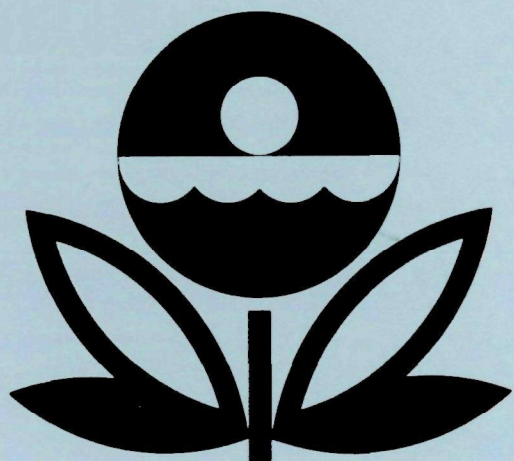


**U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY
WORKING PAPER SERIES**



REPORT
ON
HEBGEN LAKE
GALLATIN COUNTY
MONTANA
EPA REGION VIII
WORKING PAPER No. 794

**CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY - CORVALLIS, OREGON
and
ENVIRONMENTAL MONITORING & SUPPORT LABORATORY - LAS VEGAS, NEVADA**

REPORT
ON
HEBGEN LAKE
GALLATIN COUNTY
MONTANA
EPA REGION VIII
WORKING PAPER No. 794

WITH THE COOPERATION OF THE
MONTANA DEPARTMENT OF HEALTH & ENVIRONMENTAL SCIENCES
AND THE
MONTANA NATIONAL GUARD
MAY, 1977

i

CONTENTS

	<u>Page</u>
<u>Foreword</u>	ii
List of Montana Lakes and Reservoirs	iv
Lake and Drainage Area Map	v
 <u>Sections</u>	
I. Conclusions	1
II. Lake and Drainage Basin Characteristics	3
III. Lake Water Quality Summary	4
IV. Nutrient Loadings	8
V. Literature Reviewed	12
VI. Appendices	13

F O R E W O R D

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGEMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U.S. Environmental Protection Agency) express sincere appreciation to the Montana Department of Health and Environmental Sciences for professional involvement, to the Montana National Guard for conducting the tributary sampling phase of the Survey, and to those Montana wastewater treatment plant operators who voluntarily provided effluent samples.

The staff of the Water Quality Bureau provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

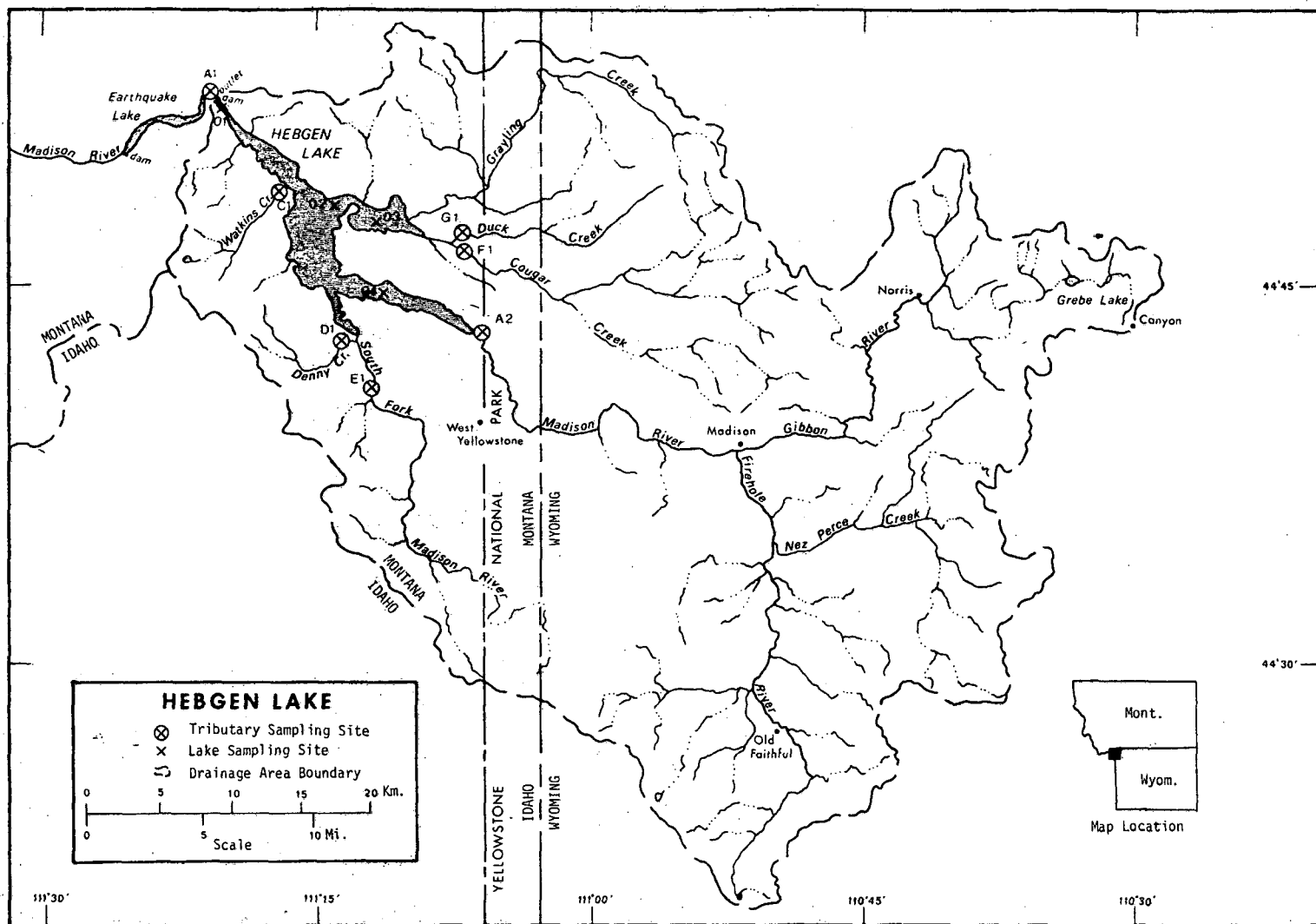
Major General John J. Womack, the Adjutant General of Montana, and Project Officer Major William Yeager, who directed the volunteer efforts of the Montana National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES AND RESERVOIRS

