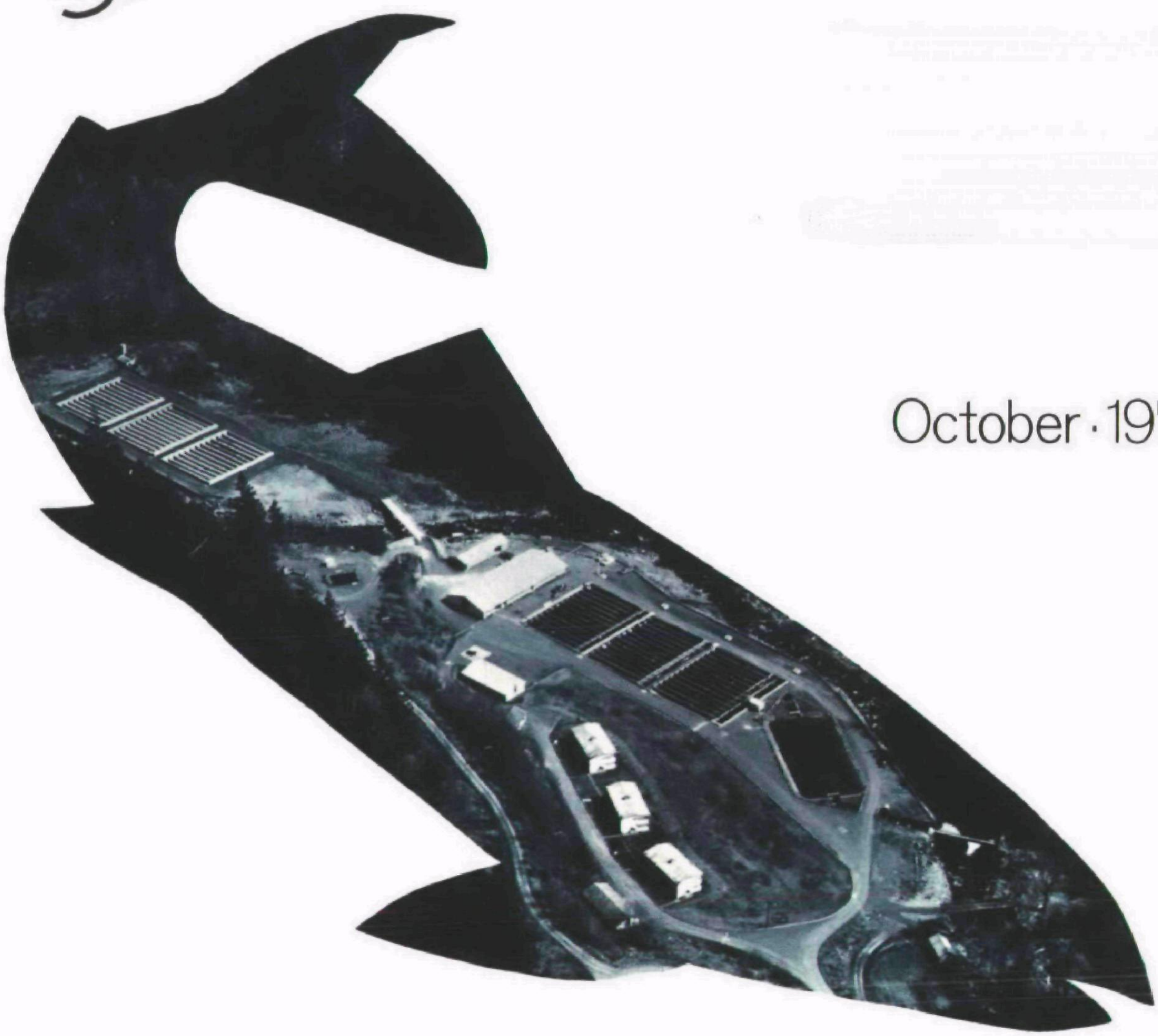
FEDERAL WATER QUALITY ADMINISTRATION
NORTHWEST REGIONAL OFFICE

an evaluation of Salmonid Hatchery Wastes



October · 1970

An Evaluation of Salmonid Hatchery Wastes

Prepared by
Danforth G. Bodien
Technical Assistance and Investigations

U.S. Department of the Interior
Federal Water Quality Administration
Northwest Region
Portland, Oregon
October, 1970

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Problem

Throughout the Northwest Region 114 State and Federal hatcheries produce an estimated 8.6 million pounds of salmonid fish annually. In addition, the Region contains numerous private hatcheries and fish farms. In the Hagerman Valley alone such hatcheries produce over 4.5 million pounds annually with a developmental potential of 20 million pounds. Large quantities of water are utilized in raising fish, and generally the water used is discharged without treatment to the receiving stream. In most cases no problems have been associated with this method of operation. Within the past few years, during low summer flows, however, wastes discharged from some hatcheries have created nuisance conditions in receiving waters. These conditions prompted the Bureau of Commercial Fisheries (BCF) and the Bureau of Sport Fisheries and Wildlife (BSF & W) to seek assistance from the Federal Water Quality Administration (FWQA, formerly Federal Water Pollution Control Administration) to define the problem and recommend methods for correction.

Problems associated with hatchery discharges are not unique to the Pacific Northwest. Investigations in other parts of the country have dealt with similar problems. Data from these studies were used when applicable.

Authority

Section 5(a) of the Federal Water Pollution Control Act, as amended, and Executive Order No. 11507 authorizes FWQA to assist Federal agencies with waste disposal problems.

In a letter dated December 24, 1968, the Program Director of BCF requested the Regional Director, FWQA, Northwest Region to conduct a survey of hatchery pollution problems. (Appendix).

Scope

The study area, illustrated in Figure 1, included the States of Idaho, Oregon, Washington and western Montana. Primary attention was given to four hatcheries which were selected as representative of hatcheries in the study area, Eagle Creek National Fish Hatchery, near Estacada, Oregon; Abernathy Creek Salmon Cultural Laboratory, near Longview, Washington; Little White Salmon National Fish Hatchery, near White Salmon, Washington; and Dworshak National Fish Hatchery at Asahka, Idaho. All four of these hatcheries are operated by BSF & W.

Objectives

The objectives of the study were to answer the following questions:

1. What is the total waste load produced by fish hatcheries in the study area?
2. What are the waste characteristics of fish hatchery effluents?

