mile section of the Snake River extending from Weiser to Lewiston, Idaho. In this 213-mile reach, the Snake borders three states: Idaho on the east, and Oregon and Washington on the west. Major tributaries include the Burnt, Powder, Imnaha, Salmon, and Grande Ronde Rivers. Ninety-three and one-half miles are impounded behind three dams built and operated by the Idaho Power Company. Data relating to these three projects can be found in Table 1.

The physical characteristics of the study area are striking. For the major portion of the 213-mile reach, the Snake River flows through a steep-walled, rough-terrained, narrow canyon which at its deepest point is over 5,500 feet deep.

Climate of the Middle Snake region is classified as semi-arid. Rainfall averages 11 inches annually at Weiser and 13 inches at Lewiston, with less than one-quarter inch during the summer months. Annual temperatures average 51° F. at Weiser and 52° F. at Lewiston with over 70 days of at least 90° F. Pan evaporation from the reservoirs averages 30 to 40 inches per year with 80 percent of the total between May and October. Winds in the canyon generally blow downstream during summer months and upstream during winter months.

TABLE 1

IDAHO POWER PROJECTS DATA

	Brownlee	Oxbow	Hells Canyon
Type of Dam	Rock fill	Rock fill	Concrete gravity
Year Completed	1959	1961	1968
Location of Dam (River mile)	284	271	247.5
Reservoir Length (miles)	57½	13	23
Reservoir Surface Area (acres)	15,000	1,145	2,400
Total Storage (acre-ft.)	1,470,000	57,500	167,200
Height of Dam (ft.)	395	205	330
Elev., Top of Dam (ft.)	2090	1825	1695
Water Surface Elev., max.	2077	1805	1688
Water Surface Elev., min.	1976	1800	1683
Elev., Tailwater (ft.)	1805	1688	1475
℄ Elev., Penstocks (ft.)	1948	1750	1550

WATER USES

The present major uses of surface water of the Middle Snake are power production, recreation, and fish and wildlife. A small amount of irrigation is practiced along benches and bottom land.

Snake River waters are used for a variety of recreational purposes. Most of these activities are centered in the Lewiston area, where two public bathing beaches are located. Pleasure boating and water skiing are also popular in this area. Elsewhere in the study area recreational uses are small due to poor accessibility and remote location. The three reservoirs studied are sparsely used with Brownlee receiving the greatest use. However, these remote areas constitute important outdoor recreational resources and legislation to set aside portions of the Snake and/or tributaries as wild rivers has been proposed.

The Bureau of Commercial Fisheries has made estimates of the maximum runs of salmon and steelhead in the Snake River system. Table 2 lists the distribution of these fish in the study area.

Fish activity in the study area is heavy. The varieties of species, listed in Table 2, are such that either up or downstream migration is ongoing each month of the year. In addition, all

TABLE 2

ESTIMATED DISTRIBUTION OF MAXIMUM RUNS OF SALMON AND STEELHEAD TROUT TO THE STUDY AREA a/

Snake River Run	Fall Chinook	Spring-Summer Chinook	Blueback (Sockeye)	Steelhead
Asotin Creek				1,900
Grande Ronde River		12,200		18,200
Snake River				
China Gardens-High Mtn. Sheep	3,600			
Salmon River		95,300	3,500	39,700
Imnaha River	300	6,700		4,600
Snake River				
High Mtn. Sheep-Appaloosa	1,100			
Appaloosa-Pleasant Valley	3,600			
Pleasant Valley-Hells Canyon	22,000			
Hells Canyon Dam Fish Facilities	17,800	2,500		6,500
Small Tributaries				
Imnaha River-Hells Canyon Dam		600		1,300
TOTAL	48,400	117,300	3,500	72,200

a/ This table is based on data available since counting began at McNary Dam in 1954 and does not reflect the distribution that could occur within any section or tributary in any given year.

Data Source: U.S. Fish and Wildlife Service life stages of development are represented throughout the year.

Many factors of water quality affect the lives of anadromous fish, including high temperature, low dissolved oxygen, dissolved nitrogen supersaturation, and disease.

WATER QUALITY CRITERIA

Standards

In compliance with Section 10 of the Federal Water Pollution Control Act, as amended, the States of Idaho, Oregon, and Washington have established water quality standards for the Snake River. A tabulation of the standards criteria for dissolved oxygen, temperature, coliform bacteria, and hydrogen ion concentration (pH) is presented in Table 3. The standards were established to conform with the present and potential water uses of the Snake River.

As part of each state's water quality standards, a statement of non-degradation is required by the Secretary of Interior. This policy provides for the maintenance of existing quality when that quality is higher than levels set in the established standards.

Other Criteria

In addition to the standards presented in Table 3 other parameters are important in maintaining water quality. Some of the more important ones in the Middle Snake are nutrients (nitrogen and phosphorus) and dissolved nitrogen gas.

Inorganic nitrogen and phosphorus are essential for the growth of algae and aquatic plants. To avoid excessive growths these nutrients should be limited in concentration to 0.30 mg/l and 0.01 mg/l, respectively, according to Sawyer.(8)

TABLE 3

STANDARDS OF QUALITY FOR SNAKE RIVER WATERS
(Established by the States of Oregon, Idaho and Washington)

	Coliform Bacteria (maximum allowable, where associated with fecal sources)	Hydrogen Ion Concentrations (pH) (allowable range)	Dissolved Oxygen (DO) (minimum allowable concentrations)	Temperatures (maximum allowable)
Idaho (river mile 139 to 247)	Average of 1000 organisms/100 ml; 2400 organisms/100 ml in 20% of samples. Between river miles 139 and 170, average of 240 organisms/100 ml.	7.0 to 9.0 (Induced variation limited to 0.5 pH unit).	75% saturation at seasonal low; 100% saturation in spawning areas during spawning, hatching and fry stages of salmonid fishes.	68°F (2°F increase when river temperatures are 66° or less).
Idaho (river mile 247 407.3)	Same as above.	Same as above.	Same as above.	70°F (2°F increase when river temperatures are 68°F or less).
Oregon (river mile 172.0 to 407.3)	Average of 1000 organisms/100 ml; 2400 organisms/100 ml in 20% of samples.	7.0 to 9.0	75% saturation at seasonal low; 95% saturation in spawning areas during spawning, hatching and fry stages of salmonid fishes.	70°F (2°F increase when river temperatures are 68°F or less).
Washington (river mile 0.0 to 172.0)	Median of 240 organisms/100 ml; 1000 organisms/100 ml in 20% of samples.	6.5 to 8.5 (Induced variation limited to 0.25 units).	8.0 mg/l	68°F (when less than 68°F the permissive increase, "t", is limited by the relationship t=110/ (T-15), where "T" represents the resulting water temperature).

Dissolved nitrogen gas is becoming an important water quality parameter in the Snake and main stem Columbia Rivers as the cause of highly fatal gas-bubble disease in fish. Concentrations of dissolved nitrogen as low as 104 percent saturation have been reported to cause gas-bubble disease in fish.

SAMPLING AND ANALYTICAL PROGRAM

Survey Data Selection

During the formulation stage of the FWPCA study, two phases of field investigation were planned. These involved the installation of continuous monitors for dissolved oxygen (D.O.) and temperature plus one-week surveys which were planned for the months of August, September, and October 1968. August was chosen as the month when the maximum effect of high temperature, low flow, and high algal activity on water quality could be observed. The September and October survey times were chosen to measure the rate and degree of change in water quality leading up to fall overturn in Brownlee and Hells Canyon Reservoirs.

Because August of 1968 was unusually wet and cool, an additional one week survey was undertaken in August of 1969.

Sampling Point Selection

Of main concern in the study was the effect of the three Idaho Power projects on water quality. Therefore, sampling stations were established above and below the three dams. In addition, samples were collected from the turbine penstocks. A sampling station at Weiser was used as a control to assess water quality entering Brownlee Reservoir. Besides these stations, others were established at approximately five-mile intervals on both Oxbow and Hells Canyon Reservoir. At these stations, as well as at the Brownlee log boom station, samples were collected in mid-stream, at depths of 3 feet, 15 feet, and each 30 feet thereafter. Below Hells Canyon Dam samples were taken approximately every half mile so that any effect of atmospheric reaeration on D.O. concentrations could be noted.

A tabulation of the points sampled with a description and location in river miles can be found in Table 4.

TABLE 4

LOCATION OF SAMPLING POINTS

STATION NO.	DESCRIPTION	RIVER MILE
1.	Brownlee Dam log boom	285.2
2.	Brownlee Dam penstock	285.0
3.	Brownlee Dam tailrace	284.8
4.	Highway bridge below Brownlee Dam	284.0
5.	Oxbow Reservoir - Opposite Idaho Powers Rest Station ½ mile upstream of Jacobs Ladder Creek	280.0
6.	Oxbow Reservoir at Sumner Creek	277.0
7.	Oxbow Dam log boom	273.7
8.	Oxbow Dam penstock	273.5
9.	Oxbow Dam tailrace	271.0
10.	Highway bridge below Oxbow Dam	269.7
11.	Hells Canyon Reservoir opposite Homestead School	265.8
12.	Hells Canyon Reservoir at Limepoint Creek	261.7
13.	Hells Canyon Reservoir at Leep Creek	256.9
14.	Hells Canyon Reservoir at Squaw Creek	252.7
15.	Hells Canyon Reservoir at Eagle Bar - opposite substation	249.4
16.	Hells Canyon Dam log boom	248.2
17.	Hells Canyon Dam penstock	248.0
18.	Hells Canyon Dam tailrace	247.8

TABLE 4 (CONT.)

LOCATION OF SAMPLING POINTS

19.	Snake River - 50 yards below Hells Canyon Dam	247.7
20.	Snake River at Deep Creek	247.4
21.	Snake River at USGS Gaging Station	247.6
22.	Snake River at Hells Canyon Creek	246.8
23.	Snake River - Halfway between Hells Canyon and Stud Creek	246.3
24.	Snake River at Stud Creek	245.9
25.	Snake River - Halfway between Stud and Brush Creek	245.3
26.	Snake River at Brush Creek	244.7
27.	Snake River - ¼ mile below Brush Creek	244.5
28.	Snake River - near Barton Heights	244.1
29.	Halfway between Brush and Battle Creek	243.5
30.	Snake River at lower Warm Springs	242.9
31.	Snake River at Battle Creek	242.2
32.	Snake River - halfway between Battle and Wild Sheep Creek	241.8
33.	Snake River at Wild Sheep Creek	241.4

Sampling Procedures and Analytical Methods

Water samples were collected with either a Kemmerer or Van Doren sampler.

When water depth was less than 50 feet, temperatures were measured with a laboratory thermometer. Samples were taken from the Kemmerer water sampler, placed in a plastic beaker, and the temperature recorded. When depth was greater than 50 feet, a fresh water bathythermograph (BT) was used in addition to the hand temperature measurements.

Dissolved oxygen was measured in the field using the Alsterberg (Azide) modification of the standard Winkler method. Oxygen saturation levels were determined using saturation tables from the twelfth edition of Standard Methods and were corrected for elevation above sea level.

All additional samples were sent to the FWPCA Pacific Northwest Water Laboratory (PNWL) in Corvallis, Oregon for analysis. Nutrient samples were preserved with mercuric chloride ($HgCl_2$), sulfate and sulfide samples were preserved with zinc acetate $[Zn(C_2H_3O_2)_2]$, and samples for biochemical oxygen damand (BOD) analysis were iced before shipment to Corvallis. After arrival in Corvallis, BOD samples were incubated for 5 days at 20° C.

Turbidity samples were sent to the PNWL where they were analysed using a Hach[1/] turbidimeter.