STATE OF MONTANA

<u>LAKE NAME</u>	<u>COUNTY</u>
Canyon Ferry	Broadwater, Lewis and Clark
Clark Canyon	Beaverhead
Flathead	Flathead, Lake
Georgetown	Deer Lodge, Granite
Hebgen	Gallatin
Koocanusa	Lincoln, MT; British Columbia, Can.
Mary Ronan	Lake
McDonald	Flathead
Nelson	Phillips
Seeley	Missoula
Swan	Lake
Tally	Flathead
Tiber	Liberty, Toole
Tongue River	Big Horn
Whitefish	Flathead
Yellowtail	Carbon, Bighorn, MT; Bighorn, WY



HEBGEN LAKE
STORET NO. 3005

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Hebgen Lake is meso-eutrophic. It ranked tenth in overall trophic quality when the 15 Montana lakes and reservoirs sampled in 1975 were compared using a combination of six water-quality parameters*. Eight of the water bodies had less and one had the same median total phosphorus, 11 had less median dissolved orthophosphorus, none had less but four had the same median inorganic nitrogen, nine had less mean chlorophyll a, and eight had greater mean Secchi disc transparency. Depression of hypolimnetic dissolved oxygen occurred at stations 1 and 2 in September.

Survey limnologists noted surface algal concentrations and some submerged and emergent macrophytes at stations 3 and 4 in September.

B. Rate-Limiting Nutrient:

The algal assay results indicate Hebgen Lake was nitrogen limited at the time the sample was collected (07/30/75). The lake data indicate nitrogen limitation at all sampling stations and times. In a previous study, it was noted that phosphorus levels are high and nitrogen is most likely the limiting factor in Hebgen Lake (Martin, 1965).

* See Appendix A.

C. Nutrient Controllability:

1. Point sources--No known municipal or industrial point sources impacted Hebgen Lake during the sampling year. Lakeshore septic tanks were estimated to have contributed 0.3% of the total phosphorus load to the lake, but a shoreline survey would be necessary to determine the significance of those sources.

The present phosphorus loading of $0.47 \text{ g/m}^2/\text{year}$ is more than that proposed by Vollenweider (Vollenweider and Dillon, 1974) as an oligotrophic loading but less than his suggested eutrophic loading (i.e., a mesotrophic loading; see page 11).

2. Non-point sources--Over 99% of the total phosphorus input to Hebgen Lake is attributed to non-point sources. The Madison River contributed 60.0%, the South Fork Madison River contributed 10.2%, Duck Creek contributed 5.8%, and Watkins Creek contributed 0.1%. Ungaged minor tributaries and immediate drainage were estimated to have contributed 19.9% of the total.

The present phosphorus export rates of the Madison and the South Fork Madison Rivers, 13 and $12 \text{ kg/km}^2/\text{year}$, respectively, are greater than the rates of the other tributaries of Hebgen Lake (range of 1 to $5 \text{ kg/km}^2/\text{year}$; see page 9). However, the higher rates most likely are due to natural sources in the drainage basin rather than unsampled point sources. A previous study showed no phosphorus decrease in the Madison River following the 1972 diversion of the seasonal discharge from the only point source in the drainage basin, the Madison Junction Plant, which served a campground at the confluence of Firehole and Gibbon Rivers (Kralich and Wright, 1974).

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS[†]A. Morphometry^{††}:

1. Surface area: 51.27 kilometers².
2. Mean depth: 8.2 meters.
3. Maximum depth: 37.5 meters.
4. Volume: 420.414 x 10⁶ m³.
5. Mean hydraulic retention time: 172 days.

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

<u>Name</u>	<u>Drainage area (km²)*</u>	<u>Mean flow (m³/sec)*</u>
Madison River	1,157.7	13.940
Watkins Creek	29.5	0.098
South Fork Madison River	211.6	3.920
Duck Creek	305.4	1.350
Minor tributaries & immediate drainage -	<u>653.2</u>	<u>9.545</u>
Totals	2,357.4	28.853**

2. Outlet -

Madison River	2,408.7***	28.330
---------------	------------	--------

C. Precipitation****:

1. Year of sampling: 89.7 centimeters.
2. Mean annual: 70.6 centimeters.

† Table of metric conversions--Appendix B.

†† Horpestad, 1975.

* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".

** Sum of inflows adjusted to equal outflow plus evaporation.

*** Includes area of lake.

**** See Working Paper No. 175.

III. WATER QUALITY SUMMARY

Hebgen Lake was sampled three times during the open-water season of 1975 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from two or more depths at four stations on the lake (see map, page v). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the July visit, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 19.2 meters at station 1, 19.5 meters at station 2, 4.3 meters at station 3, and 4.9 meters at station 4.