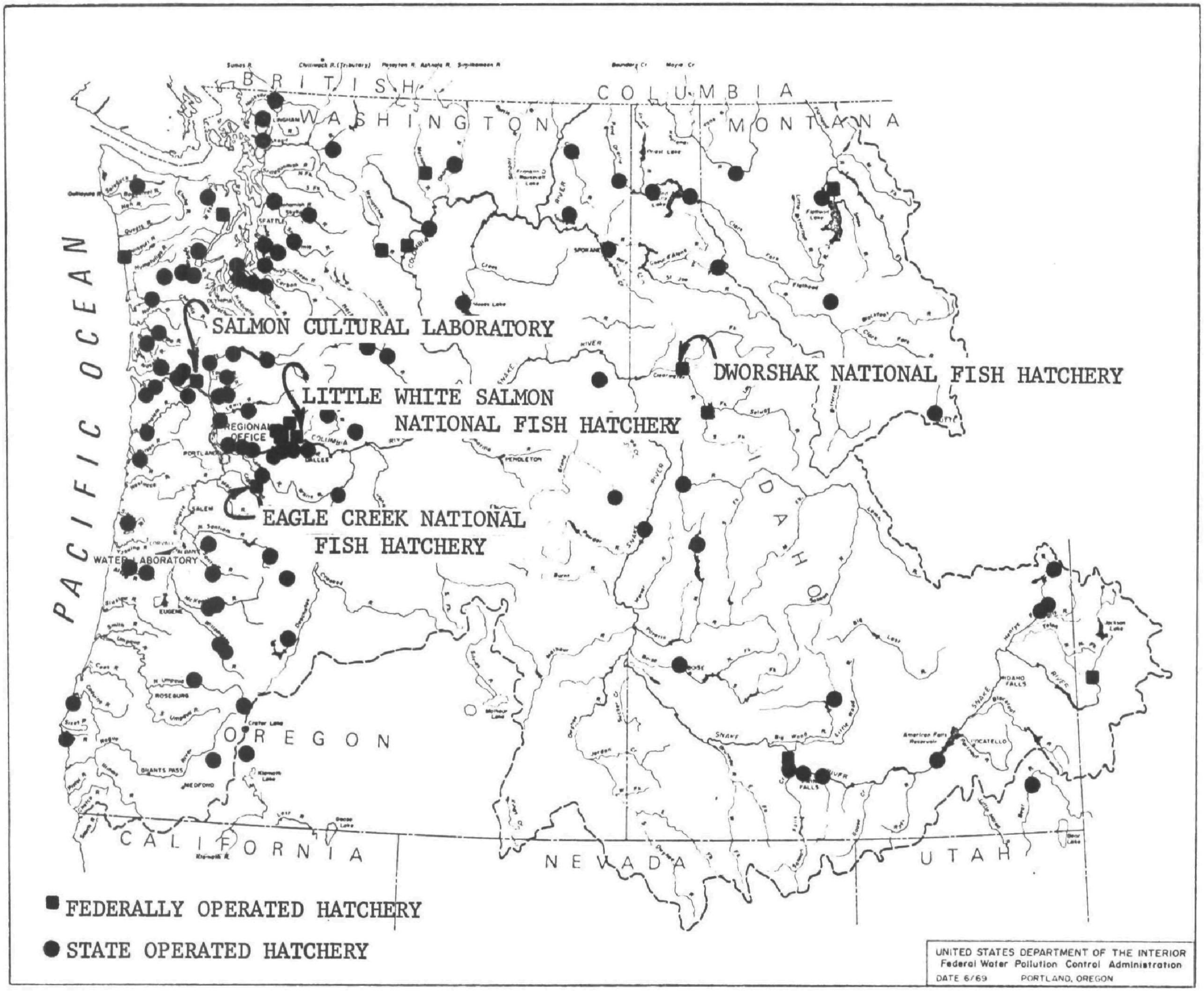


Figure 1

Location of Salmonid Hatcheries in the Pacific Northwest Indicating Those Surveyed

3. What effect does the discharge of hatchery wastes have on receiving waters?
4. What methods are available for controlling wastes from fish hatcheries?

Acknowledgements

Acknowledgement is made of the valuable assistance and guidance provided by the BSF & W and the BCF.

Thanks are expressed also to the personnel at the four hatcheries surveyed.

SUMMARY

Findings and Conclusions

1. Approximately 23 tons of Biochemical Oxygen Demand (BOD), with a population equivalent of approximately 270,000, are discharged per day by the 114 Federal and State hatcheries in the study area.
2. Waste concentrations of hatchery effluents are small; however, total pounds discharged per day can be of significant magnitude.
3. Hatchery discharges increase Chemical Oxygen Demand (COD), total phosphorus (TP), orthophosphate, total kjeldahl nitrogen (TKN) and ammonia nitrogen by 2.0, .036, .015, .20, and .058 lbs/100 lbs fish/day, respectively.
4. Hatchery discharges can result in increased productivity in receiving waters.
5. Hatchery discharges can increase the coliform bacteria count in receiving waters to a small degree.
6. The discharge of waste resulting from the flushing of raceways adds large amounts of solids and BOD to receiving waters.
7. Fish hatchery wastes are extremely amenable to biological treatment.
8. The quantity and pollutional effects of hatchery wastes can be greatly reduced when a water reconditioning/reuse system, including sedimentation of skimming and backwash water is utilized.
9. A water reconditioning/reuse system employing an oyster shell

filter converts virtually all of the ammonia nitrogen to the nitrate and nitrate forms, as well as stabilizing pH, and removing a portion of the solids.

10. Approximately 92 percent of BOD, 89 percent of suspended solids (SS), 76 percent of TKN, and 84 percent of TP can be removed from filter backwash water with 30 minutes of settling. These removal efficiencies exceed the requirements for secondary treatment.
11. The impact of hatchery discharges depends upon the quantity and quality of the receiving water.

Recommendations

Hatcheries must be considered as a waste source. Water pollution control measures should be considered for new hatcheries and at existing hatcheries on a priority basis. Discharges from Federal fish hatcheries must comply with applicable water quality standards in accordance with Executive Order 11507.

HATCHERIES SURVEYED

Salmon Cultural Laboratory

The Salmon Cultural Laboratory operated as a research hatchery by the BSF & W, is located on Abernathy Creek, near Longview, Washington.

About 22,000 pounds of fall chinook are raised annually at the Salmon Cultural Laboratory. In addition, research is carried out in areas such as fish diet, fish stamina, water supply, water sterilization, etc. One major development emanating from the laboratory was a water reconditioning/reuse system developed by Burrows (4). The system employs three 750 sg. ft. oyster shell filters which biologically convert the ammonia (NH_3) in the water to nitrates (NO_3^-). The water from the filter is then passed through an aeration tower which strips out the carbon dioxide (CO_2) and adds dissolved oxygen (DO). Discussion of this reconditioning/reuse system is presented in the section entitled "Treatment Methods and Needs."

The Salmon Cultural Laboratory obtains its water from wells. The water is aerated, filtered for iron removal, and then heated or cooled to bring the total sytem to the optimum temperature for fish production. The make-up water at the Salmon Cultural Laboratory runs about 5 percent, or 90 gallons per minute (gpm) for the 1800 gpm system.

Wastes from the Salmon Cultural Laboratory, consisting of 5 percent of the raceway effluent and backwash from the oyster shell filters, are discharged without treatment into Abernathy Creek.

The Salmon Cultural Laboratory uses automatic feeders. These disperse feed at 15-minute intervals. While moist pellets are used at the present, a change to dry pellets is planned for the near future. The possible effects of this change on water quality are not known.

Eagle Creek National Fish Hatchery

The Eagle Creek National Fish Hatchery is located on Eagle Creek, a tributary of the Clackamas River, 13 miles east of Estacada, Oregon.

This hatchery has two sections. The upper section consists of three banks of rearing ponds, each with 12 raceways. The lower section includes the hatchery, three banks of rearing ponds, each with 13 raceways, plus the fish ladder, holding pond, and spawning facilities.

Water for this hatchery is obtained solely from Eagle Creek and is used without treatment. Obtaining an adequate supply from this source is a large problem at the hatchery, especially during the dry summer months. When the water supply becomes extremely low, fresh water is added only at the head end of the upper section, and the water passes in series through both the upper and lower sections before discharge. When the water supply is normal, each raceway receives fresh water. Water temperature is also a problem at the hatchery, as low winter temperatures severely retard fish growth.

Wastes from the rearing ponds, holding pond, and hatchery room are discharged without treatment into Eagle Creek.

During 1969, 46,000 pounds of silver salmon, 43,000 pounds of spring chinook salmon, and 27,000 pounds of steelhead were raised at the Eagle Creek Hatchery. The heaviest fish load at the hatchery is during late summer and early fall.

The feed used at the Eagle Creek Hatchery is a moist pellet. Feeding is accomplished by hand, and frequency of feeding varies from hourly for small fish to two or three times a day for larger fish.

Little White Salmon National Fish Hatchery

The Little White Salmon National Fish Hatchery, is located in the State of Washington on the Little White Salmon River about one mile above its confluence with the Columbia River.

The facility has two sections. The upper section is composed of the fish ladder, holding ponds, spawning facilities, and 41 rearing ponds. The lower section includes the hatchery room, six rearing ponds, and a water reconditioning/reuse system. The water reconditioning/reuse system is used only for the hatching of eggs. It consists of three rearing ponds converted to oyster shell filters and an aeration tower.

The hatchery utilizes three water supply sources: two springs and the Little White Salmon River. This water is used without treatment. Fish are reared in spring water and converted to river water before release. Water supply at the hatchery has never been a problem from the standpoint of either quantity or quality, and all ponds are run on a once-through basis.