Monitoring Program

Early in the study, continuous recording monitors for dissolved oxygen and temperature were installed below each of the three Idaho Power Projects. The units installed were composed of an Electronics Instrument Laboratory Dissolved Oxygen Probe and two Rustrak Recorders. These monitors were installed at the end of July 1969 and were removed on October 16, 1969. During this period many problems developed which prevented obtaining continuous data. However, the data obtained were considered accurate since calibration checks were made every two weeks or less.

Data obtained from the three monitors were reduced from the charts and tabulated. These data can be found in the Appendix.

[1/] Use of product and company names is for identification only and does not constitute endorsement by the U.S. Department of the Interior or the Federal Water Pollution Control Administration.

SAMPLING RESULTS AND DISCUSSION

Hydrology

Flow data for the Snake River in the study area were obtained from USGS records. Table 5 lists these data for three periods: water year 1969 (October 1968-September 1969), water year 1968, and a 15-year average for water years 1953-1967. The use of the gauging station below Pine Creek was discontinued in 1968 because of the filling of Hells Canyon Reservoir. A station was established below Hells Canyon Dam as a replacement. The flow at this station should be very close to that measured below Pine Creek since no major tributaries enter the Snake River between these two locations. Major tributaries below Hells Canyon, such as the Salmon, Imnaha, Grande Ronde, Asotin, and Clearwater, greatly increase the flow at the Clarkston gauge.

As can be seen from Table 5, the average annual flows for the reach from Weiser, Idaho to Hells Canyon Dam are approximately 18,000 cubic feet per second (cfs). High flows occur during the months of March through June followed by low flows during July and August.

Data from Table 5 show the marked increase in flow during August 1968 which was 12 to 20 percent greater than the 15-year average for this month. These high flows necessitated spilling of water at Brownlee and Oxbow Dams. Table 6 shows the amount of spillage and the discharge at the Hells Canyon gauge.

TABLE 5

AVERAGE MONTHLY DISCHARGE IN CFS FOR SNAKE RIVER IN STUDY AREA[a/]

Station	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Ave.
						Water Years 1953-1967							
Snake River at Weiser	14,610	14,010	15,080	15,360	18,300	19,120	21,190	23,620	23,540	11,170	11,160	13,050	16,720
Snake River below Pine Creek[b/]	15,140	14,520	16,490	18,470	21,330	21,170	23,180	24,090	24,440	11,290	11,040	13,440	17,840
Snake River at Clarkston (adj.)	26,330	27,940	32,250	31,180	39,780	44,010	75,740	124,500	124,500	41,680	22,570	22,730	50,970
						Water Year 1968							
Snake River at Weiser	14,900	15,800	15,400	15,100	18,800	14,200	11,100	11,300	13,100	9,380	12,950	12,300	13,600
Snake River at Hells Canyon Dam	------	------	------	------	------	------	------	------	------	------	14.140	15,220	14,680
Snake River at Clarkston	26,100	30,800	31,100	33,200	55,400	44,060	44,610	74,650	93,170	31,140	25,170	26,500	42,840
						Water Year 1969							
Snake River at Weiser	14,200	15,900	16,200	24,100	25,600	29,700	39,000	28,700	19,000	10,800	10,500	13,300	20,500
Snake River at Hells Canyon Dam	14,800	17,100	20,600	27,500	23,200	40,100	46,700	29,400	19,000	11,600	11,700	14,100	23,700
Snake River at Clarkston	31,300	39,100	37,000	55,300	48,300	62,600	117,000	143,000	86,900	33,700	20,500	21,400	58,000

a/U.S.G.S. Data, subject to revision.
b/Snake River at Oxbow + incremental inflow from Pine Creek and ungaged area prior to January 1968.

TABLE 6

SPILLAGE FOR BROWNLEE and OXBOW PLUS the DISCHARGE at the HELLS CANYON GAUGE a/

Date	Brownlee Spill (cfs)	Oxbow Spill (cfs)	Hells Canyon USGS Gauge Discharge (cfs)
August 1968			
12	-	-	10,900
13	-	-	10,200
14	-	-	14,100
15	-	-	14,100
16	-	-	16,400
17	1,600	-	13,300
18	9,500	1,900	12,600
19	9,500	5,300	18,500
20	12,400	8,500	22,000
21	16,000	7,800	23,600
22	17,900	4,400	23,200
23	15,900	-	22,400
24	18,200	5,500	21,000
25	9,900	3,600	17,500
26	9,800	-	15,800
27	17,400	-	18,400
28	8,900	-	15,700
29	8,400	-	15,100
30	8,500	-	14,700
31	3,300	-	14,400
September			
1	3,500	-	12,600
2	4,300	-	10,400
3	100	-	13,200
4	-	-	9,700
5	-	-	10,000

a/ Idaho Power Data

Assuming plug flow in Oxbow and Hells Canyon Reservoirs, and using a flow of 10,000 cfs for the summer months, the detention times for Oxbow and Hells Canyon Reservoirs are about 3 days and 8 days, respectively.

Another item of interest in Table 5 is the large spring flows for 1969. These flows, which were 90 to 100 percent greater than the 15-year average flow, were accompanied by spilling at all three dams. Table 7 lists the actual spillage rates for the months of March through May 1969. Associated with this great amount of spilling was a dissolved nitrogen problem which will be discussed in detail in a later section.

Water Quality

Dissolved Oxygen

Of the parameters measured in the Middle Snake River Study, dissolved oxygen (D.O.) was considered most important. Dissolved oxygen concentrations are critical relative to the water quality standards which were established to protect the fisheries. Linked closely with D.O. is temperature which will be discussed in the next section.

The first data evaluated for this report was collected from March 1968 through August 1969 by the Pollution Surveillance Branch, Northwest Regional Office, FWPCA. Stations sampled on the Snake River are located at Weiser; below Brownlee, Oxbow and Hells Canyon Dams; and near the mouth of Asotin Creek. Data

TABLE 7

WATER SPILLED IN CFS--MARCH, APRIL AND MAY, 1969
AT BROWNLEE, OXBOW, AND HELLS CANYON DAMS[a/]

	March			April			May		
	Brownlee	Oxbow	Hells Canyon	Brownlee	Oxbow	Hells Canyon	Brownlee	Oxbow	Hells Canyon
1	36,205	8,115	7,400	45,000	29,458	20,000	21,933	7,250	-0-
2	38,203	18,938	7,400	47,969	28,229	19,500	18,573	7,934	-0-
3	35,173	12,188	7,400	46,125	26,806	18,000	7,510	-0-	-0-
4	28,750	7,656	7,050	45,000	31,365	18,667	8,281	-0-	-0-
5	19,938	2,656	2,250	46,667	34,042	17,875	12,396	-0-	-0-
6	37,154	15,000	11,500	50,000	39,000	17,000	27,710	9,167	6,333
7	31,260	113	7,849	36,250	19,399	17,000	40,000	15,781	12,000
8	26,875	5,000	3,750	48,750	29,438	17,000	36,822	16,458	12,000
9	34,219	11,701	3,750	44,166	24,388	17,000	38,490	16,875	12,000
10	24,760	6,953	3,750	41,458	20,208	19,333	35,000	15,000	12,000
11	29,708	8,500	9,750	45,000	23,625	21,000	38,333	17,500	12,000
12	15,931	13,188	14,750	49,688	33,698	21,000	31,146	14,313	8,292
13	29,063	10,387	14,750	52,500	31,042	21,000	24,792	4,938	2,300
14	29,675	10,688	14,156	47,746	25,792	21,000	18,750	3,614	2,300
15	33,729	12,000	11,500	42,146	25,250	21,000	25,000	4,542	2,300
16	36,979	12,000	11,500	44,292	22,375	21,000	20,771	5,250	2,300
17	34,883	13,875	11,500	39,167	16,708	14,446	22,813	4,833	2,300
18	39,938	15,229	12,463	37,708	14,438	8,000	25,833	5,917	2,300
19	22,266	10,064	3,329	36,854	14,250	8,250	21,563	6,365	2,300
20	16,146	1,333	-0-	40,240	22,177	8,000	22,313	4,396	2,300
21	26,250	6,545	1,885	38,000	15,420	8,958	24,167	5,041	767
22	33,958	18,000	4,500	36,250	14,187	8,000	5,000	-0-	2,979
23	32,478	14,304	10,354	34,520	14,583	8,000	-0-	-0-	3,400
24	30,833	13,385	7,250	31,375	14,028	8,000	-0-	-0-	3,260
25	33,021	13,802	8,500	35,781	15,229	3,954	3,073	-0-	5,854
26	28,854	8,615	2,396	25,404	12,458	-0-	3,315	1,146	-0-
27	26,666	4,567	-0-	26,357	10,000	-0-	-0-	-0-	-0-
28	28,496	8,229	6,635	28,233	6,250	-0-	-0-	-0-	-0-
29	40,000	28,643	15,000	25,510	6,000	-0-	-0-	-0-	-0-
30	44,666	28,646	15,000	19,735	9,208	-0-	-0-	-0-	-0-
31	46,604	25,333	17,452				-0-	-0-	-0-

a/ Idaho Power Data

from these stations are contained in Tables 8 through 12. The average annual D.O. levels were 10.9, 7.5, 8.8, 7.9, and 10.6 mg/l for Weiser, Brownlee, Oxbow, Hells Canyon and the Asotin stations, respectively. Summer D.O. values for the same stations average 9.5, 5.8, 6.9, 6.1, and 9.2 mg/l. Comparison of the D.O.'s at Weiser and Brownlee shows a 31 percent reduction annually, and a 39 percent reduction during the summer months through Brownlee Reservoir. A slight increase in D.O. through Oxbow Reservoir is offset by an almost equal reduction through Hells Canyon Reservoir, leaving the D.O. concentration about the same below Hells Canyon Dam as below Brownlee Dam. Values for Asotin show an increase over those for the Hells Canyon station. This is due to atmospheric reaeration plus dilution from high quality tributaries such as the Salmon and Imnaha Rivers.

The first phase of the 1968-69 FWPCA field surveys involved the installation of continuous recording monitors for D.O. and temperature. These monitors produced a considerable amount of data which were reduced and tabulated for daily maximums, minimums, and averages. This tabulated data can be found in the Appendix. The data for the Brownlee monitor shows an average D.O. of 5.2 mg/l for the days of record. During this period the daily average ranged from 1.6 to 10.1 mg/l. Spillage at Brownlee Dam, which commenced on August 17 and ended on

TABLE 8
STORET DATA--WEISER

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00665 PHOS-T P-WET MG/L	70507 PHOS-T ORTHO MG/L-P	00610 AMMONIA NH3-N MG/L	00625 TOT KJEL N MG/L	00945 SULFATE SO4 MG/L	00070 TURB JKSN JU	31503 COLIFORM DLY ENDO MF/100ML
68/03/19	16 00		9.0	14.1		0.10	0.042					310
68/04/03	15 00		9.9	13.3		0.09	0.026	0.100	0.700			383
68/04/24	09 30		13.0	12.2		0.04	0.022	0.100K		38	7	4700
68/05/23	14 30		17.0	11.0		0.16	0.024	0.100K	0.900	37	9	2900
68/06/05	00 15		19.9	9.6	112.0	0.08	0.012	0.080	0.700	36	8	2400
68/06/24	16 15		25.0	12.0	154.0	0.16	0.029	0.050K	1.100	44	18	3100
68/07/24	07 30		22.5	8.1	99.0	0.19	0.031	0.010K	1.200	38	17	2400
68/08/08	06 15		21.0	8.0	95.0	0.28	0.079	0.080	1.000	39	35	11900
68/08/21	12 30		17.6	7.8	87.0	0.28	0.093	0.040	0.900	51	30	13600
68/09/04	10 15		18.0	10.3	117.0	0.16	0.065	0.040	0.900		15	7200
68/09/18	11 20		18.5	10.8	123.0	0.14	0.017	0.005K	1.200	44	5	1300
68/10/01	08 30		16.0	9.4	101.0	0.17	0.017	0.005K	1.000	50	6	6000
68/10/16	12 30		11.5	11.2	110.0	0.09	0.017	0.005K	0.730	45	3	3700
68/10/30	07 45		10.0	9.9	94.0	0.08	0.027	0.010K	0.600	55	2	9400
68/11/13	14 30		8.3	10.3	94.0	0.15	0.050	0.010K	0.700	54	16	100K
68/12/03	14 15		6.0	12.2	105.0	0.06	0.038	0.030	0.300	48	1	2800
69/01/08	09 00		3.0	12.3	98.0	0.12	0.120	0.030	0.500	44	15	6600
69/02/05	12 00		1.9	12.3	95.0	0.13	0.079	0.030	0.500	28	15	1100
69/03/11	08 15		4.5	11.9	99.0	0.10	0.041	0.010K	0.400	17	10	16100
69/04/08	14 15		9.1	10.1	94.0	0.30	0.068	0.070	0.700	38	41	3200
69/06/26	17 00		18.6	14.2	162.0	0.02	0.015	0.040	1.100	42	27	1600L