The sampling results are presented in full in Appendix D and are summarized in the following table.

A. SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR HEBGEN RESERVOIR
STORET CODE 3005

PARAMETER	1ST SAMPLING (7/30/75)				2ND SAMPLING (9/ 3/75)				3RD SAMPLING (10/20/75)			
	4 SITES				4 SITES				4 SITES			
	RANGE	MEAN	MEDIAN		RANGE	MEAN	MEDIAN		RANGE	MEAN	MEDIAN	
TEMP (C)	7.4 - 17.3	14.2	16.3		10.8 - 17.0	15.3	15.4		7.9 - 11.3	9.9	10.6	
DISS OXY (MG/L)	4.4 - 10.0	7.1	7.3		1.2 - 9.0	6.8	7.6		7.6 - 10.1	8.5	8.1	
CNDCTVY (MCROMO)	92. - 302.	174.	172.		126. - 281.	181.	178.		131. - 279.	191.	183.	
PH (STAND UNITS)	7.5 - 9.1	8.4	8.6		7.6 - 8.6	8.3	8.5		8.1 - 8.4	8.2	8.3	
TOT ALK (MG/L)	47. - 93.	68.	68.		58. - 96.	73.	68.		75. - 110.	86.	80.	
TOT P (MG/L)	0.014 - 0.065	0.023	0.019		0.012 - 0.088	0.024	0.020		0.021 - 0.040	0.028	0.028	
ORTHO P (MG/L)	0.008 - 0.036	0.022	0.021		0.005 - 0.048	0.016	0.013		0.006 - 0.030	0.020	0.022	
NO2+NO3 (MG/L)	0.020 - 0.040	0.022	0.020		0.020 - 0.110	0.031	0.020		0.020 - 0.020	0.020	0.020	
AMMONIA (MG/L)	0.020 - 0.100	0.035	0.030		0.020 - 0.060	0.023	0.020		0.020 - 0.040	0.024	0.020	
KJEL N (MG/L)	0.200 - 0.500	0.287	0.300		0.200 - 0.300	0.213	0.200		0.200 - 0.200	0.200	0.200	
INORG N (MG/L)	0.040 - 0.140	0.057	0.050		0.040 - 0.170	0.054	0.040		0.040 - 0.060	0.044	0.040	
TOTAL N (MG/L)	0.220 - 0.520	0.310	0.320		0.220 - 0.410	0.245	0.220		0.220 - 0.220	0.220	0.220	
CHLRPYL A (UG/L)	2.0 - 4.4	3.3	3.3		4.3 - 11.4	7.8	7.8		0.4 - 2.4	1.1	0.9	
SECCHI (METERS)	4.0 - 4.3	4.1	4.1		0.5 - 4.1	2.8	3.2		3.0 - 4.3	3.6	3.5	

B. Biological Characteristics:

1. Phytoplankton -

<u>Sampling Date</u>	<u>Dominant Genera</u>	<u>Algal Units per ml</u>
07/30/75	1. <u>Chroomonas sp.</u>	171
	2. <u>Fragilaria sp.</u>	128
	3. <u>Aphanizomenon sp.</u>	86
	4. <u>Anabaena sp.</u>	86
	5. <u>Aphanothece sp.</u>	86
	Other genera	<u>42</u>
	Total	599
09/03/75	1. <u>Fragilaria sp.</u>	316
	2. <u>Chroomonas sp.</u>	281
	3. <u>Asterionella sp.</u>	105
	4. <u>Cryptomonas sp.</u>	70
	5. <u>Stephanodiscus sp.</u>	35
	Other genera	<u>105</u>
	Total	912
10/20/75	1. <u>Melosira sp.</u>	428
	2. <u>Microcystis sp.</u>	86
	3. <u>Schroederia sp.</u>	86
	4. <u>Chroomonas sp.</u>	86
	5. <u>Gomphosphaeria sp.</u>	43
	Other genera	<u>169</u>
	Total	898

2. Chlorophyll a -

<u>Sampling Date</u>	<u>Station Number</u>	<u>Chlorophyll a ($\mu\text{g/l}$)</u>
07/30/75	1	2.0
	2	3.5
	3	4.4
	4	3.2
09/03/75	1	8.5
	2	7.1
	3	11.4
	4	4.3
10/20/75	1	0.8
	2	1.0
	3	2.4
	4	0.4

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

<u>Spike (mg/l)</u>	<u>Ortho P Conc. (mg/l)</u>	<u>Inorganic N Conc. (mg/l)</u>	<u>Maximum yield (mg/l-dry wt.)</u>
Control	0.015	0.015	1.7
0.050 P	0.065	0.015	2.3
0.050 P + 1.0 N	0.065	1.015	26.4
1.0 N	0.015	1.015	4.0

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity of Hebgen Lake was moderate at the time the sample was taken (07/30/75). Also, lack of yield response with the addition of phosphorus until nitrogen also was added indicates the lake was nitrogen limited at that time. Note that the addition of only nitrogen resulted in a yield significantly greater than that of the control.

The lake data also indicate nitrogen limitation. The mean inorganic nitrogen/orthophosphorus ratios were 7/1 or less at all sampling stations and times, and nitrogen limitation would be expected.