The wastes from the rearing ponds, holding ponds, and the hatchery room are discharged without treatment into Drano Lake, a backwater on the Little White Salmon.

During the year 1969, 70,000 pounds of fall chinook, 13,000 pounds of spring chinook and 32,000 pounds of silver salmon were raised at the Little White Salmon National Fish Hatchery. The heaviest fish load at the hatchery is from December to January. During summer months only 20 of the total 56 rearing ponds are utilized; however, the same pond loadings are used as during months of heavy loads. These loadings run from 7 to 12 pounds of fish per cubic foot of tank, with a flow of approximately 470 gpm per tank.

The feed used at the hatchery is the moist pellet. Feeding is done by hand about twice per day.

<u>Dworshak National Fish Hatchery</u>

Dworshak National Fish Hatchery is located in Asahka, Idaho, at the mouth of the North Fork Clearwater River.

This facility, less than a year old, is the largest hatchery presently utilizing a water reconditioning/reuse system. The hatchery has 84 rearing ponds, 25 of which are on the reuse system. The ultimate plan calls for 50 ponds on reuse and 34 on river water. Eight oyster shell filters, each with a surface area of 1650 sq. ft. are used for treatment of the rearing pond effluent. Eight additional filters are planned for the 25 ponds to be added to the reuse system.

Water for make-up in the reuse system and for the ponds not on the system comes from the North Fork Clearwater River. Make-up water for the reuse system is filtered and sterilized with ultra-violet light before it is combined with the reconditioned water from the oyster shell filters. At the present time, the make-up water constitutes ten percent of the total water in the system.

Backwash water from the oyster shell filters, hatchery room wastes, and effluent from the rearing ponds not on the water reuse system is discharged without treatment into the North Fork Clearwater River.

Although the hatchery has not operated for a full year, the calculated production for fiscal year 1970 is 295,000 pounds. For fiscal years 1971 and 1972, production is estimated at 520,000 and 620,000 pounds, respectively. The majority of fish raised are steelhead; rainbow trout make up the rest.

Dworshak uses an automatic feeding system. Moist pelletized food is now used; however, a conversion to a dry pellet is expected in the near future. Frequency of feeding varies with the size of the fish, ranging from once an hour for small fish to four times per day for the large fish.

SAMPLING PROGRAM AND ANALYTICAL METHODS

Sampling sites were selected to determine incremental changes in the water quality through individual rearing ponds, a group of ponds, or the hatchery as a whole. Table 1 lists the sampling sites. Stream sampling was done above and below two hatcheries to measure pollutional effects and stream recovery.

For the most part, grap samples were taken for analysis. One 24-hour composite was made with physical-chemical samples taken every two hours and bacteriological samples taken every four hours.

Biological sampling was done in the receiving stream above and below Eagle Creek Hatchery to assess the effects of hatchery discharges on the aquatic community. Biological samples were collected with a Surber[1/] sampler, preserved in the field with ten percent formalin, and returned to Portland to be identified and enumerated.

Physical-chemical and bacteriological samples were collected with a Kemmerer sampler. The bacteriological samples were iced and sent to the FWQA, Pacific Northwest Water Laboratory (PNWL) in Corvallis, Oregon, or returned to Portland to be incubated and analyzed. During the 24-hour composite, bacteriological samples were incubated and analyzed in the field.

Dissolved oxygen and temperature were measured in the field.

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 FWQA.

TABLE 1

HATCHERY SAMPLING SITES

Abernathy Creek Salmon Cultural Laboratory		
Station	1	Well water after treatment
	2	Rearing Pond effluent - influent to filter
	3	Filter effluent
	4	Aeration tower effluent
	5	Filter backwash water
	6	Abernathy Creek above hatchery
	7	Abernathy Creek - 30 yards below hatchery
	8	Abernathy Creek - 3 miles below hatchery
Eagle Creek National Fish Hatchery		
Station	1	Hatchery influent water
	2	Upper Pond effluent
	3	Lower Pond effluent
	4	Eagle Creek between Upper and Lower Ponds, below upper bridge
	5	Eagle Creek - 50 yards below hatchery, below lower bridge
	6	Eagle Creek - 3.4 miles below hatchery
Little White Salmon National Fish Hatchery		
Station	1	Upper pond influent
	2	Upper pond effluent
	3	Spring Water
	4	Lower pond influent
	5	Lower pond effluent
Dworshak National Fish Hatchery		
Station	1	Hatchery influent before treatment
	2	Hatchery influent after treatment
	3	Rearing pond effluent - influent to filter
	4	Filter effluent
	5	Filter backwash water

The Alsterberg (Azide) modification of the Winkler Method was used for DO determinations and a laboratory thermometer was used for temperature.

All other samples were sent to the PNWL for analysis. Nutrient samples were preserved in the field with mercuric chloride ($HgCl_2$). COD and Total Organic Carbon (TOC) samples were preserved in the field with sulfuric acid (H_2SO_4). Samples for BOD analysis were preserved by icing before shipment. Upon arrival at the PNWL, BOD samples were set up and incubated at 20^o C.

WASTE CHARACTERISTICS

Wastes from fish production are from metabolic waste products and residual food. The metabolic products consist mainly of ammonia-nitrogen and urea (5). These products vary in amount depending on water temperature, size and species of fish, type and amount of food consumed, etc.

Excess food is also a source of wastes. Residual food sinks to raceway bottoms where the soluble portion leaches out. The remainder of this food ends up in the receiving water when raceways are periodically flushed out.

Physical-Chemical Characteristics

Of primary concern were the physical-chemical characteristics of hatchery effluents. These effluents include, for the most part, the normal raceway discharges and the backwash water from a hatchery employing a water reconditioning/reuse system. The parameters measured included temperature, dissolved oxygen, BOD, COD, nutrients, total and fecal coliforms.

Hatchery effluents were characterized by analysis of both grab and composite samples. For the most part, grab samples were taken. One set of 24-hour composite samples were collected, however, so that diurnal changes could be noted. To reduce the data for comparisons among hatcheries, the waste units of lbs/100 lbs fish/day were used. Because of the large flows encountered at the hatcheries surveyed, incremental changes were small and in many cases were less than analytical accuracy. For this reason wide variations can be noted in the data. An average of the data, however, reveals answers comparable to the findings of other studies of a similar nature.

Figure 2 shows a daily record of temperature for five sampling stations at the Eagle Creek Hatchery. This record shows a rather large (6.5^{o} C) diurnal change in temperature. No significant change in temperature is noted through the hatchery.

Concurrently with temperature, dissolved oxygen was measured every two hours at Eagle Creek. Figure 3 indicates results of these analyses. While no significant change is noted through the total hatchery, a definite decrease is shown through the upper ponds. Figure 4, which indicates only the upper pond influent and effluent DO's, shows this most clearly. Here, an average decrease of 0.6 mg/l for the period surveyed can be noted. The reason that a similar decrease was not measured through the lower pond is that the lower pond effluent passes through a holding basin (which contains three small aerators) and through the fish ladder before it is discharged to Eagle Creek.