TABLE 9
STORET DATA--BROWNLEE

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00665 PHOS-T P-WET MG/L	70507 PHOS-T ORTHO MG/L-P	00610 AMMONIA NH3-N MG/L	00625 TOT KJEL N MG/L	00945 SULFATE SO4 MG/L	00070 TURB JKSN JU	31503 COLIFORM DLY ENDO MF/100ML
68/07/23	07 00		14.3	4.8	49.0	0.07	0.051	0.050K	0.300		1	
68/08/06	14 15		23.0	5.4	66.0	0.03	0.013	0.020	0.400		1	
68/08/13	14 45	0003	22.4	5.8		0.06	0.029	0.140	0.700			
68/08/21	16 00		20.8	9.7	114.0	0.06	0.040	0.060	0.500		2	5
68/09/04	11 50		21.0	3.4	40.0	0.09	0.082	0.090	0.600		7	
68/09/18	14 30		20.0	4.3	49.0	0.08		0.035	0.520			100K
68/10/01	11 00		19.5	4.6	52.0	0.13	0.084	0.055	0.590		12	
68/10/16	15 00		15.0	4.8	50.0	0.07	0.065	0.010	0.600		1K	80
68/10/30	10 30		14.0	5.5	56.0	0.07	0.060					
68/11/13	17 00		11.1	11.5	110.0	0.06	0.049	0.010K	0.500		1K	
68/12/04	08 00		8.0	6.2	55.0	0.11	0.080	0.020	0.400		0.5	
69/01/08	15 20		6.0	11.1	94.0	0.15	0.090	0.040	0.800		14	
69/02/05	14 00		2.9	14.5	114.0	0.12	0.096	0.080	0.300		3	100
69/03/10	20 00		5.0	14.6	121.0	0.09	0.049	0.050	0.500	49	3	
69/04/10	15 45	0001	10.6	12.6								
	16 00	0001	11.1	9.6								
69/04/15	10 00		10.0	9.4	122.0	0.11	0.071	0.140	0.600	37	15	
69/04/29	07 30	0001	11.6	0.6								
	07 55	0015	11.3	0.3								
69/05/22	08 30		16.3	9.7	104.0	0.06	0.018		0.500	26	5	
69/06/26	19 00		19.7	9.0	104.0	0.04	0.019	0.080	0.500	26	2	

TABLE 10
STORET DATA--OXBOW

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00665 PHOS-T P-WET MG/L	70507 PHOS-T ORTHO MG/L-P	00610 AMMONIA NH3-N MG/L	00625 TOT KJEL N MG/L	00945 SULFATE SO4 MG/L	00070 TURB JKSN JU	31503 COLIFORM DLY ENDO MF/100ML
68/08/05	18 15		21.0	6.0	70.0	0.04	0.018	0.010	0.400		1	
68/08/13	19 05	0003	22.0	6.2		0.05	0.024	0.030	0.400			
68/08/21	18 00		20.8	8.8	103.0	0.06	0.034	0.020	0.600		2	100
68/09/04	13 15		21.0	6.5	76.0	0.09	0.081	0.060	0.600		13	
68/09/18	17 20		20.0	5.6	65.0	0.07	0.059	0.030	0.520			
68/10/01	13 00		20.0	6.6	76.0	0.11	0.091	0.050	0.590		15	
68/10/16	17 00		15.0	6.0	62.0	0.07	0.063	0.060	0.330		1K	115
68/10/30	11 10		14.0	5.3	54.0	0.09	0.070					
68/11/13	19 00		11.0	7.8	74.0	0.06	0.056	0.010K	0.500		1K	
68/12/03	19 20		9.0	8.2	75.0	0.08	0.073	0.010K	0.500		0.5	
69/01/08	16 00		6.5	11.2	96.0	0.12	0.060	0.060	0.500		13	
69/02/05	15 00		2.8	14.7	115.0	0.09	0.110	0.080	0.400		4	130
69/02/11	15 00						0.004					
69/03/10	19 20		5.0	14.5	120.0	0.09	0.048	0.030	0.400	49	5	
69/04/10	14 50	0001	10.8	12.1								
	15 15	0030	10.5	12.5								
69/04/15	11 25		10.3	12.7	120.0	0.11	0.071	0.130	0.800	37	15	
69/04/29	08 40	0015	11.6	0.6								
	09 00	0001	11.4	11.5								
69/05/22	10 15		16.3	11.6	125.0	0.07	0.031		0.500	28	4	
69/06/26	19 45		19.2	8.5	97.0	0.04	0.023	0.060	0.300	25	3	

TABLE 11
STORET DATA--HELLS CANYON

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00665 PHOS-T P-WET MG/L	70507 PHOS-T ORTHO MG/L-P	00610 AMMONIA NH3-N MG/L	00625 TOT KJEL N MG/L	00945 SULFATE SO4 MG/L	00070 TURB JKSN JU	31503 COLIFORM DLY ENDO MF/100ML
68/07/24	14 00		21.7	7.0	83.0	0.05	0.024	0.050K	0.400		1K	
68/08/06	08 30		18.0	5.4	60.0	0.04	0.024	0.050	0.400		1	
68/08/14	15 15	0003	21.0	5.0		0.06	0.029	0.060	0.500			
68/08/21	20 00		19.9	5.6	64.0	0.05	0.026	0.010	0.500		2	155
68/09/04	15 00		21.0	7.3	85.0	0.09	0.075	0.060	0.500		10	
68/09/19	09 30		18.7	4.7	53.0	0.08	0.068	0.015	0.460			
68/10/01	14 15		20.0	6.4	73.0	0.09	0.072	0.010	0.780		2	
68/10/16	16 15		15.5	5.8	60.0	0.08	0.073	0.050	0.600		1K	660
68/11/13	18 00		11.0	7.6	72.0	0.07	0.055	0.010K	0.600		1K	
68/11/30	12 30		14.5	5.9	60.0	0.09	0.067					
68/12/03	17 30		9.5	8.2	75.0	0.08	0.074	0.030	0.500		0.5	
69/01/08	17 30		6.5	12.0	102.0	0.13	0.054	0.060	0.600		13	
69/02/11	16 00						0.002K					
69/03/10	18 15		5.1	13.4	111.0	0.09	0.052	0.010	0.500	49	4	
69/04/10	14 10	0001	10.5	12.0								
69/04/15	08 00		9.3	13.0	124.0	0.12	0.066	0.150	0.500	31	12	
69/04/28	19 00	0001	11.2	11.4								
	19 45	0001	11.5	0.5								
69/05/22	12 15		16.7	12.1	131.0	0.08	0.026		0.300	28	3	
69/06/26	21 00		18.9	7.3	82.0	0.05	0.021	0.030	0.400	24	5	

TABLE 12
STORET DATA--ASOTIN

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00301 DO SATUR PERCENT	00665 PHOS-T P-WET MG/L	70507 PHOS-T ORTHO MG/L-P	00610 AMMONIA NH3-N MG/L	00625 TOT KJEL N MG/L	00945 SULFATE SO4 MG/L	00070 TURB JKSN JU	31503 COLIFORM DLY ENDO MF/100ML
69/02/12	11 50			12.6		0.12	0.082	0.070	0.400	28	20	1560
69/03/12	10 55		4.2	13.2		0.09	0.052	0.010	0.500	39	2	145
69/04/03	12 30		8.8	11.4	100.0	0.16	0.052	0.110	0.900			600
69/05/14	16 15		11.9	10.8	102.0	0.10	0.030	0.060	0.400	15	13	1430
69/06/11	10 10		15.5	9.5	97.0	0.12	0.035	0.030	0.500	12	10	
69/07/09	12 00		19.5	9.6	106.0	0.03	0.014	0.030	0.200	17	1K	
69/08/04	20 30		21.3	8.9	102.0	0.06	0.035			22	1	1080
69/08/26	11 45		22.0	8.7	102.0	0.05				37	1	400L

September 3, 1968, caused an average increase of 80 percent over average D.O. values measured when no spilling occurred. Data from Oxbow Dam show a daily average D.O. of 6.1 mg/l with a daily average high of 9.0 mg/l and a daily average low of 4.3 mg/l. D.O. values at Oxbow Dam show an increase for Brownlee which is due partially to the fact that the Brownlee monitor ran 60 days compared with 48 at Oxbow.

At the Hells Canyon station, 39 days of record were compiled. During this time the average D.O. was 6.7 mg/l with a daily average high and low of 9.2 and 4.4 mg/l, respectively.

Of interest at Brownlee was the great depression in D.O. measured during the morning hours when high flows were needed for power peaking. The low values of D.O. can be seen most dramatically for August 25 through 29, 1968, when daily minimum averaged 3.3 mg/l, which was only 46 percent of the daily average for the same period.

During the four weeks of field surveys, D.O. and temperature profiles were completed for Oxbow and Hells Canyon Reservoirs plus a station located at the Brownlee log boom. These profiles are shown in Figures 2 through 6. Figure 2 for Brownlee Reservoir shows D.O. decreasing with depth for all four sampling periods. The August 13, 1968, survey shows great increase in D.O. in the top 30 feet which is due to algal activity. Figure 2 also shows the D.O. profiles in percent saturation. Except for the areas