IV. NUTRIENT LOADINGS (See Appendix E for data)

For the determination of nutrient loadings, the Montana National Guard collected monthly near-surface grab samples when possible from each of the tributary sites indicated on the map (page v). Sampling was begun in October, 1974, and was completed in September, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Montana District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were calculated using mean annual concentrations and mean annual flows. Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the mean concentrations in Denny Creek at station D-1 and the mean annual ZZ flow.

No known wastewater treatment plants impacted Hebgen Lake during the sampling year.

A. Waste Sources:

1. Known municipal - None
2. Known industrial - None

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

<u>Source</u>	<u>kg P/ yr</u>	<u>% of total</u>
a. Tributaries (non-point load) -		
Madison River	14,505	60.0
Watkins Creek	30	0.1
S. Fk. Madison River	2,470	10.2
Duck Creek	1,405	5.8
b. Minor tributaries & immediate drainage (non-point load) -	4,815	19.9
c. Known municipal STP's - None	-	-
d. Septic tanks* -	55	0.3
e. Known industrial - None	-	-
f. Direct precipitation** - None	<u>895</u>	<u>3.7</u>
Total	24,175	100.0

2. Outputs -

Lake outlet - Madison River 20,550

3. Net annual P accumulation - 3,625 kg.

* Estimate based on 96 permanent lakeshore dwellings and 5 campgrounds;
see Working Paper No. 175.

** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

<u>Source</u>	<u>kg N/ yr</u>	<u>% of total</u>
a. Tributaries (non-point load) -		
Madison River	244,425	36.9
Watkins Creek	1,045	0.2
S. Fk. Madison River	94,075	14.2
Duck Creek	40,360	6.1
b. Minor tributaries & immediate drainage (non-point load) -	225,760	34.0
c. Known municipal STP's - None	-	-
d. Septic tanks* -	1,985	0.3
e. Known industrial - None	-	-
f. Direct precipitation** -	<u>55,350</u>	<u>8.3</u>
Total	663,000	100.0

2. Outputs -

Lake outlet - Madison River 691,505

3. Net annual N loss - 28,505 kg.

D. Non-point Nutrient Export by Subdrainage Area:

<u>Tributary</u>	<u>kg P/km²/yr</u>	<u>kg N/km²/yr</u>
Madison River	13	211
Watkins Creek	1	35
S. Fk. Madison River	12	445
Duck Creek	5	132

* Estimate based on 96 permanent lakeshore dwellings and 5 campgrounds;
see Working Paper No. 175.

** See Working Paper No. 175.

E. Mean Nutrient Concentrations in Ungaged Streams:

<u>Tributary</u>	<u>Mean Total P Conc. (mg/l)</u>	<u>Mean Total N Conc. (mg/l)</u>
Denny Creek	0.016	0.750
Cougar Creek	0.029	0.556

F. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	<u>Total Phosphorus</u>		<u>Total Nitrogen</u>	
	<u>Total</u>	<u>Accumulated</u>	<u>Total</u>	<u>Accumulated</u>
grams/m ² /yr	0.47	0.07	12.9	loss*

Vollenweider phosphorus loadings
(g/m²/yr) based on mean depth and mean
hydraulic retention time of Hebgen Lake:

"Dangerous" (eutrophic loading)	0.80
"Permissible" (oligotrophic loading)	0.40

* There was an apparent loss of nitrogen during the sampling year. This may have been due to nitrogen fixation in the lake, solubilization of previously sedimented nitrogen, recharge with nitrogen rich ground water, or unknown and unsampled point sources discharging directly to the lake. Whatever the cause, a similar loss has occurred at Shagawa Lake, Minnesota, which has been intensively studied by EPA's former National Eutrophication and Lake Restoration Branch (Malueg et al., 1975).

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VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500- MEAN SEC	MEAN CHLORA	15- MIN DO	MEDIAN DISS ORTHO P
3001	CANYON FERRY RESERVOIR	0.047	0.170	442.800	5.816	14.400	0.029
3002	CLARK CANYON RESERVOIR	0.049	0.160	398.750	2.375	12.000	0.027
3003	FLATHEAD LAKE	0.008	0.050	267.833	1.273	9.000	0.004
3004	GEORGETOWN RESERVOIR	0.022	0.040	367.333	6.983	10.200	0.011
3005	HEBGEN RESERVOIR	0.022	0.040	367.700	4.083	13.800	0.020
3006	KOOCANUSA RESERVOIR	0.045	0.100	337.643	2.669	10.400	0.044
3007	MARY RONAN LAKE	0.020	0.040	371.091	4.673	14.200	0.006
3008	MC DONALD LAKE	0.006	0.180	190.667	0.467	6.400	0.002
3009	NELSON RESERVOIR	0.029	0.075	456.750	7.233	11.400	0.007
3010	SEELEY LAKE	0.015	0.040	362.857	2.171	13.200	0.010
3011	SWAN LAKE	0.010	0.050	282.750	3.289	9.600	0.004
3012	TALLY LAKE	0.011	0.050	339.167	2.083	9.200	0.004
3013	TIBER RESERVOIR	0.018	0.180	448.555	2.806	9.600	0.004
3014	TONGUE RIVER RESERVOIR	0.051	0.050	474.111	16.878	13.600	0.008
3016	WHITEFISH LAKE (LOWER)	0.008	0.040	290.000	1.400	7.000	0.003