Table 2 contains data collected at Eagle Creek and the Little White Salmon Hatchery. Averages for COD, SS, orthosphosphate, TKN, and NH_3-N in lbs per 100 lbs of fish per day ran 2.0, 0.026, 0.015, 0.20 and 0.058, respectively. No BOD samples were taken at Eagle Creek or Little White Salmon, but the COD value of 2.0 lbs/100 lbs fish/day correlates well with the BOD value of 1.34 lbs/100 fish/day

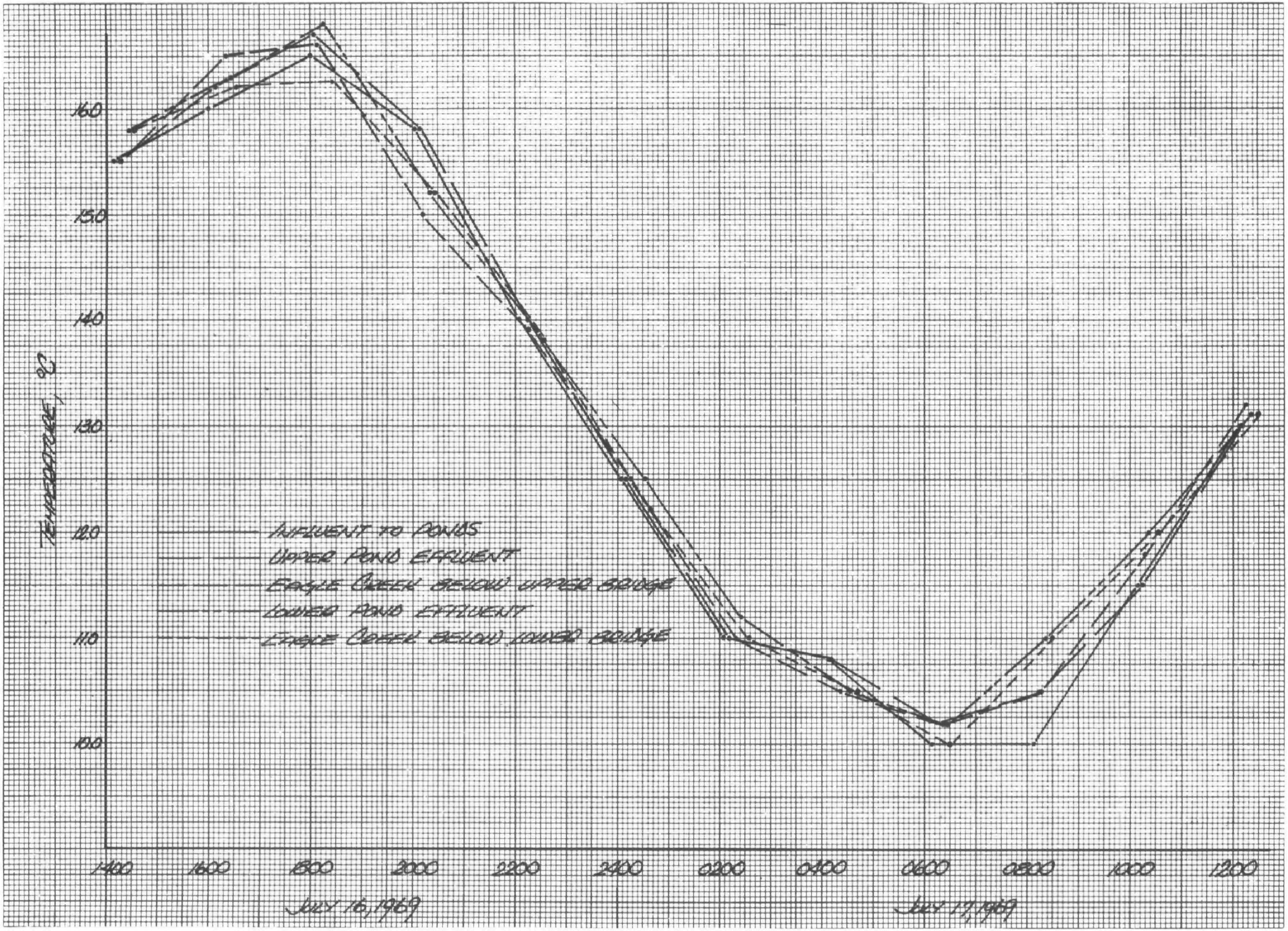


FIGURE 2. Diurnal Temperature Curves for Five Stations at the Eagle Creek Hatchery.

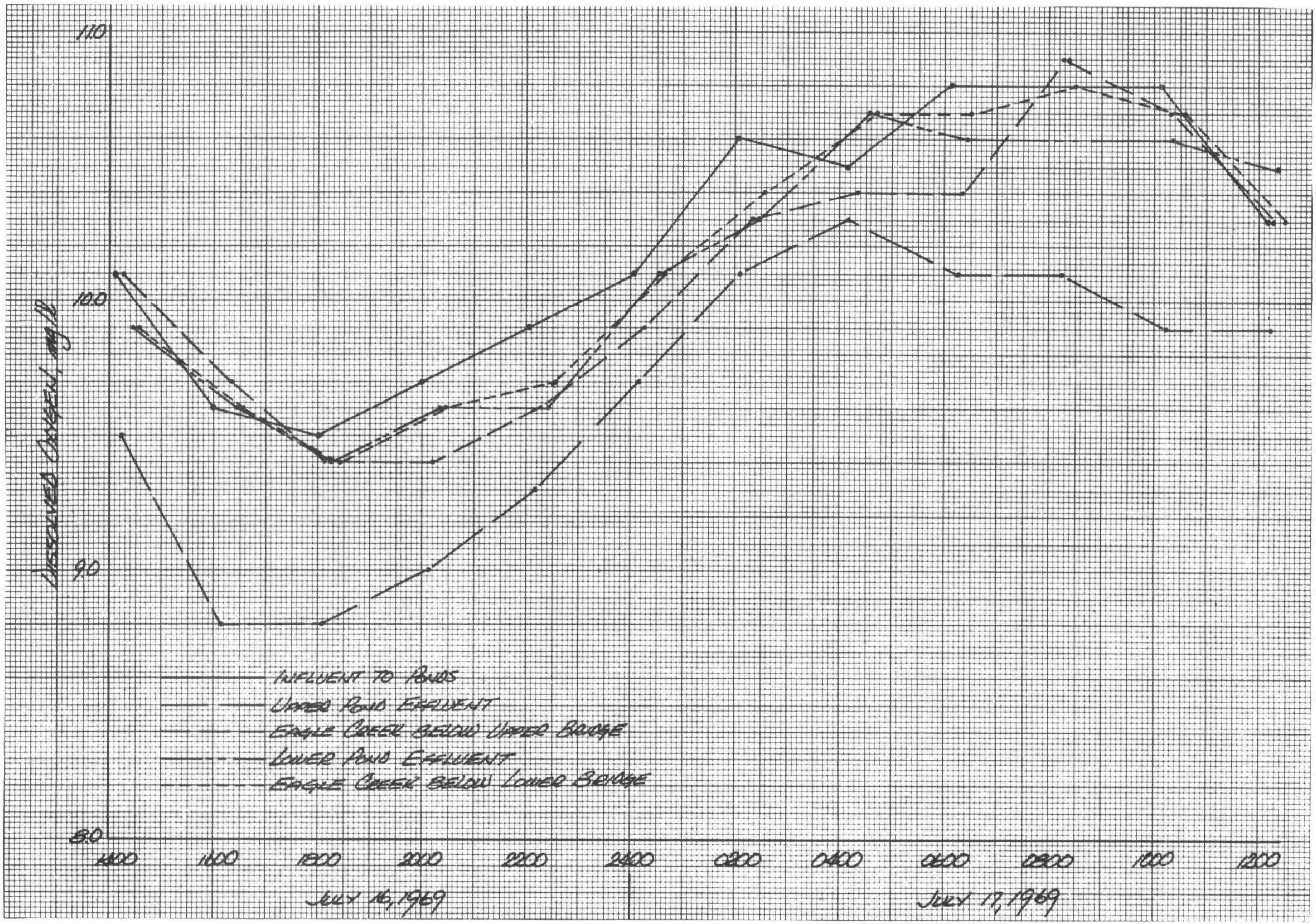


FIGURE 3. Diurnal Dissolved Oxygen Curves for Five Stations at the Eagle Creek Hathcery.