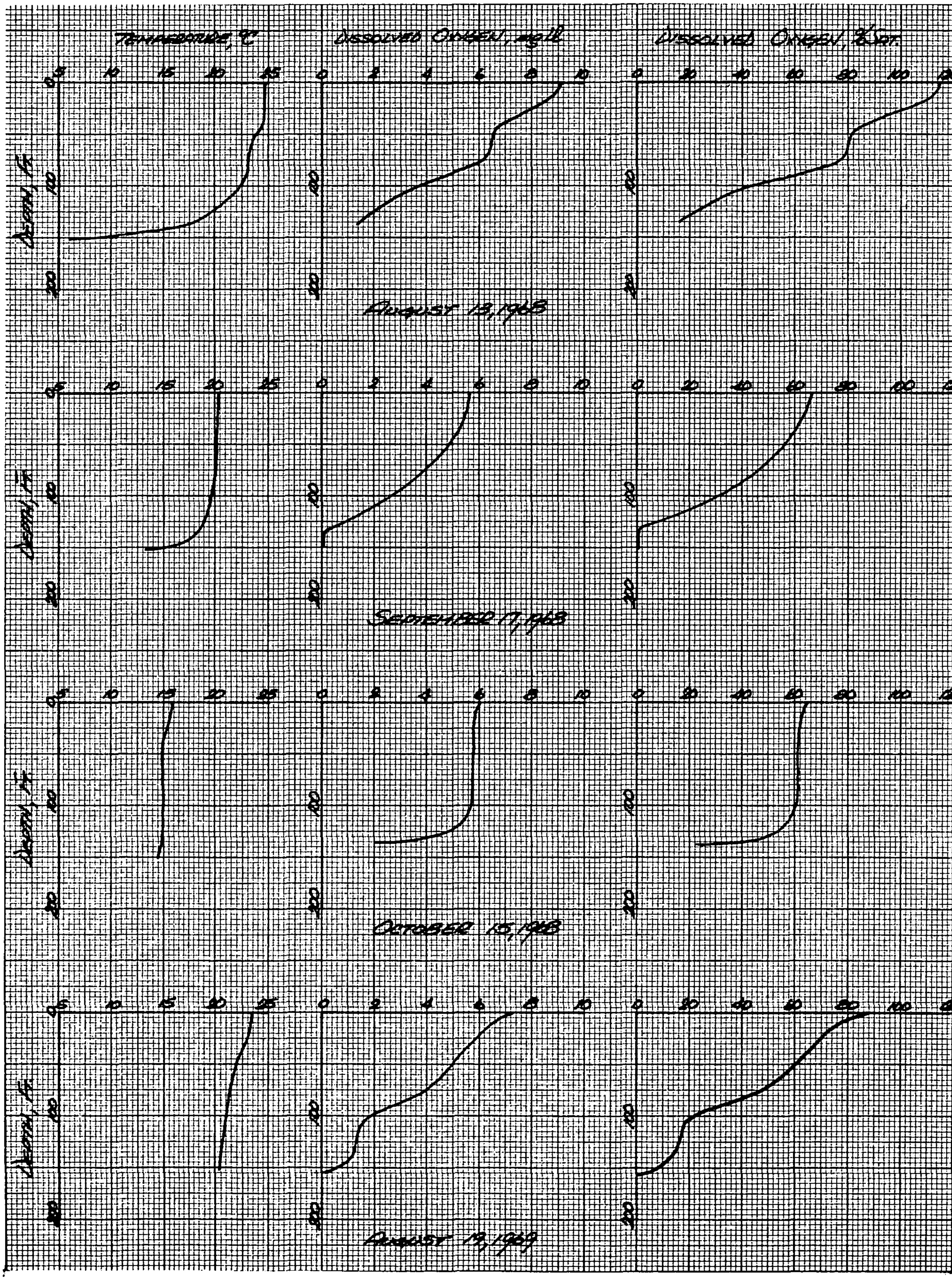

FIGURE 2 Isotherms, Dissolved Oxygen and Dissolved Oxygen Saturation Profiles for Station 1 (Brownlee Log Boom)