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500- MEAN SEC	MEAN CHLORA	15- MIN DO	MEDIAN DISS ORTHO P	INDEX NO
3001	CANYON FERRY RESERVOIR	14 (2)	14 (2)	21 (3)	21 (3)	0 (0)	7 (1)	77
3002	CLARK CANYON RESERVOIR	7 (1)	21 (3)	29 (4)	64 (9)	36 (5)	14 (2)	171
3003	FLATHEAD LAKE	89 (12)	61 (8)	93 (13)	93 (13)	86 (12)	75 (9)	497
3004	GEORGETOWN RESERVOIR	39 (5)	79 (10)	50 (7)	14 (2)	57 (8)	29 (4)	268
3005	HEBGEN RESERVOIR	39 (5)	79 (10)	43 (6)	36 (5)	14 (2)	21 (3)	232
3006	KOOCANUSA RESERVOIR	21 (3)	29 (4)	71 (10)	57 (8)	50 (7)	0 (0)	228
3007	MARY RONAN LAKE	50 (7)	96 (13)	36 (5)	29 (4)	7 (1)	57 (8)	275
3008	MC DONALD LAKE	100 (14)	4 (0)	100 (14)	100 (14)	100 (14)	100 (14)	504
3009	NELSON RESERVOIR	29 (4)	36 (5)	7 (1)	7 (1)	43 (6)	50 (7)	172
3010	SEELEY LAKE	64 (9)	96 (13)	57 (8)	71 (10)	29 (4)	36 (5)	353
3011	SWAN LAKE	79 (11)	46 (6)	86 (12)	43 (6)	68 (9)	75 (9)	397
3012	TALLY LAKE	71 (10)	61 (8)	64 (9)	79 (11)	79 (11)	75 (9)	429
3013	TIBER RESERVOIR	57 (8)	4 (0)	14 (2)	50 (7)	68 (9)	75 (9)	268
3014	TONGUE RIVER RESERVOIR	0 (0)	46 (6)	0 (0)	0 (0)	21 (3)	43 (6)	110
3016	WHITEFISH LAKE (LOWER)	89 (12)	79 (10)	79 (11)	86 (12)	93 (13)	93 (13)	519

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
1	3016	WHITEFISH LAKE (LOWER)	519
2	3008	MC DONALD LAKE	504
3	3003	FLATHEAD LAKE	497
4	3012	TALLY LAKE	429
5	3011	SWAN LAKE	397
6	3010	SEELEY LAKE	353
7	3007	MARY RONAN LAKE	275
8	3013	TIBER RESERVOIR	268
9	3004	GEORGETOWN RESERVOIR	268
10	3005	HEBGEN RESERVOIR	232
11	3006	KOOCANUSA RESERVOIR	228
12	3009	NELSON RESERVOIR	172
13	3002	CLARK CANYON RESERVOIR	171
14	3014	TONGUE RIVER RESERVOIR	110
15	3001	CANYON FERRY RESERVOIR	77

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR MONTANA

08/05/76

LAKE CODE 3005 HEBGEN LAKE

TOTAL DRAINAGE AREA OF LAKE(SQ KM) 2408.7

TRIBUTARY	SUB-DRAINAGE AREA(SQ KM)	NORMALIZED FLOWS(CMS)												MEAN
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
3005A1	2408.7	25.49	22.65	21.24	22.09	20.67	39.64	28.32	31.15	29.73	35.40	35.40	28.03	28.33
3005A2	1157.7	11.33	11.04	11.33	13.88	22.65	22.09	14.16	12.74	11.61	12.74	11.89	11.61	13.94
3005C1	29.5	0.017	0.014	0.014	0.023	0.255	0.396	0.283	0.057	0.028	0.028	0.028	0.023	0.098
3005E1	211.6	2.27	2.83	2.69	3.68	7.65	11.89	3.11	1.98	2.27	3.68	2.83	2.27	3.92
3005G1	305.4	0.57	0.42	0.85	0.85	2.55	3.96	1.70	1.56	0.85	1.13	0.99	0.71	1.35
3005Z2	704.5	6.80	6.51	6.80	8.21	14.16	13.59	8.21	7.08	6.80	7.36	7.08	6.80	8.29

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 2408.7
SUM OF SUB-DRAINAGE AREAS = 2408.7

TOTAL FLOW IN = 330.91
TOTAL FLOW OUT = 339.80

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW
3005A1	10	74	48.224	5	47.572		
	11	74	41.229	2	29.450		
	12	74	38.030	7	60.315		
	1	75	26.901	4	26.986		
	2	75	26.448	9	0.0		
	3	75	26.561	9	0.0		
	4	75	33.980	6	0.0		
	5	75	39.077	3	0.0		
	6	75	45.505	7	46.156		
	7	75	19.539	13	14.328		
	8	75	27.807	2	25.740		
	9	75	33.782	6	33.697		
3005A2	10	74	16.990	5	16.990		
	11	74	15.857	2	17.273		
	12	74	14.158	7	14.158		
	1	75	15.857	4	15.857		
	2	75	15.291	9	15.857		
	3	75	14.442	9	14.725		
	4	75	15.008	6	15.291		
	5	75	28.317	3	15.291		
	6	75	45.307	7	45.307		
	7	75	22.653	13	23.220		
	8	75	18.123	2	0.0		
	9	75	16.424	6	0.0		