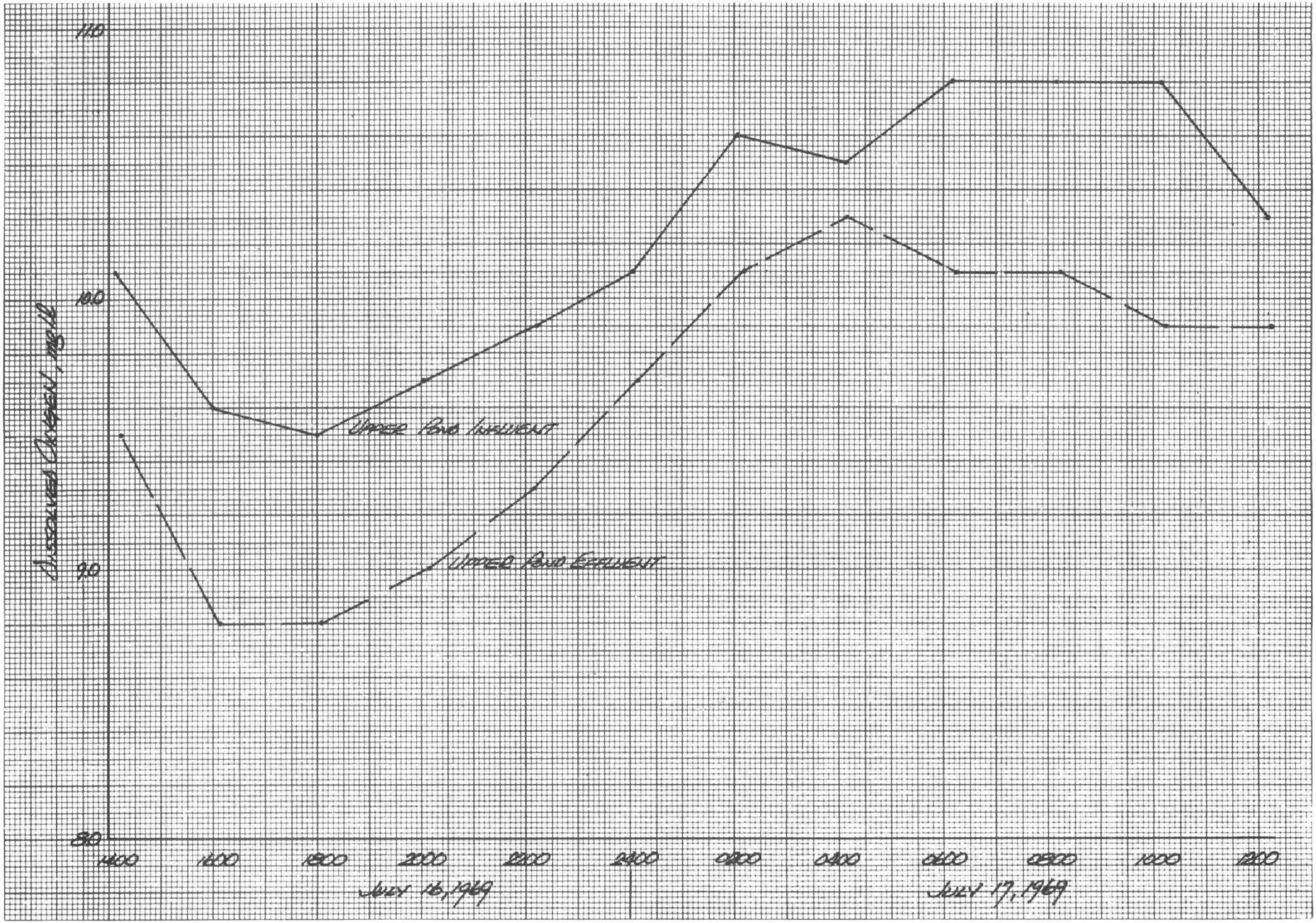


FIGURE 4. Diurnal Dissolved Oxygen Curves for Upper Pond Influent and Effluent at the Eagle Creek Hatchery.

TABLE 2

WASTE LOADING FACTORS OF HATCHERIES SURVEYED WITH RECONDITIONING/REUSE

Hatchery	Location	Date	Pounds Fish	Flow mgd	#/100# Fish/Day				
					COD	Total Phosphorus	Orthophosphate	TKN	NH_3-N
Eagle Creek[a/]	Upper Ponds	7/17/69	4,000	7.8	3.2	.037	.019	---	.080
Eagle Creek[a/]	Lower Ponds	7/17/69	6,500	8.4	6.5	.015	.006	---	----
Little White Salmon	Upper Raceway	8/14/69	1,337	.68	---	.069	.032	.21	.120
Little White Salmon	Lower Raceway	8/14/69	1,337	.68	---	.042	.003	---	.050
Eagle Creek	Upper Ponds	8/28/69	7,700	7.8	.84	.076	.043	.50	----
Eagle Creek	Lower Ponds	8/28/69	12,700	8.4	0	.019	.011	.22	----
Eagle Creek	Upper Ponds	9/11/69	14,600	7.1	.82	.016	.010	.17	.074
Eagle Creek	Lower Ponds	9/11/69	14,400	7.7	.88	.023	.015	.13	.040
Little White Salmon	Upper Raceway	9/16/69	1,581	.68	----	----	.001	.07	.015
Little White Salmon	Lower Raceway	9/16/69	1,581	.68	----	.027	.005	.07	.025
			Averages		2.0	.036	.015	.20	.058

a/ 24-hour composite sample

reported by Kramer, Chin and Mayo (1) in a study of a Washington trout hatchery.

Bacteriological samples were taken during the 24-hour study at Eagle Creek. Samples were collected every four hours and analysed for total and fecal coliforms. Figure 5 shows total coliform counts for the five sampling sites. The data show that a source of contamination existed above the hatchery during the first few hours of sampling. Comparison of values from above and below the hatchery suggests that regrowth of coliforms may be occurring as a result of the hatchery discharge.

A large amount of the waste from hatcheries results from the flushing of solids from the raceways. Huber and Valentine (3) measured 2.7 pounds of BOD and 8.9 pounds of total solids from the flushing of one raceway which contained a seven-day accumulation of solids. They also showed that 93 percent of the solids could be removed with 15 minutes of detention time.

Hatcheries utilizing water reconditioning/reuse systems have two primary sources of waste. These are filter backwash water and the raceway effluent, used as skimming water for the filters. Skimming water is discharged to allow for the addition of 5 to 10 percent make-up water. It is approximately equal in volume to the amount of make-up water minus the amount of water used in the backwashing process.