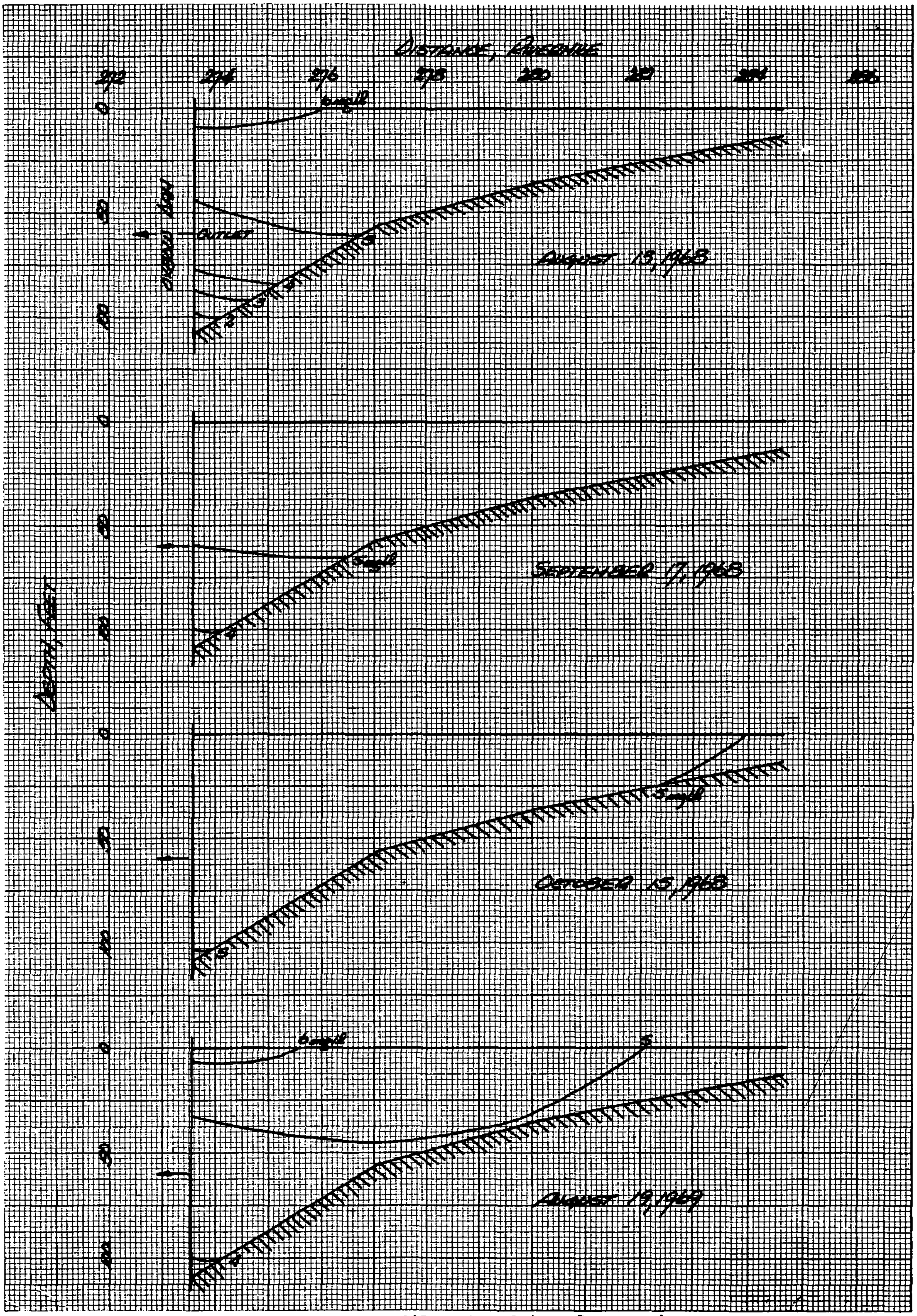

FIGURE 3 Dissolved Oxygen Profiles for Oxbow Reservoir

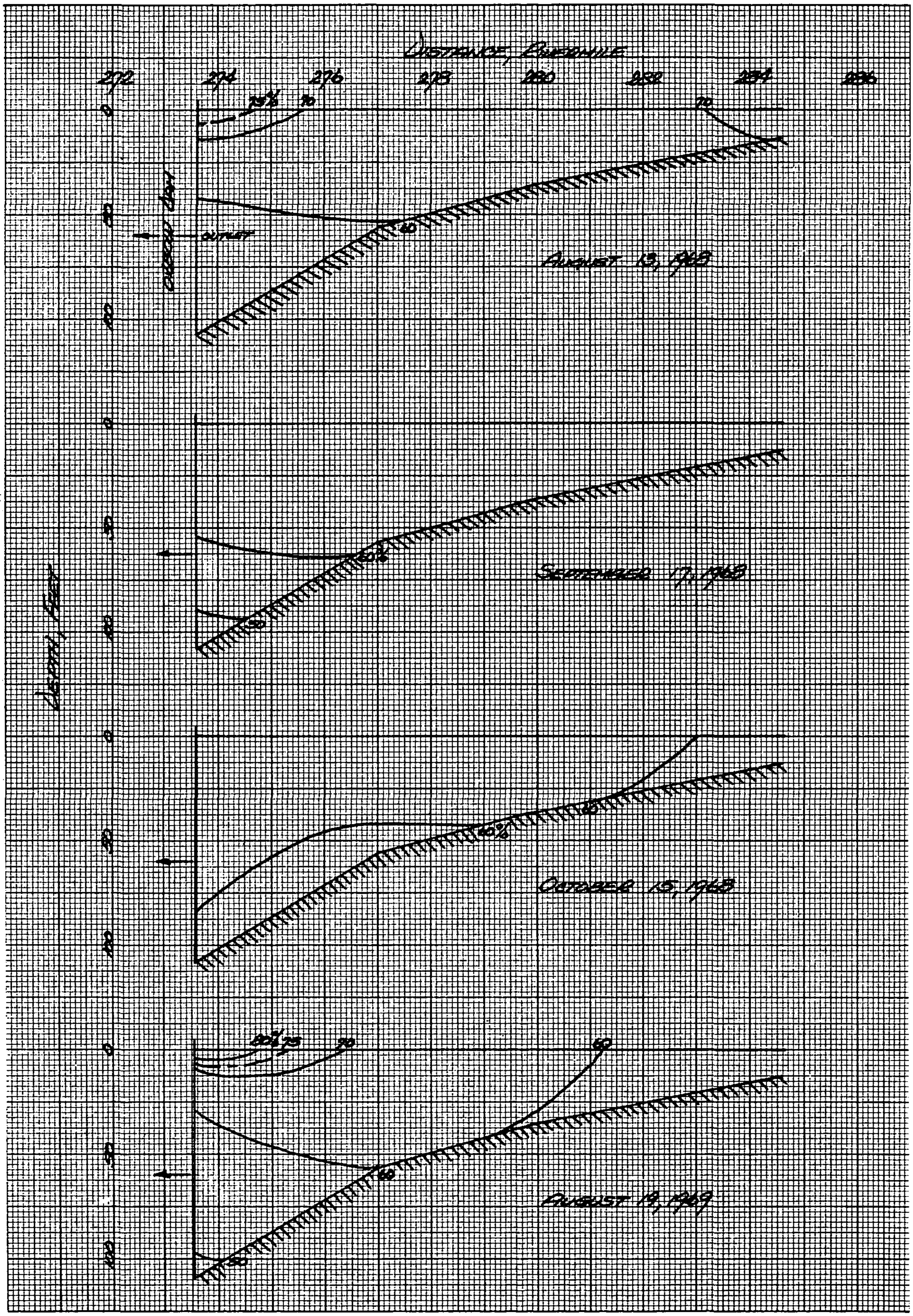

FIGURE 4 Dissolved Oxygen Saturation Profiles for Oxbow Reservoir

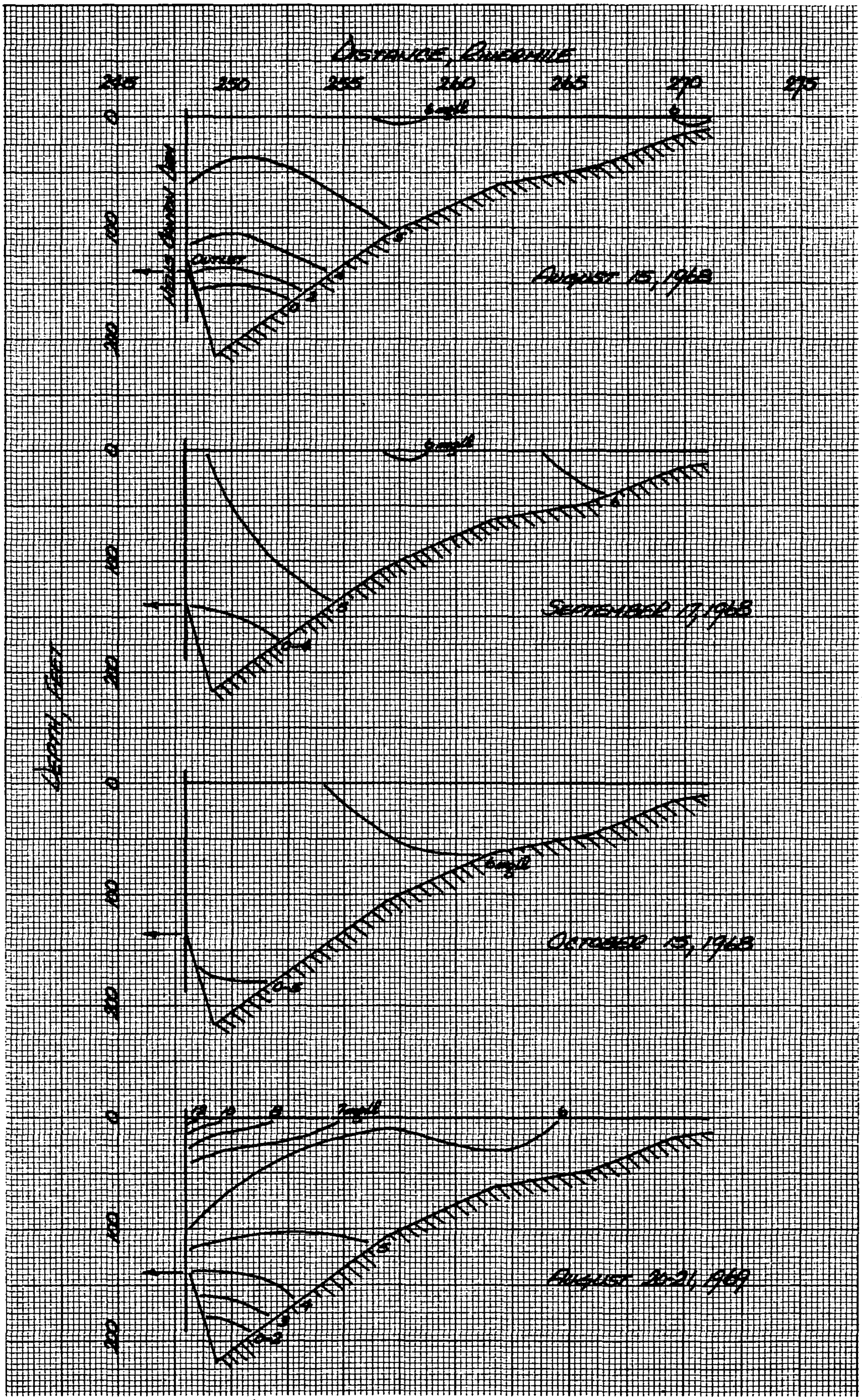

FIGURE 5 Dissolved Oxygen Profiles for Hells Canyon Reservoir

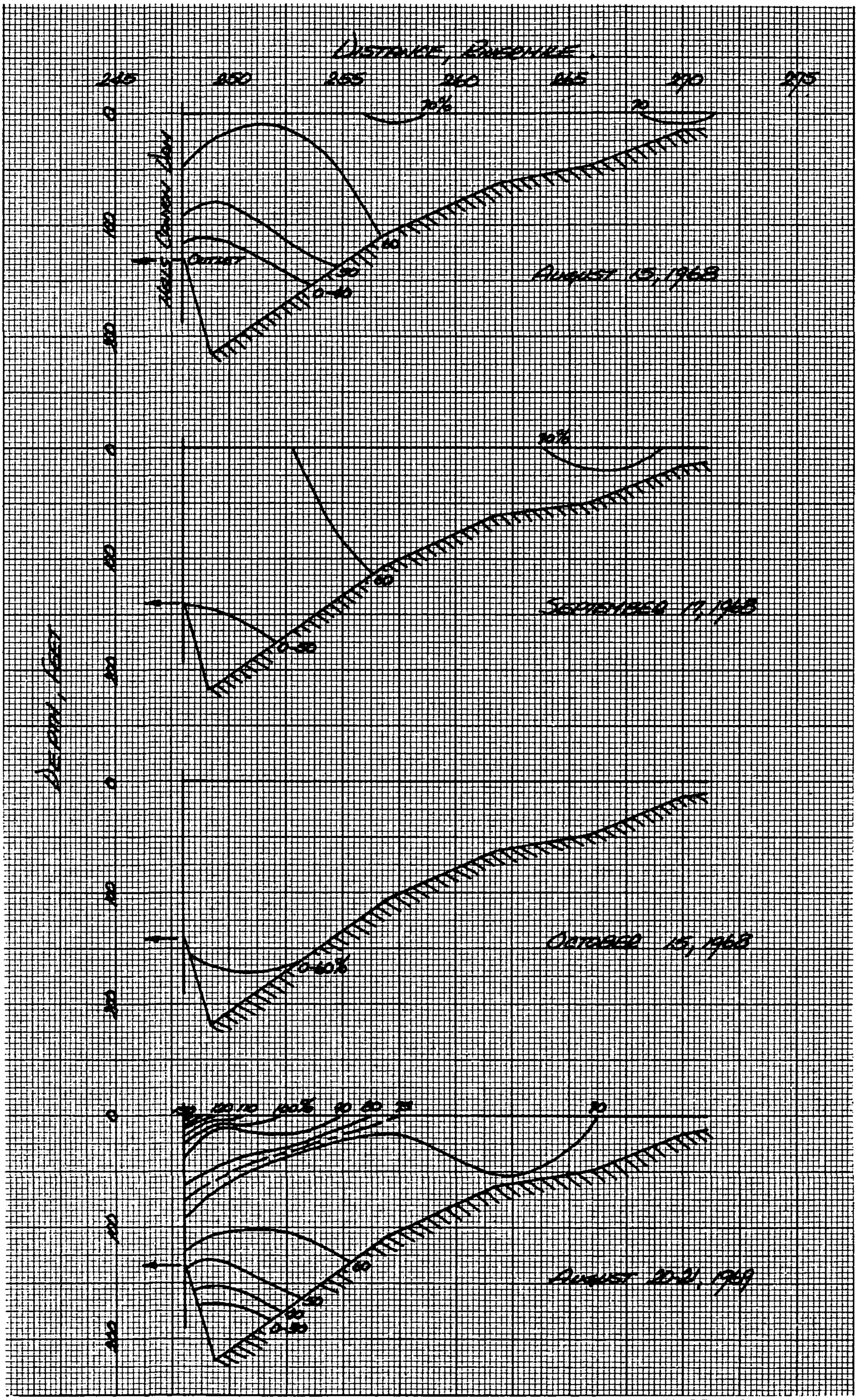

FIGURE 6 Dissolved Oxygen Saturation Profiles for Hells Canyon Reservoir

having high algal activity, the quality of water in Brownlee Reservoir was below the Standards' minimum D.O. criteria of 75 percent saturation. Figures 3 and 4 show the D.O. and D.O. saturation profiles for Oxbow Reservoir. These profiles show that during the survey period the greater portion of the reservoir had a D.O. level of 5 to 6 mg/l. Only during the August 1968 survey was a great difference in D.O. observed between the surface and bottom waters of Oxbow Reservoir. The D.O. percent saturation profiles in Figure 4, like those for Brownlee, show that the whole reservoir, except at the surface near the face of the dam where algal activity was highest, was below the standard of 75 percent saturation.

Hells Canyon Reservoir had the greatest gradient of D.O. values as can be seen in Figure 5. This reservoir had a thermocline which ranged from 100 to 175 feet deep, below which the D.O. was zero. As in Oxbow and Brownlee, algal activity near the dam face caused D.O. values to exceed 100 percent saturation in the surface layers during the dry 1969 survey. Only in this area did the water in Hells Canyon Reservoir meet the D.O. Standard of 75 percent saturation. The D.O. saturation profiles for Hells Canyon Reservoir are shown in Figure 6. During the study period, the majority of the reservoir had a D.O. value of 5 to 6 mg/l.

Sampling was performed for a distance of six miles below Hells Canyon Dam to see how long it would require low D.O. water from Hells Canyon Dam to reach 100 percent saturation. Only six miles of river could be sampled as Wild Sheep Creek Rapids was not navigable. Table 13 contains the D.O. data obtained from four trips below Hells Canyon Dam. The range of D.O. increase over the six mile reach was only 0.9 to 1.4 mg/l. In two cases of the four, the percent saturation at Wild Sheep Creek was above the Standard of 75 percent.

Temperature

Three approaches were taken to evaluate effects of the three Idaho Power Projects on temperature. These involved sampling by the FWPCA Surveillance Branch, continuous monitors below the dams, and temperature profile studies.

Surveillance sampling was done at five stations in the study area. These were located on the Snake River at Weiser, below Brownlee, Oxbow, and Hells Canyon Dams, and at Asotin Creek. Data for this sampling are provided in Tables 8 through 12. Comparison of these tables shows that the annual temperature averages 13.3, 14.0, 13.9, 14.7 and 14.7^{o} C. for the stations at Weiser, Brownlee, Oxbow, Hells Canyon, and Asotin, respectively. An increase of 0.7^{o} C. through Brownlee and 0.8^{o} C. for Hells Canyon Reservoirs is noted with essentially no change in Oxbow Reservoir. In 1968, summer temperatures for Weiser, Brownlee, Oxbow, and Hells Canyon averaged 20.4, 20.3, 21.2, and 20.3^{o} C. respectively.

TABLE 13

DISSOLVED OXYGEN LEVELS BELOW HELLS CANYON DAM

Station	River Mile	8/14/68 D.O. mg/l	8/14/68 %Sat.	9/18/68 D.O. mg/l	9/18/68 %Sat.	10/16/68 D.O. mg/l	10/16/68 %Sat.	8/10/69 D.O. mg/l	8/10/69 %Sat.
Hells Canyon Tailrace	247.8	4.8	56	4.9	58	6.0	66	5.7	70
Hells Canyon Creek	246.8	4.7	56			6.2	68	6.0	72
Stud Creek	245.9	5.8	66	5.2	61	6.2	68	6.2	74
Brush Creek	244.7	6.3	73	5.7	67	6.8	75	6.5	78
Halfway between Brush & Battle Creek	243.5	6.2	72	5.8	68	6.8	75	6.5	78
Battle Creek	242.2	6.4	74	5.9	69	6.8	75	6.7	83
Wild Sheep Creek	241.4	6.2	72	6.0	70	6.9	76	7.0	86
Increase in D.O.		1.4	16	1.1	12	0.9	10	1.3	16
Total Distance	6.4								

Over the total period monitored, 87 percent of the data for all three stations showed a diurnal fluctuation of 2° C. or less between maximum and minimum temperatures, and 83 percent of the data showed a diurnal fluctuation of 1° C. or less between maximum and minimum temperatures. Whereas D.O.'s below Brownlee fluctuated considerably during power peaking at the dam, no apparent change in temperature was noted. Tabulated data for the temperature monitors is provided in the Appendix.