TRIBUTARY FLOW INFORMATION FOR MONTANA

08/05/76

LAKE CODE 3005 HEBGEN LAKE

MEAN MONTHLY FLOWS AND DAILY FLOWS (CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW
3005C1	10	74	0.042	5	0.045		
	11	74	0.037	2	0.042		
	12	74	0.028	7	0.028		
	1	75	0.020	4	0.0		
	2	75	0.014	9	0.0		
	3	75	0.020	9	0.0		
	4	75	0.028	6	0.0		
	5	75	0.181	3	0.0		
	6	75	0.680	7	0.0		
	7	75	0.793	13	0.991		
	8	75	0.085	2	0.130		
	9	75	0.057	6	0.062		
3005E1	10	74	4.248	5	4.814		
	11	74	3.398	2	3.115		
	12	74	2.832	7	2.832		
	1	75	2.832	4	2.832		
	2	75	3.115	9	3.115		
	3	75	3.115	9	3.115		
	4	75	2.973	6	2.832		
	5	75	5.805	4	3.398		
	6	75	16.990	7	11.327		
	7	75	9.345	13	5.947		
	8	75	3.398	2	2.407		
	9	75	3.115	6	3.398		
3005G1	10	74	1.274	5	1.303		
	11	74	0.991	2	1.246		
	12	74	0.708	7	0.793		
	1	75	0.510	4	0.510		
	2	75	0.368	9	0.255		
	3	75	0.765	9	0.850		
	4	75	0.793	6	0.736		
	5	75	1.841	3	0.765		
	6	75	5.663	7	4.531		
	7	75	4.531	18	2.209		
	8	75	2.690	2	1.699		
	9	75	0.850	6	0.850		

APPENDIX D

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 76/08/05

300501
44 51 48.0 111 20 00.0 3
HEBGEN RESERVOIR
30031 MONTANA

11EPALES 2111202
0065 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CONDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CAC03 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
75/07/30	11 00	0000	17.1	9.2	156	183	9.10	69	0.030	0.200	0.020K	0.022
	11 00	0005	17.3	7.8		176	8.70	68	0.030	0.300	0.020K	0.028K
	11 00	0025	16.8	7.2		172	8.50	67	0.020	0.200K	0.020K	0.021K
	11 00	0040	8.8	7.0		163	7.80	68	0.040	0.200K	0.020K	0.023K
	11 00	0061	7.4	7.6		163	8.10	73	0.040	0.200K	0.040	0.031K
75/09/03	12 50	0000	16.7	7.6	160	178	8.40	68	0.020K	0.200K	0.020K	0.012
	12 50	0005	16.7	7.4		178	8.50	67	0.020K	0.200K	0.020K	0.013
	12 50	0020	16.6	7.8		178	8.50	65	0.020K	0.200K	0.020K	0.013
	12 50	0040	16.5	7.2		179	8.35	64	0.020K	0.200K	0.020K	0.014
	12 50	0061	12.1	3.0		166	7.70	68	0.020	0.200K	0.100	0.027
75/10/20	13 45	0000	11.3	7.6	168	183	8.20	79	0.030	0.200K	0.020K	0.023
	13 45	0005	11.3	7.8		181	8.15	79	0.030	0.200K	0.020K	0.025
	13 45	0021	11.2	7.8		182	8.10	79	0.030	0.200K	0.020K	0.024
	13 45	0040	11.1	7.7		181	8.10	79	0.040	0.200K	0.020K	0.023
	13 45	0063	11.1	7.8		182	8.10	79	0.030	0.200K	0.020K	0.023

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
75/07/30	11 00	0000	0.024	2.0	
	11 00	0005	0.019		
	11 00	0025	0.014		
	11 00	0040	0.018		
	11 00	0061	0.026		
75/09/03	12 50	0000	0.012	8.5	
	12 50	0005	0.013		
	12 50	0020	0.015		
	12 50	0040	0.014		
	12 50	0061	0.027		
75/10/20	13 45	0000	0.029	0.8	
	13 45	0005	0.031		
	13 45	0021	0.032		
	13 45	0040	0.030		
	13 45	0063	0.030		

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/08/05

300502
44 48 00.0 111 14 55.0 3
HEBGEN RESERVOIR
30031 MONTANA

11EPALES 2111202
0060 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CONDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
75/07/30	11 30	0000	16.3	8.0	168	172	8.70	68	0.020	0.200	0.020K	0.019K
	11 30	0005	16.3	7.4		183	8.70	67	0.020	0.200	0.020K	0.021K
	11 30	0020	16.3	4.4		180	8.50	65	0.020	0.200	0.020K	0.013
	11 30	0040	9.1	4.4		149	7.80	67	0.050	0.300	0.020K	0.017J
	11 30	0056	7.6	4.4		159	7.50	70	0.100	0.400	0.040	0.036J
75/09/03	13 15	0000	17.0	7.6	135	180	8.50	76	0.020K	0.200	0.020K	0.011
	13 15	0005	16.6	7.8		178	8.60	77	0.020K	0.200	0.020K	0.014
	13 15	0022	16.4	7.8		177	8.45	77	0.020K	0.200	0.020K	0.011
	13 15	0045	15.4	5.0		180	7.80	78	0.020K	0.200	0.020	0.020
	13 15	0064	10.8	1.2		174	7.60	86	0.060	0.300	0.110	0.048
75/10/20	13 15	0000	10.8	8.2	120	185	8.30	80	0.020K	0.200K	0.020K	0.024
	13 15	0005	10.7	8.1		184	8.30	80	0.020K	0.200K	0.020K	0.020
	13 15	0020	10.7	8.0		187	8.20	80	0.020K	0.200K	0.020K	0.019
	13 15	0035	10.5	8.1		183	8.20	81	0.020K	0.200K	0.020K	0.018
	13 15	0051	10.4	8.3		180	8.30	79	0.020K	0.200K	0.020K	0.018