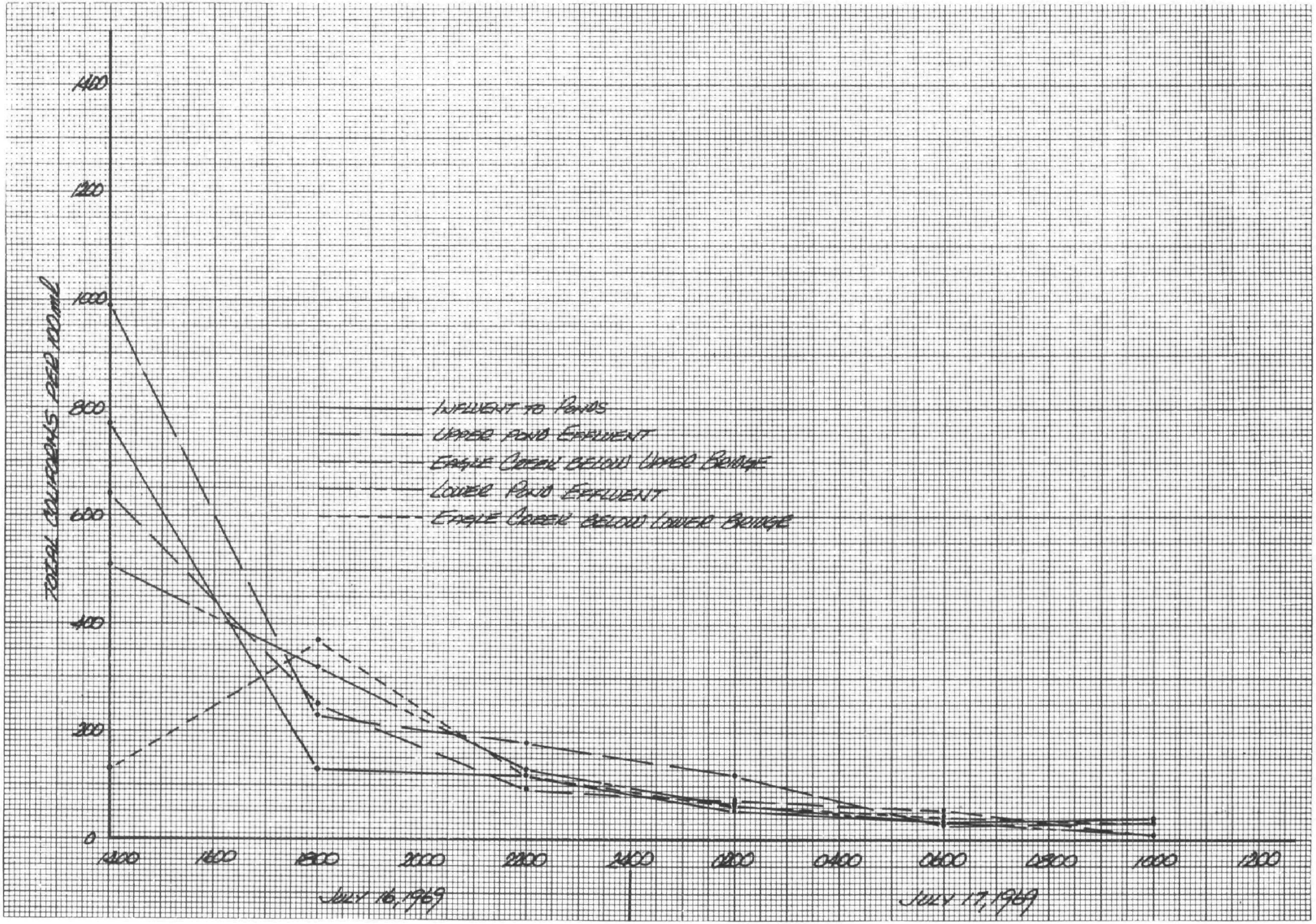


FIGURE 5. Diurnal Total Coliform Counts for Five Stations at the Eagle Creek Hatchery.

Backwash wastes were analysed at two of the hatcheries surveyed. The results of the analyses are in Table 3. The wastes from the two hatcheries were very similar with respect to DO, BOD, COD, and nitrogen compounds. The Salmon Cultural Laboratory waste had higher total solids but was lower in suspended solids than the Dworshak waste. The Salmon Cultural Laboratory waste also had a high total coliform count (43,000/100 ml). Both five-day and ultimate BOD values for the two hatcheries are almost identical. For the Salmon Cultural Laboratory and the Dworshak Hatchery, five-day values were 31 and 36 mg/l, and ultimate values were 160 and 150 mg/l, respectively. Figure 6 shows a plot of BOD vs time for each of the two backwash wastes. While the Salmon Cultural Laboratory waste showed a definite carbonaceous and nitrogeneous demand, the waste from Dworshak did not. This disparity may have been caused by holding the Dworshak sample in an iced condition for a longer period of time before incubation.

To assess the removal efficiencies of settling, and to obtain some design criteria, settling tests were run on the filter backwash water from the Dworshak Hatchery. Each test consisted of filling two 1,000 ml graduated cylinders with backwash water and allowing the solids to settle out. One graduate was run 30 minutes and the other 60 minutes. At these times the supernatent was siphoned off for analysis. The results of these analyses were compared with those for the backwash water which are listed in Table 3.

TABLE 3

WASTE CHARACTERISTICS OF OYSTER SHELL
FILTER BACKWASH WATER

	Salmon Cultural Laboratory 5/22/69	Dworshak National Fish Hatchery 12/17/69
Temperature, °C	16.0	13.5
Dissolved Oxygen, mg/l	9.6	8.8
5 Day BOD, mg/l	31	36
Ultimate BOD, mg/l	155	152
COD, mg/l	91	81
TOC, mg/l	4	16
Total Solids, mg/l	314	171
Total Volatile Solids, mg/l	152	--
Suspended Solids, mg/l	10	34
Total Phosphorus, mg/l as P	4.4	1.6
Orthophosphate, mg/l as P	0.58	0.38
NH_3-N, mg/l as N	.1	0.13
NO_2-N, mg/l as N	<0.05	0.033
NO_3-N, mg/l as N	3.6	2.4
TKN, mg/l as N	3.8	4.7
Total Coliform, per 100 ml	43,000	--
Fecal Coliform, per 100 ml	<2	--

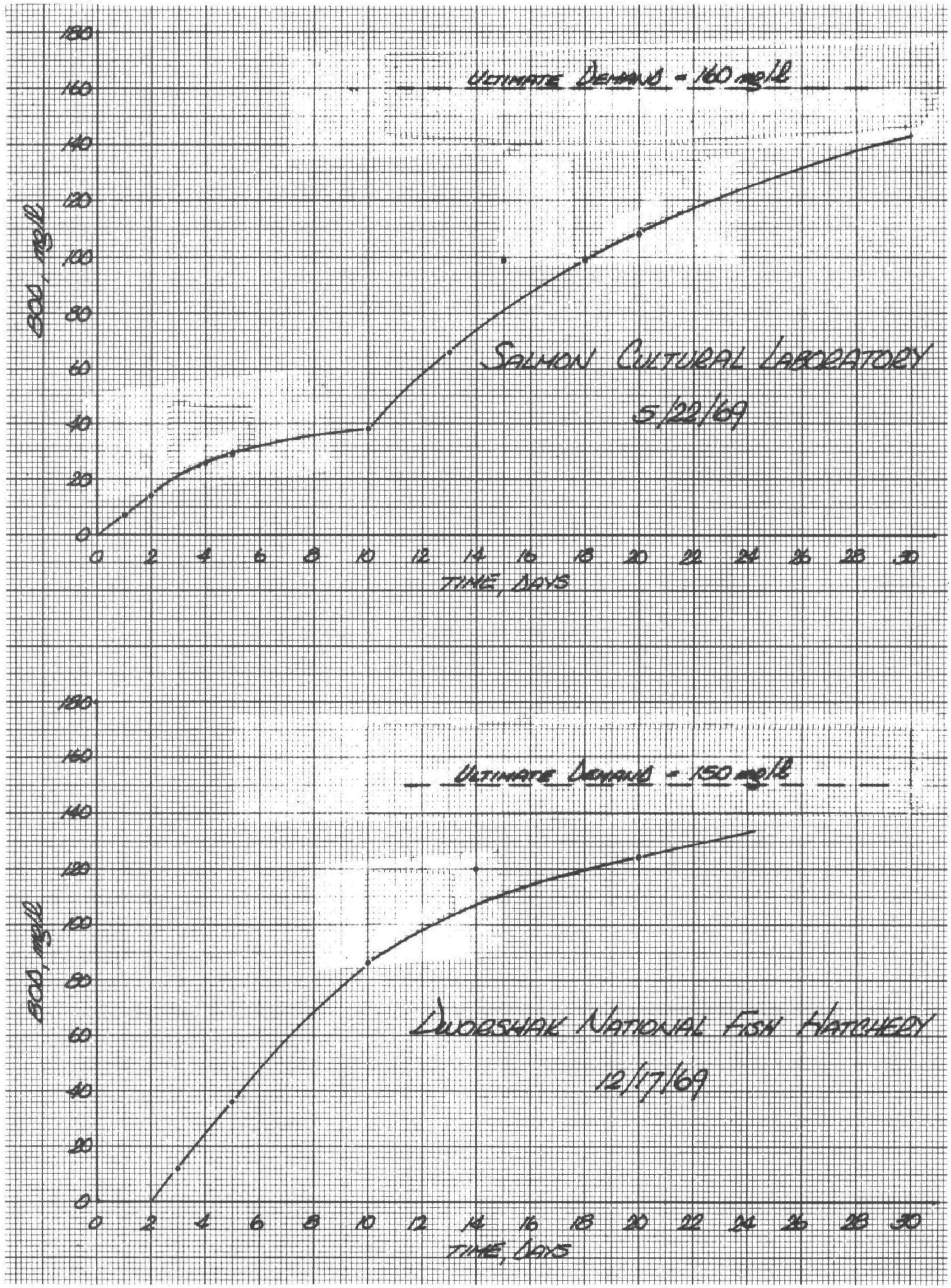


FIGURE 6. Filter Backwash Water BOD Curves.