The data provided by the temperature monitors were verified by running temperature profiles in the three reservoirs. Figure 2 shows the temperature profile at the Brownlee Dam log boom. Data from four different surveys show the top 100 to 150 feet of the reservoir to be nearly isothermal. A thermocline was found at this station during the August and September 1968 surveys but was absent during the October 1968 and August 1969 surveys. The thermocline was located in both instances at approximately 140 feet. Figure 7 shows the isotherms for Oxbow Reservoir. Except for the August 1968 survey, temperature differences from water surface to bottom were less than 2° C. No thermocline was observed in Oxbow Reservoir which is only 105 feet deep. The isotherms for Hells Canyon Reservoir are shown in Figure 8. This reservoir, like Brownlee and Oxbow, was found to be nearly isothermal in the top 150 feet. During all surveys a

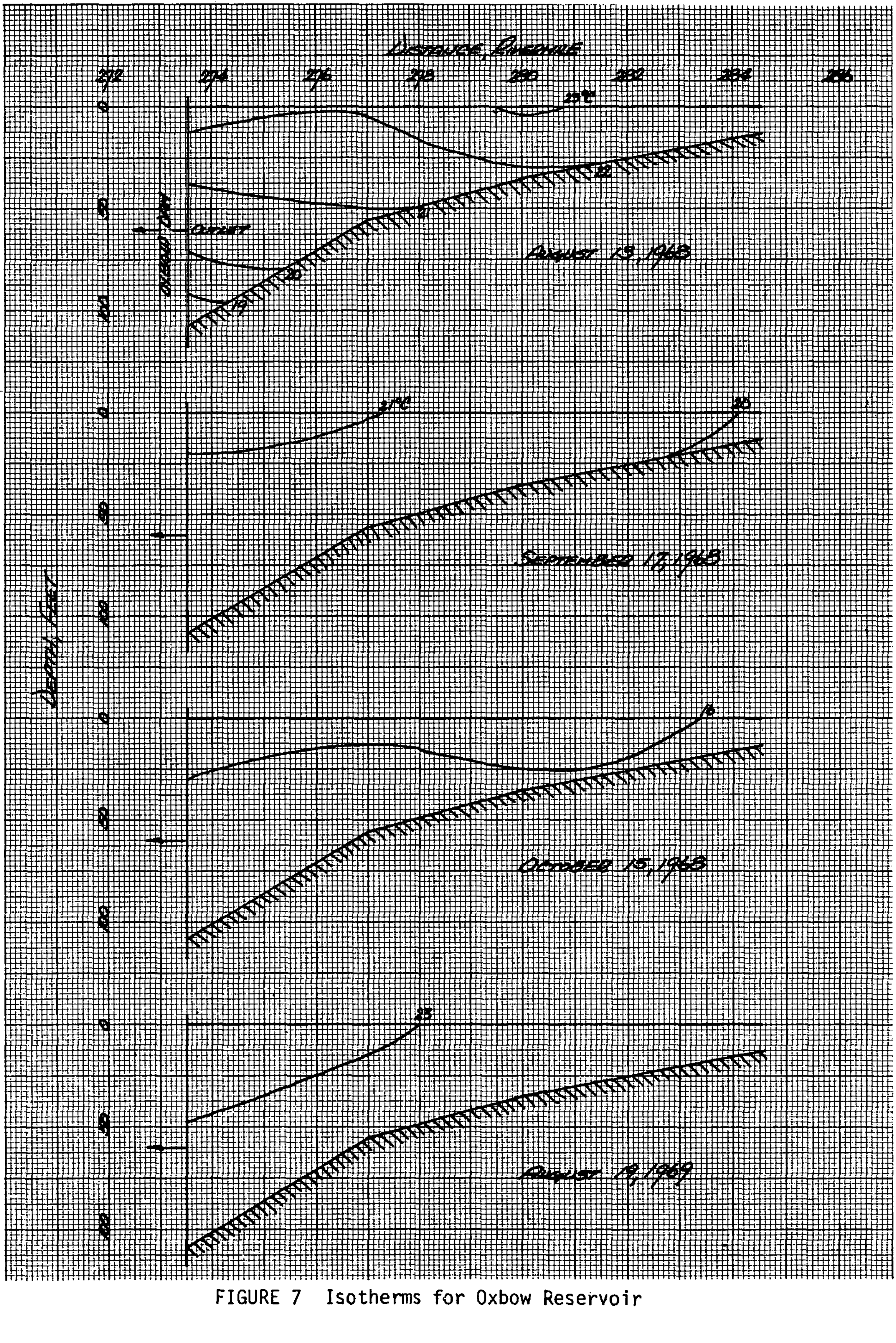

FIGURE 7 Isotherms for Oxbow Reservoir

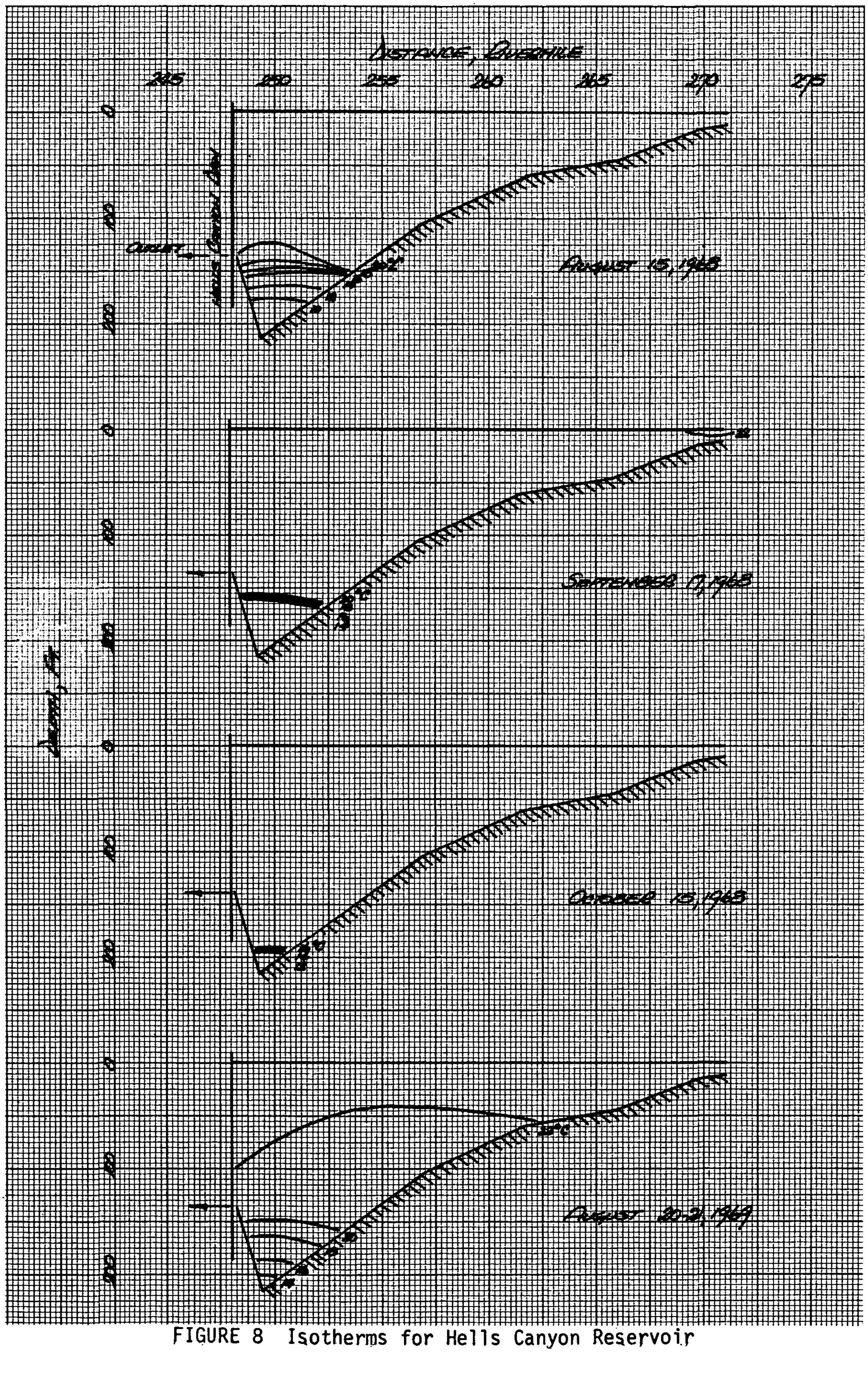

FIGURE 8 Isotherms for Hells Canyon Reservoir

thermocline was found at Hells Canyon which affected only a small portion of the reservoir, as can be seen in Figure 8.

From all the data evaluated it can be concluded that during the summer months most of the water in the three reservoirs was of approximately the same temperature; if a thermocline existed, it was at least 140 feet below the surface.

Nutrients and Algal Production

There is direct evidence that waters of the Snake River have high enough nutrient levels to support abundant growths of algae. Kari and Calloway report "great algal blooms in most areas" between Adrian, Oregon and Weiser, Idaho on August 22 and 23, 1961. (7) They also state: "The Snake River carried an exceptionally heavy load of algae in suspension. Dominant genera at the time of the survey were *Anabaena*, *Pediastrum*, *Spirogryra*, *Aphanizomenon*, *Staurastruem*, and *Anacystis*." (7) Three of the genera are "blue-greens" and are indicators of enriched waters.

Ebel and Koski report that "the large phytoplankton blooms in Brownlee Reservoir throughout the summer indicated that high turbidity did not seriously hinder primary production at the surface." (5)

Area residents report that the second year after filling seemed to be the worst as far as algal production was concerned. The reports were partially verified for Hells Canyon Reservoir which was relatively free of algal blooms in 1968 but which had profuse growths in 1969. A floating mat of blue-greens two to three inches in thickness was observed at the downstream end of the reservoir during the August 1969 survey.

Algal growths cause aesthetic problems besides interfering with recreational and municipal uses. Another effect on reservoirs that are rich in algae is that dead or dying algal cells settle into the hypolimnetic (below the thermocline) waters. Decomposition of these cells consumes the D.O. supply. Because there is no atmospheric reaeration and because there is no photosynthetic activity at these levels, the D.O. concentrations may go to zero.

Algal-producing nutrients are becoming increasingly important as water quality indicators. As previously mentioned, the Snake River in the study area supports abundant algal growths. In evaluating the effect of the three reservoirs on water quality, nutrient transport and removal becomes important. To accomplish this, the year of data collected at Weiser and below each of the three dams was evaluated. Tables 8 through 11 contain this data.

For the stations at Weiser, Brownlee, Oxbow and Hells Canyon, respectively, annual concentration averages were: total phosphate .14, .08, .07, and .08 mg/l; orthosphosphate .04, .06, .05, and .05 mg/l; ammonia nitrogen .04, .06, .05, and .04 mg/l and total kjeldahl nitrogen .8, .5, .5, and .5 mg/l. It is interesting to note the 43 percent removal of total phosphate and 3 percent removal of kjeldahl nitrogen in Brownlee Reservoir with essentially no additional removal in Oxbow or Hells Canyon Reservoirs. This can be explained by examining the turbidity data which averages 15, 5, 6, and 4 Jackson Turbidity Units (JU) for stations at Weiser, Brownlee, Oxbow, and Hells Canyon, respectively. The 60 percent removal of turbidity in Brownlee Reservoir must be related to the total phosphorus and kjeldahl nitrogen removals, since these nutrients are found in suspended organic solids. The soluble orthophosphate and ammonia nitrogen concentrations are not reduced, however, as seen from a comparison of Tables 8 through 11. After the initial removal of the nutrients associated with the settleable organic solids, little additional removal can be expected. It is also apparent that enough nutrients exist in the soluble form to promote the growth of algae in downstream Snake River reservoirs.

During the August 1969 survey, samples were taken to see how nutrient levels vary with depth in a stratified reservoir.

Table 14 contains the data from this survey. For the Eagle Bar Station in Hells Canyon Reservoir, at depths of 3, 75, and 195 feet, respectively, total phosphates were 0.23, 0.08, and 0.10 mg/l, while orthophosphates were 0.031, 0.036, and 0.002 mg/l. The high values at the 3-foot level were due to the presence of algal cells. Similarly, the kjeldahl nitrogen values at the 3-foot level were 2.8 mg/l compared to 0.4 mg/l and 0.5 mg/l at the 75 and 195-foot depths, respectively. The low value for kjeldahl nitrogen at the 195-foot depth indicates minimal organic deposits on the bottom. A significant deposit would release ammonia and organic forms of nitrogen into the overlying waters during decomposition.

Sulfates and Sulfides

There is considerable concern over the possibility of large fish kills due to hydrogen sulfide (H_2S) production in the reservoirs on the Middle and Lower Snake River. This production of H_2S results from the reduction of sulfate and sulfites to sulfides under anaerobic (without oxygen) conditions. The H_2S produced under these conditions is toxic to fish and aquatic life at concentrations of 0.1 mg/l as reported by Haydu, et al.(2,6) H_2S can also affect the use of water for domestic sources at concentrations of 0.05 mg/l or greater.