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
75/07/30	11 30	0000	0.016	3.5	
	11 30	0005	0.017		
	11 30	0020	0.015		
	11 30	0040	0.019		
	11 30	0056	0.065		
75/09/03	13 15	0000	0.019	7.1	
	13 15	0005	0.021		
	13 15	0022	0.018		
	13 15	0045	0.033		
	13 15	0064	0.088		
75/10/20	13 15	0000	0.035	1.0	
	13 15	0005	0.040		
	13 15	0020	0.026		
	13 15	0035	0.029		
	13 15	0051	0.025		

* VALUE KNOWN TO BE LESS
THAN INDICATED

* VALUE KNOWN TO BE IN ERROR

STORET RETRIEVAL DATE 76/08/05

300503
44 47 15.0 111 11 22.0 3
HEBGEN RESERVOIR
30031 MONTANA

11EPALES 2111202
0018 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CONDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CAC03 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
75/07/30	12 00	0000	16.4	8.0		105	8.70	47	0.030	0.500	0.020K	0.008
	12 00	0005	16.4	8.2		98	8.90	48	0.020	0.400	0.020K	0.009
	12 00	0014	14.3	6.7		92	7.90	54	0.040	0.400	0.020K	0.011
75/09/03	11 10	0000	15.3	8.2	20	128	8.60	59	0.020K	0.200K	0.020K	0.008
	11 10	0005	14.8	8.0		126	8.60	60	0.020K	0.200	0.021K	0.005
	11 10	0011	14.6	8.2		130	8.60	58	0.020K	0.300	0.020K	0.005
75/10/20	12 00	0000	7.9	10.1	156	131	8.25	104	0.020K	0.200K	0.020K	0.006
	12 00	0005	7.9	9.6		133	8.40	75	0.020K	0.200	0.020K	0.010
	12 00	0012	7.9	9.2		132	8.40	77	0.020K	0.200	0.020K	0.009

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
75/07/30	12 00	0000	0.037	4.4	
	12 00	0005	0.018		
	12 00	0014	0.016		
75/09/03	11 10	0000	0.020	11.4	
	11 10	0005	0.027		
	11 10	0011	0.020		
75/10/20	12 00	0000	0.022	2.4	
	12 00	0005	0.026		
	12 00	0012	0.027		

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/08/05

300504
44 44 25.0 111 10 40.0 3
HEBGEN RESERVOIR
30031 MONTANA

11EPALES 2111202
0020 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	90300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CONDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CAC03 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
75/07/30	12 15	0000	16.8	10.0		302	8.80	92	0.030	0.300	0.020K	0.031K
	12 15	0005	16.8	7.2		296	8.80	93	0.030	0.300	0.020K	0.033
	12 15	0016	13.8	6.2		187	8.20	66	0.040	0.300	0.020K	0.027
75/09/03	10 55	0000	14.8	6.8	120	281	8.55	96	0.020K	0.200K	0.020K	0.019
	10 55	0005	14.6	9.0		281	8.10	96	0.020K	0.200K	0.020K	0.021
75/10/20	11 45	0000	8.5	9.4	120	277	8.30	107	0.020	0.200	0.020K	0.030
	11 45	0005	8.5	9.0		278	8.30	107	0.020K	0.200K	0.020K	0.021
	11 45	0015	8.5	9.4		279	8.30	110	0.020K	0.200K	0.020K	0.023

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
75/07/30	12 15	0000	0.019	3.2	
	12 15	0005	0.021		
	12 15	0016	0.024		
75/09/03	10 55	0000	0.016	4.3	
	10 55	0005	0.021		
75/10/20	11 45	0000	0.026	0.4	
	11 45	0005	0.021		
	11 45	0015	0.023		

K VALUE KNOWN TO BE
LESS THAN INDICATED

APPENDIX E

TRIBUTARY DATA

STORET RETRIEVAL DATE 76/08/05

300541
 44 52 10.0 111 20 30.0 4
 MADISON RIVER
 30 15 HEBGEN DAM
 O/HEBGEN LAKE 090191
 BNK END OF GRVL RD .7 M NW OF HEBGEN DAM
 11EPALES 2111204
 0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/02	09 45		0.016	0.600	0.025	0.010	0.010
74/10/05	11 40		0.016	0.250	0.010	0.005	0.010
74/12/07	10 15		0.024	0.200	0.015	0.010	0.010K
75/01/04	10 50		0.040	1.000	0.010	0.010	0.020
75/02/09	11 25		0.040	1.200	0.008	0.016	0.040
75/03/09	10 50		0.032	0.300	0.016	0.008K	0.020
75/04/06	15 55		0.025	1.200	0.025	0.015	0.015
75/05/03	12 45		0.010	0.400	0.010	0.008	0.010K
75/06/07	12 55		0.010	0.450	0.015	0.015	0.060
75/07/13	16 15		0.010	3.000	0.055	0.025	0.040
75/08/02	14 25		0.005	0.100	0.005	0.015	0.020
75/09/06	12 50		0.010	0.350	0.015	0.020	0.020