Removal efficiencies for the 30 and 60 minute tests, as well as the analysis for the 60 minute test, are shown in Table 4. These data show a significant reduction of SS, BOD, TKN, and TP in the first 30 minutes of settling, with little additional removal in the next 30 minutes. The close correlation between BOD, TKN, TP and the SS removals indicates that BOD, TKN, and TP are associated with the solids. In contrast to TP, removals for the orthophosphates were small. This is because orthophosphates are usually in a soluble form.

TABLE 4

REMOVAL EFFICIENCIES OF SETTLING FOR BACKWASH WATER

	% Removal		Final Effluent
	30 minutes	60 minutes	conc. @ 60 min., mg/l
Suspended Solids	89	90	3
5 Day BOD	92	94	2
Total Kjeldahl Nitrogen as N	76	83	1.2
Total Phosphorus as P	84	85	0.2
Orthophosphate as P	38	38	0.2

Although most of the removals were accomplished in the first 30 minutes, it must be emphasized that these were static tests performed under quiescent conditions. Detention times approaching 60 minutes would be advisable for the design of a continuous flow-through system.

Total Waste Load

The estimated total waste load per day produced by all the Federal and State hatcheries in the study area was computed by employing average waste loading factors presented in Table 2 and in reference 1.

BOD_5	1.3 lbs/100 lbs fish/day (1)
TKN	0.20 lbs/100 lbs fish/day
TP	0.036 lbs/100 lbs fish/day

Applying these factors to the 8.6 million pounds of fish raised annually in the 114 Federal and State hatcheries in the study area, it has been calculated that approximately 23 tons of BOD are discharged per day. This discharge is roughly equivalent to raw sewage from a city of 270,000 people. In addition, 8,600 pounds of TKN and 1,500 pounds of TP are added daily to receiving waters.

The amount of pollutants discharged by each hatchery is not extremely large; however, it becomes significant when the receiving body of water is small.

EFFECTS ON WATER QUALITY

Physical-Chemical Effects

To assess the effects of hatchery discharges on receiving water quality, stream sampling was undertaken at the Eagle Creek Hatchery and the Salmon Cultural Laboratory. Since the Dworshak and Little White Salmon Hatcheries discharge their effluents into extremely large bodies of water it was considered impractical to assess the effects on water quality of these hatcheries.

Two sampling surveys were made at Eagle Creek and one at Abernathy Creek. Grab samples were taken above and below each hatchery as well as a few miles downstream. The downstream samples were to check for persistence of pollution and to assess stream recovery, if any.

Table 5 presents data for the two Eagle Creek surveys. During each of these surveys, essentially the entire flow of Eagle Creek was utilized by the hatchery.

Data from the August 28 survey at Eagle Creek show an increase in temperature, total solids, COD, NO_2-N, NO_3-N, TKN, total phosphorus, and total coliforms, as well as a decrease in DO as a result of the hatchery discharge. About 100 yards downstream from the hatchery the odor of ammonia was highly noticeable. At a point 3.4 miles downstream the dissolved oxygen levels had returned to those measured above the hatchery and the total solids were reduced. The nutrients, especially nitrate nitrogen, were still high. The great

TABLE 5

HATCHERY DISCHARGE EFFECTS ON WATER QUALITY OF EAGLE CREEK

	8/28/69 Above Hatchery Intake	8/28/69 50 yds. Below Hatchery	8/28/69 3.4 mi. Below Hatchery	9/11/69 Above Hatchery	9/11/69 50 yds. Below Hatchery	9/11/69 3.4 mi. Below Hatchery
Temperature, °C	13.0	14.0	14.8	15.0	15.8	15.8
Total Solids, mg/l	109	145	108	53	72	69
DO, mg/l	10.4	9.8	10.0	10.0	9.0	10.0
COD, mg/l	4	5	3	<1	4	13
NO_2-N, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
NO_3-N, mg/l	0.05	0.07	0.22	0.08	0.12	0.42
NH_3-N, mg/l	----	----	----	0.06	0.16	0.06
TKN, mg/l	0.2	0.5	0.4	0.2	0.7	0.2
Total Phosphorus, mg/l	0.010	0.048	0.028	0.011	0.75	0.04
Total Coliform /100 ml	78	90	240	124	970	820
Fecal Coliform /100 ml	16	4	120	4	8	2

increase in nitrate nitrogen resulted from the conversion of ammonia to this form. Although an increase in total coliforms was measured at the downstream station, it is impossible to determine with the available data if this increase is due to regrowth or a secondary source.

Data from the September 11 survey at Eagle Creek are also presented in Table 5. These data further substantiate the findings of the August 28 survey. The ammonia odor was again apparent below the hatchery. As in the August survey, there was an increase in NO_3 at the 3.4 mile station, which correlates with the reduction in ammonia.

Table 6 contains the data obtained in the survey of Abernathy Creek, which receives the discharge from the Salmon Cultural Laboratory. These data show about the same results as the Eagle Creek data, except to a lesser degree. This is because the hatchery discharge constitutes only a portion of the total streamflow.

Biological Effects

A survey was conducted at the Eagle Creek National Fish Hatchery to assess the effects of hatchery discharges on the biota of a receiving stream. Four Surber samples were collected at each of three stations. These stations were selected on the basis of geologic and hydraulic similarity. Table 7 lists the organisms found at each of the three stations. A description of the station location and observations of the benthos follows Table 7.

TABLE 6

HATCHERY DISCHARGE EFFECTS ON WATER QUALITY OF ABERNATHY CREEK
5/22/69

	Above Hatchery	30 yds. Below Hatchery	3 mi. Below Hatchery
Temperature, ^{o}C	13.8	13.0	13.5
Total Solids, mg/l	24	46	40
DO, mg/l	10.7	10.4	10.6
TOC, mg/l	<1	2	1
pH	6.3	5.9	5.8
NO_2-N, mg/l	<0.1	<0.1	<1
NO_3-N, mg/l	0.1	0.1	<0.1
TKN, mg/l	0.2	0.2	0.2
Total Phosphorus, mg/l	0.2	0.2	0.1
Total Coliform /100 ml	54	530	230
Fecal Coliform /100 ml	6	8	8

TABLE 7

EAGLE CREEK BIOLOGICAL DATA

Organisms		Station I	II	III
Stoneflies (nymphs)				
Perlodidae		13	67	41
Perlidae		7	14	12
Nemourida		2	17	0
Peltoperlidae		5	0	0
Mayflies (nymph)				
Baetidae		23	201	125
Ephemeridae		21	32	6
Heptageniidae		16	60	91
Leptophlebiidae		7	0	2
Caddisflies				
Glassosomatidae	Larvae	7	10	2
	Pupae	2	0	1
Hydropsychidae	Larvae	19	36	43
Limnephilidae	Larvae	3	1	1
	Pupae	3	6	1
Phyacophilidae	Larvae	11	30	13
	Pupae	6	1	5
Hydroptilidae	Larvae	8	0	0
	Pupae	1	0	0
Brachycentridae	Larvae	3	0	0
Trueflies				
Tendipediead	Larvae	11	98	12
	Pupae	6	14	1
Meleidae	Larvae	2	4	0
Rhagionidae	Larvae	1	1	0
Similiidae	Larvae	2	4	3
	Pupae	1	0	0
Tipulidae	Larvae	5	10	3
	Pupae	1	7	0
Tabanidae	Larvae	5	0	0
Beetles				
Elmidae	Larvae	4	8	12
Psephenidae	Larvae	1	0	0
Amphizoidae	Adult	2	0	0
Scuds				
Gammeridae		4	0	0
Sow Bug				
Asellidae		1	0	0
Mite		14	0	0
Crayfish				
Astacidae		1	0	1
Snails				
Physidae		0	0	8

Station 1

This station was located several hundred yards upstream from the submerged weir control dam used for diversion of the hatchery water supply system. Half of the stream bed at this location was boulders and bedrock the rest was packed gravel, small rocks, and very coarse sand. About half the boulders and gravels were covered with diatoms. Green algae growth at the station was very scarce.