In contrast to H_2S, sulfates are relatively non-toxic; however, a maximum concentration of 250 mg/l has been set for

TABLE 14

Chemical Parameter Profiles for Study Area

8/19 - 21/69

Station	Depth Ft.	D.O. mg/l	Sulfate mg/l	Sulfide mg/l	Total Phosphorus mg/l	Orthophosphorus mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	Kjeldahl -N mg/l
Brownlee Log Boom	15	6.0	60	.14	-	-	-	-	-	-
	165	0.0	44	.18	-	-	-	-	-	-
Oxbow Log Boom	45	4.7	60	.12	-	-	-	-	-	-
Eagle Bar	3	10.0	52	.24	.23	.031	.04	.01	.08	2.8
	75	5.5	56	.12	.08	.036	.04	.02	.18	.4
	195	0.0	26	.36	.10	.002	-	-	-	.5
Wild Sheep Creek	3	7.0	52	.12	.17	.032	.07	.02	.18	.4

sulfates in the U.S. Public Health Service Drinking Water Standards. This value was based on the potential laxative effect to new users.

Both sulfates and sulfides were measured in the Middle Snake during the August 1969 survey. The determination of sulfides is not selective for H_2S, but measures all forms of sulfides (colloidal, soluble and gaseous). Table 14 contains the results of these analyses. The level of sulfates in the upper strata of the three reservoirs, as well as below Hells Canyon Dam, ranges from 44 to 60 mg/l. The sulfides also are fairly consistent, ranging from 0.12 to 0.24 mg/l. Because the upper strata of the reservoirs contain dissolved oxygen, these sulfide values of 0.12 to 0.24 mg/l do not include any H_2S but consist only of soluble and/or colloidal forms. The dissolved oxygen at 195 feet at the Eagle Bar Station in Hells Canyon was zero, however, and the samples collected had a strong odor of H_2S. The presence of H_2S was further verified by the reduction of sulfates from 52 to 26 mg/l and the increase in sulfides to 0.36 mg/l. It therefore appears that H_2S is a problem in Hells Canyon Reservoir whenever dissolved oxygen is absent.

Dissolved Nitrogen

Dissolved nitrogen (D.N.) supersaturation in water, while not a new phenomenon, is causing increasing problems relative to fisheries. The supersaturation of D.N. may lead to embolism (gas-bubble disease) resulting in large fish kills.

Dissolved nitrogen supersaturation seems to occur most frequently below dams where excess water which is spilled entrains air in its mass and plunges to depths where increased static pressure causes a supersaturated condition to occur. From data gathered it appears that the time required for the D.N. concentrations to return to equilibrium is fairly long. In the Middle Snake very little change in D.N. was measured from Brownlee to below Hells Canyon Dam, a distance which required 3 days flow time at a discharge of 40,000 cfs.

While it is agreed that D.N. supersaturation is a problem, agreement cannot be reached either on a reliable method for analysis or on a physiological threshold concentration. Two methods of analysis are presently being used. One uses a Van Slyke gas blood analyses,(11) and the other a gas partitioner.(9) While the analytical difference between these methods is not known, it probably is less than that caused by non-uniform sample preservation. A number of threshold values of D.N. have been reported, ranging from 104 to 120 percent of saturation.

During the spring of 1969 sampling for D.N. on the Middle Snake was performed. Four different surveys were run, one by the Bureau of Commercial Fisheries (BCF) and three by FWPCA. Data from these four surveys are presented in Tables 15 through 18.

TABLE 15

Analysis of Dissolved Gases for the Middle Snake River a/

March 29, 1969 b/

Location	Depth Ft.	Temp. °C	D.O. mg/l	N_2 c/ mg/l	% N_2 Sat.
Brownlee Dam Forebay	10	8.0	9.8	18.5	104
Brownlee Dam Forebay	30	7.6	13.6	22.4	116
Oxbow Hatchery Intake	Surface	8.0	13.7	22.7	118
Oxbow Hatchery East Pond	Surface	8.2	12.1	19.9	104
Oxbow Hatchery West Pond	Surface	8.2	12.2	19.9	104
Hells Canyon Dam Forebay	Surface	7.4	13.3	22.8	117
Grand Ronde	Surface	7.7	12.3	20.5	106

a/ Bureau of Commercial Fisheries Data
b/ Discharge at Hells Canyon gauge 49,896 cfs.
c/ Analyzed by Van Slyke Gas Blood Analyzer 11/

The first survey was conducted on March 29, 1969 by the BCF. Table 15 contains the data for this survey. As can be noted an increase in D.N. saturation can be seen from the Brownlee forebay (104 to 116 percent) to the Oxbow Hatchery (118 percent), which is located below Oxbow Dam at the head end of Hells Canyon Reservoir. Essentially no change in D.N. saturation was measured in Hells Canyon Reservoir. Table 7 shows that spillage for the days sampled was quite high (40,000, 29,000, and 15,000 cfs at Brownlee, Oxbow and Hells Canyon Dams, respectively).

Table 16 contains data from the second survey on April 10, 1969. This survey showed a substantial increase in D.N. saturation, from 95 to 97 percent above Brownlee to 121 percent below Brownlee. A slight decrease is noted through Oxbow Reservoir (114 to 116 percent above the dam). From here to below Hells Canyon Dam only minor changes were measured, with a saturation value of 117 percent recorded at the station below the dam. Spillage for the days sampled was about the same as for the March survey (41,000, 10,000, and 19,000 cfs at Brownlee, Oxbow, and Hells Canyon Dams respectively).

The third survey was conducted on April 24 and April 30, 1969. Table 17 contains the data for this survey. Very little change is seen through Oxbow Reservoir and a decrease occurs at Oxbow

TABLE 16

Analysis of Dissolved Gases for the Middle Snake River

April 10, 1969a/

Location	Depth Ft.	Temp. °C	D.O.b/ mg/l	%D.O. Sat.	N_2c/ mg/l	%N_2 Sat.	Argon mg/l
Above Brownlee Dam	Surface	11.1	9.6	87	16.8	95	0.6
Above Brownlee Dam	30	10.7	9.4	85	17.3	97	0.6
Below Brownlee Dam	Surface	10.6	12.6	114	21.5	121	0.8
Above Oxbow Dam	30	10.5	12.5	113	20.3	114	0.8
Below Oxbow Dam	Surface	10.8	12.1	109	20.0	112	0.8
Above Hells Canyon Dam	Surface	10.7	12.0	112	20.5	115	0.8
Above Hells Canyon Dam	30	10.5	12.0	108	20.1	112	0.7
Below Hells Canyon Dam	Surface	10.4	13.0	116	21.0	117	0.8

a/ Discharge at Hells Canyon gauge = 55,000 cfs.
b/ Field Analysis
c/ Analyzed with Gas Partitioner 9/

TABLE 17

Analysis of Dissolved Gases for the Middle Snake River

April 30, 1969 a/

Location	Depth Ft.	Temp. °C	D.O. b/ mg/l	%D.O. Sat.	N_2 c/ mg/l	%N_2 Sat.	Argon mg/l
Above Brownlee Dam d/	15	11.3	9.7	89	17.5	99	0.6
Below Brownlee Dam	Surface	11.6	12.3	113	20.2	115	0.8
Above Oxbow Dam	15	11.6	12.1	111	20.0	114	0.8
Below Oxbow Dam	Surface	11.4	11.5 e/	106	18.4	106	0.7
Above Hells Canyon Dam	Surface	11.5	11.2	105	18.8	107	0.7
Above Hells Canyon Dam	30	11.5	11.4	104	19.2	110	0.7
Below Hells Canyon Dam	Surface	11.2	11.4	104	18.7	106	0.7
Above Grande Ronde River	Surface	10.5	11.0	97	15.8	85	0.7

a/ Discharge at Hells Canyon gauge = 29,900 cfs.
b/ Field analysis
c/ Analyzed with Gas Partitioner 9/
d/ Sampled April 24, 1969, Discharge at Hells Canyon gauge = 40,500 cfs.
e/ Lab analysis

Dam, going from 114 percent saturation above the Dam to 106 percent below the Dam. Essentially no change is noted in Hells Canyon Reservoir or over Hells Canyon Dam. Of interest in this survey is the drop in D.N. saturation from below Hells Canyon Dam (106 percent) to the Grande Ronde (85 percent). The distance between these stations is 78 river miles, and two large tributaries, the Salmon and Imnaha, enter in this reach. Spillage for the days sampled was reduced from the first two surveys (31,000, 9,000, and zero cfs for Brownlee, Oxbow, and Hells Canyon Dams, respectively).

Table 18 contains the data for the final survey which was conducted on May 22, 1969. Data from this survey shows essentially no change over Brownlee Dam, but a big jump from the head of Oxbow Reservoir (100 percent saturation) to the Dam (121 percent). This change can be explained by looking at the spillage records and noting that, on the day sampled, the spillage at Brownlee was only 5,000 cfs, but the previous day's spillage ranged from 21,000 to 24,000 cfs. Presumably the high D.N. above Oxbow Dam was the result of the increase due to spillage at Brownlee Dam for three preceding days. Essentially no change is noted over Oxbow where no spillage was taking place. This survey brought out the large change noted over Hells Canyon Dam where the D.N. saturation increased from 115 to 135 percent, with a spillage of only 3,000 cfs.

In general, it can be concluded that the increase in D.N. saturation due to spillage is a function of the depth of plunge in the pool and amount of water spilled. It is also shown that the return to equilibrium is fairly slow, since no appreciable change could be seen from one end of a reservoir to the other.

TABLE 18

Analysis of Dissolved Gases for the Middle Snake River

May 22, 1969a/

Location	Depth Ft.	Temp. °C	D.O.b/ mg/l	%D.O. Sat.	N_2c/ mg/l	%N_2 Sat.	Argon mg/l
Above Brownlee Dam	Surface	17.5	12.1	127	15.0	100	0.8
Above Brownlee Dam	30	16.8	8.9	92	14.9	94	0.6
Below Brownlee Dam	Surface	16.3	9.7	100	16.0	100	0.6
Above Oxbow Dam	Surface	17.0	11.8	123	18.9	121	0.7
Above Oxbow Dam	30	16.0	11.0	113	19.1	119	0.7
Below Oxbow Dam	Surface	16.3	11.6	118	19.5	123	0.7
Above Hells Canyon Dam	Surface	17.3	11.0	116	17.9	114	0.6
Above Hells Canyon Dam	30	16.6	10.5	108	18.1	115	0.7
Below Hells Canyon Dam	Surface	16.7	12.1	125	21.4	135	0.7

a/ Discharge at Hells Canyon gauge = 23,000 cfs.
b/ Field analysis
c/ Analyzed with Gas Partitioner 9/

DEFINITION OF TERMS

Algae--Simple plants, many microscopic, containing chlorophyll.

Benthic Region--The bottom of all waters.

BOD--Biochemical Oxygen Demand. A measure of the amount of oxygen required for the biological decomposition of dissolved organic solids to occur under aerobic conditions and at a standardized incubation time and temperature.

cfs--Cubic feet per second.

Epilimnion--That region of a body of water that extends from the surface to the thermocline and does not have a permanent temperature stratification.

Hypolimnion--The region of a body of water that extends from the thermocline to the bottom and is removed from surface influence.

JU--Jackson unit, a measure of turbidity which was derived from a Jackson candle turbidimeter.

mg/l--Milligrams per liter (1000 mg/l=1gm/l)

Orthophosphate--A stable form of phosphorus which is the only available form for biological activity.

Phytoplankton--Plant microorganisms, such as algae, living unattached in the water.

Plankton--Aquatic plant and animal organisms of small size, mostly microscopic, that have relatively small powers of locomotion or drift in the water subject to wave action and currents.