K VALUE KNOWN TO BE
 LESS THAN INDICATED

STORET RETRIEVAL DATE 76/08/05

300542
 44 43 00.0 111 06 05.0 4
 MADISON RIVER
 30 15 W YELLOWSTONE
 T/HEBGEN LAKE 090192
 HWY 191 BRDG 3.6 MI N OF W YELLOWSTONE
 11EPALES 2111204
 0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 N02&N03 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/02	09 05		0.016	0.400	0.017	0.010	0.010
74/10/05	12 45		0.024	0.400	0.040	0.015	0.030
74/12/07	09 35		0.010	1.100	0.040	0.013	0.013
75/01/04	09 30		0.016	1.100	0.025	0.015	0.020
75/06/07	12 10		0.035	0.375	0.030	0.025	0.095
75/07/13	15 40		0.015	0.700	0.030	0.015	0.040
75/08/02	12 00		0.025	0.100	0.020	0.020	0.040
75/09/06	11 30		0.030	0.100	0.017	0.015	0.015

STORET RETRIEVAL DATE 76/08/05

3005C1
44 48 10.0 111 17 00.0 4
WATKINS CREEK
30 15 HEBGEN DAM
T/HEBGEN LAKE 090191
SEC RD BRDG 1 MI S OF WATKINS CRK RANCH
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 N02&N03 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/02	13 15		0.016	0.100	0.015	0.005K	0.010K
74/10/05	14 45		0.020	0.400	0.015	0.005K	0.005K
74/12/07	13 15		0.064	0.400	0.040	0.005K	0.010K
75/07/13	13 30		0.020	0.450	0.045	0.005	0.010K
75/08/03	16 00		0.020	0.200	0.025	0.010	0.010

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/08/05

300501
44 42 35.0 111 13 00.0 4
DENNY CREEK
30 15 W YELLOWSTONE
T/HEBGEN LAKE 090192
UNIMPRVD RD XING 6.5 MI NW OF W YLLWSTONE
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS URTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/05	13 05		0.056	1.100	0.025	0.005K	0.005K
75/07/13	14 30		0.010	1.050	0.030	0.005	0.020
75/08/07	17 00		0.045	0.450	0.015	0.010	0.030
75/09/06	14 00		0.040	0.250	0.040	0.010	0.010

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/08/05

3005E1
44 40 50.0 111 11 35.0 4
S FORK MADISON RIVER
30 15 W YELLOWSTONE
T/HEBGEN LAKE 090192
HWY 20/191 BRDG 4.5 MI WNW OF W YLLWSTNE
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/02	12 30		0.032	0.700	0.025	0.005K	0.010K
74/10/05	12 10		0.044	0.600	0.025	0.010	0.010
74/12/07	14 00		0.032	0.650	0.020	0.005K	0.010K
75/01/04	13 00		0.184	0.600	0.010	0.010	0.040
75/02/09	13 30		0.040	1.800	0.032	0.008K	0.020
75/03/09	11 25		0.032	0.200	0.016	0.008K	0.010
75/04/06	15 00		0.120	1.850	0.030	0.020	0.030
75/05/04	13 00		0.035	0.650	0.030	0.005	0.010K
75/06/07	12 30		0.020	0.100	0.010	0.010	0.030
75/07/13	14 40		0.025	0.750	0.020	0.010	0.020
75/08/07	17 45		0.030	0.550	0.015	0.015	0.030
75/09/06	13 20		0.040	0.050	0.025	0.015	0.020

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/08/05

3005F1
44 46 10.0 111 06 45.0 4
COUGAR CREEK
30 15 TEPEE CREEK
T/HEBGEN LAKE 090191
HWY 191/287 BRDG 8 MI N OF W YELLOWSTONE
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/02	09 40		0.032	0.100K	0.065	0.015	0.015
74/10/05	12 00		0.024	0.100K	0.015	0.010	0.020
74/12/07	10 05		0.040	0.500	0.045	0.015	0.020
75/01/04	10 35		0.056	0.600	0.040	0.028	0.030
75/02/09	11 10		0.056	0.900	0.048	0.016	0.040
75/03/09	10 47		0.056	0.500	0.048	0.008	0.030
75/04/06	15 40		0.060	0.800	0.050	0.025	0.030
75/05/03	12 35		0.040	0.300	0.025	0.020	0.030
75/06/07	12 45		0.015	0.250	0.010	0.010	0.080
75/07/13	16 05		0.010	2.100	0.035	0.010	0.020
75/08/02	14 10		0.010	0.050	0.010	0.020	0.020
75/09/06	12 40		0.020	0.050	0.015	0.010	0.010

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/08/05

3005G1
44 46 45.0 111 06 45.0 4
DUCK CREEK
30 15 TEPEE CREEK
T/HEBGEN LAKE 090191
HWY 191/287 BRDG 9 MI N OF W YELLOWSTONE
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&N03 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/02	09 35		0.024	0.200	0.015	0.010	0.020
74/10/05	12 15		0.020	0.300	0.015	0.010	0.020
74/12/07	10 00		0.056	0.100K	0.015	0.010	0.020
75/01/04	10 30		0.080	1.000	0.030	0.015	0.050
75/02/09	11 05		0.080	0.700	0.032	0.016	0.040
75/03/09	10 45		0.056	0.900	0.032	0.016	0.030
75/04/06	15 30		0.060	3.300	0.065	0.020	0.040
75/05/03	12 30		0.030	0.900	0.025	0.020	0.030
75/06/07	12 40		0.015	0.300	0.015	0.026	0.060
75/07/13	16 00		0.010	2.900	0.045	0.025	0.030
75/08/02	14 05		0.005	0.150	0.010	0.020	0.040
75/09/06	12 30		0.010	0.175	0.015	0.015	0.020

K VALUE KNOWN TO BE
LESS THAN INDICATED