Reservoir Overturn--In deep lakes and reservoirs, the seasons induce a cycle of physical and chemical changes in the water that are often conditioned by temperature. For a few weeks in the spring and again in the autumn water temperatures may be homogeneous from the top to the bottom. Vertical water density is also homogeneous and it becomes possible for the wind to mix the water, distributing nutrients and flocculent bottom solids from the deeper waters. This is a period of water overturn.

Thermocline--The layer in a body of water in which the drop in temperature equals or exceeds 1^{o} C. for each meter or approximately 3 feet of water depth.

Total Kjeldahl Nitrogen--Organic nitrogen and nitrogen in the form of ammonia (NH_3). Does not include nitrogen in the form of nitrates (NO_3^-) or nitrites (NO_2^-).

Total Phosphorus--Phosphorus in organic and inorganic forms. Phosphorus and nitrogen are nutrients necessary for maintaining biological growth.

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APPENDIX

Dissolved Oxygen and Temperature Monitoring Data

TABLE 1
MONITORING DATA
BELOW BROWNLEE DAM

DATE	DISSOLVED OXYGEN, mg/l			TEMPERATURE, °C		
	Max.	Min.	Ave.	Max.	Min.	Ave.
7/24/68	No Record			No Record		
25	6.0	4.3	5.3	20	18	19
26	6.4	3.0	4.8	20	16	19
27	5.9	3.6	4.9	21	17	20
28	5.2	3.0	4.8	20	17	19
29	6.7	3.4	5.3	21	16	19
30	6.0	2.3	4.8	21	16	19
31	6.3	3.3	4.8	21	16	19
8/1/68	5.3	3.6	4.3	21	17	20
2	5.5	3.8	4.3	20	17	20
3	4.7	3.2	3.9	21	17	20
4	5.2	3.6	3.9	20	17	20
5	5.9	2.8	3.8	21	17	21
6	5.4	2.5	3.3	23	22	22
7	4.6	2.0	2.6	23	18	23
8	2.4	1.2	1.8	23	18	22
9	2.0	1.3	1.6	23	19	22
10	5.3	2.6	4.1	23	19	22
11	5.1	2.8	3.8	22	19	21
12	4.9	1.9	4.4	23	18	21

TABLE 1
MONITORING DATA
BELOW BROWNLEE DAM (Cont.)

DATE	DISSOLVED OXYGEN, mg/l			TEMPERATURE, °C		
	Max.	Min.	Ave.	Max.	Min.	Ave.
8/13/68	6.9	1.9	4.6	23	19	21
14	5.9	2.4	4.9	23	19	22
15	6.2	4.9	5.8	23	21	22
16	10.1	4.1	7.5	23	22	22
17	10.2	10.1	10.1	23	21	22
18 - 21	No Record			No Record		
22	9.6	9.2	9.4	22	22	22
23	9.6	8.0	9.2	22	21	22
24	9.6	8.9	9.2	22	22	22
25	9.2	4.0	7.4	22	21	22
26	9.2	3.5	7.2	22	19	21
27	9.3	3.1	8.4	21	20	21
28	9.5	3.1	6.3	21	20	21
29	9.5	3.0	7.2	21	21	21
30	No Record			21	20	21
31	No Record			21	20	21
9/1/68	No Record			22	21	21
2	No Record			21	21	21
3	No Record			21	20	21
4	3.4	2.3	2.9	21	19	21

TABLE 1
MONITORING DATA
BELOW BROWNLEE DAM (Cont.)

DATE	DISSOLVED OXYGEN, mg/l			TEMPERATURE, ^{o}C		
	Max.	Min.	Ave.	Max.	Min.	Ave.
9/5/68	3.7	1.3	3.2	21	19	21
6	3.8	2.0	3.2	22	19	21
7	4.5	2.8	3.3	22	21	21
8	4.9	3.9	4.3	22	21	21
9	4.3	2.8	3.3	21	20	21
10	3.8	2.9	3.6	22	21	21
11	5.2	3.0	3.2	21	20	21
12	4.9	4.0	4.0	21	21	21
13	4.9	3.2	4.2	22	21	21
14	4.7	3.7	4.2	21	20	21
15	5.4	3.1*	4.2	21	20	21
16	5.5*	4.1*	4.3*	No Record		
17	5.5*	3.8*	4.5*	No Record		
18	5.0*	3.5*	3.8*	No Record		
19	4.3	4.2	4.2	22	21	22
20	5.0	3.5	4.1	22	22	22
21	9.0	3.6	7.5	22	22	22
22	9.2	9.2	9.2	22	22	22
23	9.2	3.6	7.6	22	22	22
24	9.4	9.0	9.0	22	21	22
25	8.9	3.7	7.1	22	21	21

*Estimates

TABLE 1
MONITORING DATA
BELOW BROWNLEE DAM (Cont.)

DATE	DISSOLVED OXYGEN, mg/l			TEMPERATURE, °C		
	Max.	Min.	Ave.	Max.	Min.	Ave.
9/26/68	8.8	2.7	5.8	22	20	21
27	8.9	3.4	6.8	20	20	20
28	8.2	3.5	4.5	20	19	20
29	9.1	3.4	7.4	20	19	20
30	3.4	2.8	3.3	20	18	19
10/1/68	3.9	2.8	3.3	19	19	19
10/2-17	No Record			No Record		

TABLE 2
MONITORING DATA
BELOW OXBOW DAM

DATE	DISSOLVED OXYGEN, mg/l			TEMPERATURE, °C		
	Max.	Min.	Ave.	Max.	Min.	Ave.
8/6/68	6.1	5.1	5.1	21	21	21
7	6.7	5.0	5.6	22	21	21
8	6.3	5.0	5.3	22	22	22
9	6.0	5.0	5.4	22	22	22
10	6.6	5.3	5.5	22	22	22
11	6.0	4.8	5.0	22	22	22
12	5.6	5.0	5.2	22	22	22
13	5.8	4.9	5.2	22	22	22
14	6.7	5.0	5.8	22	22	22
15	6.0	5.0	5.4	22	22	22
16	6.6	5.8	6.2	22	22	22
17	6.6	5.8	6.2	22	22	22
18	7.0	5.0	5.8	22	22	22
19	7.5	6.3	6.6	22	22	22
20	No record			No record		
21	8.8	8.5	8.5	21	21	21
22	9.3	8.5	8.8	21	21	21
23	9.3	9.2	9.2	21	21	21
24	9.3	8.5	8.9	21	21	21
25	9.2	8.8	9.0	21	21	21
26	9.7	8.5	9.0	21	21	21

TABLE 2
MONITORING DATA
BELOW OXBOW DAM (Cont.)

DATE	DISSOLVED OXYGEN, mg/l			TEMPERATURE, °C		
	Max.	Min.	Ave.	Max.	Min.	Ave.
8/27/68	8.5	6.6	7.6	21	21	21
28	8.8	7.6	8.0	21	20	21
29	8.8	7.5	8.0	21	20	21
30	8.5	7.6	8.0	21	20	21
31	8.3	7.5	8.0	21	21	21
9/1/68	7.8	6.8	7.2	21	21	21
2	6.8	5.1	5.9	21	21	21
3	6.4	5.1	5.8	21	21	21
4	6.8	5.9	6.3	21	21	21
5	6.8	4.8	6.0	21	21	21
6	6.0	4.2	5.2	21	20	20
7	5.6	3.8	4.3	21	20	20
8	5.6	4.9	5.2	20	20	20
9-18	No Record			No Record		
19	No Record			22	21	21
20	No Record			21	20	21
21	No Record			20	20	20
22	No Record			20	19	20
23	No Record			20	20	20
24	No Record			20	19	20
25	No Record			20	20	20

TABLE 2
MONITORING DATA
BELOW OXBOW DAM (Cont.)

DATE	DISSOLVED OXYGEN, mg/l			TEMPERATURE, °C		
	Max.	Min.	Ave.	Max.	Min.	Ave.
9/26/68	No Record			20	19	20
27	No Record			20	19	19
28	No Record			19	19	19
29	No Record			19	18	18
30	No Record			18	18	18
10/1/68	No Record			18	18	18
2	5.3	4.5	4.7	20	20	20
3	5.2	4.5	4.7	20	20	20
4	5.2	4.6	4.6	20	19	20
5	5.3	4.2	4.6	20	19	19
6	4.9	4.2	4.5	19	19	19
7	5.3	4.9	4.9	19	19	19
8	5.3	5.0	5.1	18	18	18
9	5.7	5.0	5.0	18	18	18
10	5.3	4.6	5.0	18	18	18
11	5.3	4.6	4.8	18	18	18
12	5.5	5.1	5.2	17	17	17
13	5.8	5.1	5.2	17	17	17
14	5.8	5.2	5.4	17	17	17
15	6.0	5.5	5.5	17	17	17
16	5.6	5.4	5.6	16	16	16

TABLE 3
MONITORING DATA
BELOW HELLS CANYON DAM

DATE	DISSOLVED OXYGEN, mg/l			TEMPERATURE, °C		
	Max.	Min.	Ave.	Max.	Min.	Ave.
7/24-8/22/68	No Record			No Record		
8/23/68	8.4	7.2	7.9	20	20	20
24	8.7	8.4	8.6	20	20	20
25	9.3	8.7	9.0	20	20	20
26	9.6	8.7	9.2	21	20	20
27	9.1	9.1	9.1	20	20	20
28	9.6	8.7	9.2	20	20	20
29	9.6	8.7	9.2	20	20	20
30	9.6	8.7	9.2	20	20	20
31	8.9	8.7	8.7	21	20	21
9/1/68	8.5	8.2	8.4	21	20	21
2	No Record			No Record		
3	8.2	8.2	8.2	21	20	21
4	7.5	7.2	7.2	21	21	21
5	7.8	7.3	7.5	21	20	21
6	7.7	7.3	7.4	21	20	20
7	7.3	6.8	7.1	21	20	20
8	7.3	6.8	7.0	21	20	20
9	7.2	6.6	6.7	21	20	21
10	7.0	6.1	6.5	21	20	21
11	6.1	5.2	5.8	21	20	21

TABLE 3
MONITORING DATA
BELOW HELLS CANYON DAM (Cont.)

DATE	DISSOLVED OXYGEN, mg/l			TEMPERATURE, °C		
	Max.	Min.	Ave.	Max.	Min.	Ave.
9/12/68	5.8	4.9	5.2	21	20	21
13	6.1	5.2	5.4	21	20	21
14	7.0	5.1	5.4	21	20	21
15	5.2	4.9	5.0	20	20	20
16	5.7	4.9	5.1	20	20	20
17	5.6*	5.2*	5.2*	No Record		
18	5.4*	5.0*	5.2*	No Record		
19	4.8	4.4	4.4	19	19	19
20	4.9	4.4	4.8	19	19	19
21	5.3	4.8	4.9	19	18	18
22	5.5	5.1	5.3	19	18	18
23	5.5	5.1	5.3	19	18	18
24	5.5	5.3	5.3	19	18	19
25	5.5	5.1	5.3	19	18	18
26	5.5	5.3	5.4	19	18	19
27	5.8	5.5	5.5	19	18	19
28	6.5	6.1	6.1	19	18	19
29	6.8	6.5	6.7	19	18	19
30	7.6	6.8	7.1	19	18	19
10/1/68	7.5	7.2	7.3	19	19	19

*Estimates

TABLE 3
MONITORING DATA
BELOW HELLS CANYON DAM (Cont.)

DATE	DISSOLVED OXYGEN, mg/l			TEMPERATURE, °C		
	Max.	Min.	Ave.	Max.	Min.	Ave.
10/2/68	7.5	6.8	6.8	17	16	17
3	No Record			16	16	16
4	No Record			16	15	16
10/5-16/68	No Record			No Record		