The benthic animal community consisted of only modest numbers of many diversified kinds of fauna. This diversified community included mayflies, stoneflies, true flies, caddisflies, beetles, mites, isopods, and crayfish.

Station 2

Station 2 was located about 150 yards below the hatchery's lowest outfall. Here the stream bed was mostly bedrock and smooth boulders resulting from annual scouring. The water at this station was slightly milky in appearance and the air had an odor of ammonia and dead fish. The sand in the eddies was covered by silt, fish feces, and fish food. Dead salmon and trout fingerlings and lamprey carcasses were noted in most of the eddies and caught on some of the rocks. The lamprey had died from natural causes. From their appearance and location, it was concluded that some of the dead salmon fingerling had been flushed from the hatchery ponds and the remainder had died in Eagle Creek below the Hatchery from unknown causes.

The majority of the rocks and smooth rubble supported benthic life. Most of the aquatic insects were strainer types such as midges and caddisflies which were present in greater than modest numbers on some of the smaller rocks. In general, the benthic community at this station was less diverse than at Station 1, but of greater numbers.

Station 3

Station 3 was located approximately 3.4 miles below the hatchery. Here the stream bottom was covered by boulders, rubble, and coarse gravel. The water was a light brown, but was clear. Lamprey carcasses were particularly abundant, but no dead salmon or trout fry or fingerlings were observed. All of the submerged boulders, rubble and gravels were covered with diatoms. Clumps of filamentous green algae were observed. These clumps of algae contained mayflies, stoneflies, isopods, amphypods, mematods, and many kinds of true fly larvae. In addition, crayfish, beetles, snails, and caddisflies were found on and under the rubble and coarse gravels. Snails, mayflies and diatoms were particularly abundant at this station.

TREATMENT METHODS AND NEEDS

Water Reconditioning/Reuse

During the past decade, much work has been done in the field of controlled environment for fish propagation. This approach offers great promise in maximizing production.

Because different species have varying environmental requirements, flexibility is needed. This flexibility is most dependent upon the water supply. Burrows and Combs (4) list five major criteria for a potential water supply; quality, quantity, temperature, disease incidence--low or absent, and location near the outlet for release. Natural sites which meet all of the above criteria are nonexistent. Therefore, a solution is needed to alter those factors which are not suited for optimum production.

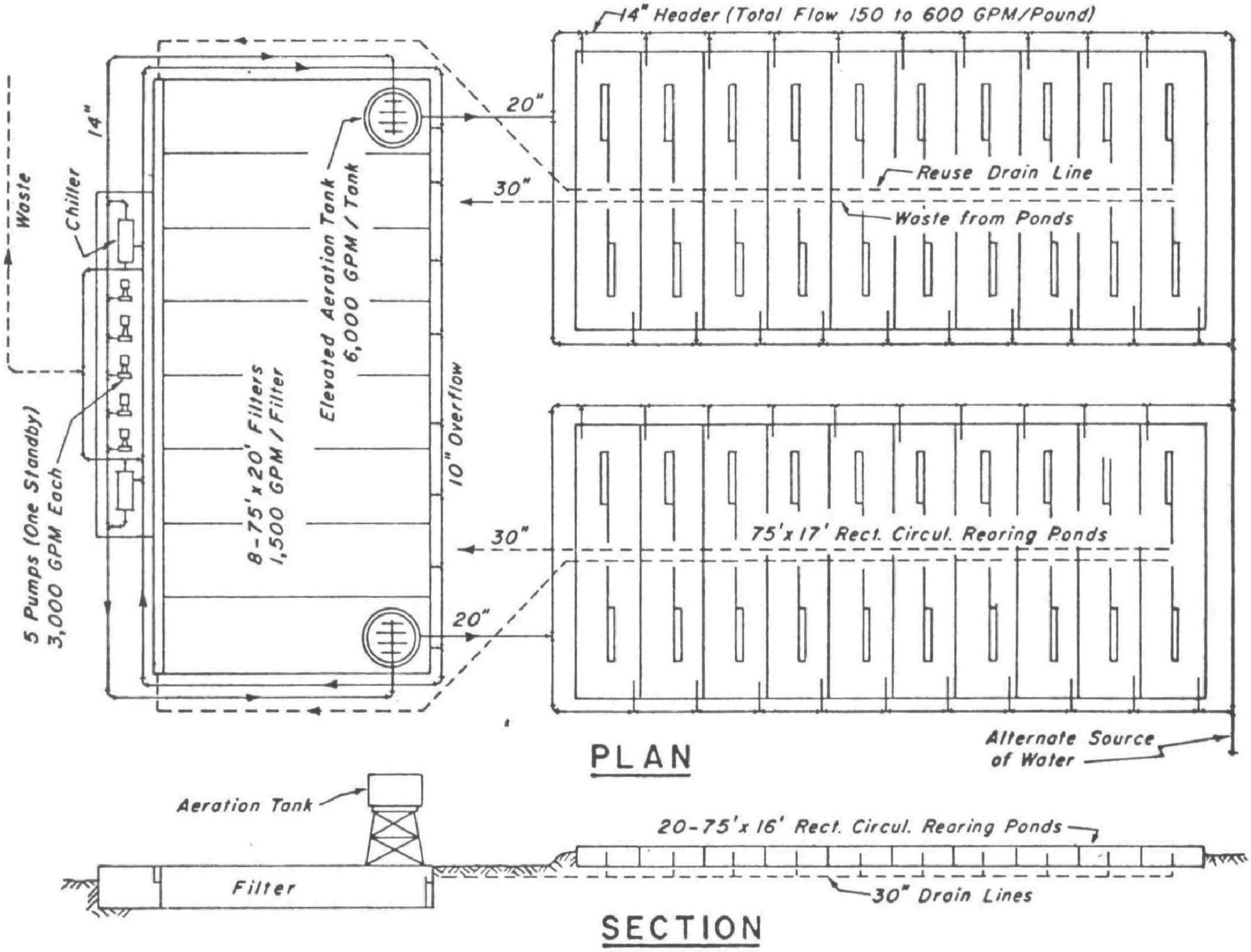
One solution which has proved successful is a water reconditioning/reuse system using 5 to 10 percent make-up, developed by Burrows and Combs (4). With this reduced water requirement, problems of quality, temperature control and sterilization become economically feasible. The major problem encountered in the development of a water reconditioning/reuse system was the gradual build-up of metabolic waste which became toxic to the fish. The main metabolic products as mentioned earlier are urea and ammonia (NH_3). Burrows (5) found that at stocking rates of less than 5 pounds of fish per gpm, urea was the dominant excreatory product; at higher rates ammonia became dominant. In addition, he found that whereas urea exhibited no deleterious effects, concentrations of un-ionized ammonia as low as 0.006 ppm in continuous exposure became toxic to fish. To correct this problem, a treatment system was devised consisting of a biological filter followed by aeration. A schematic drawing of this system is shown in Figure 7. The heart of the system is the biological filter which is shown in detail in Figure 8. This filter is composed of 4 feet of crushed rock overlain by 1 foot of oyster shell. The crushed rock provides a surface for the growth of nitrifying bacteria which convert the toxic ammonia or ammonium ion (NH_4^+) to nitrate ions (NO_3^-) which are non-toxic. In making this conversion, 2 moles of oxygen are required to convert each ammonium ion to a nitrate ion, as shown in the following equations:

$$NH_4^+ + 1.5O_2 \xrightarrow{\text{Nitrosomonas}} 2H^+ + H_2O + NO_2^-$$

$$NO_2^- + .5O_2 \xrightarrow{\text{Nitrobacter}} NO_3^-$$

The oyster shell which overlies the crushed rock serves many functions. It keeps the pH adjusted as the CO_2 produced by the fish and the NO_3^- produced by the bacteria create an acidic condition. In addition to stabilizing pH, the oyster shells trap the larger solids and provide a large amount of trace minerals required by the nitrifying bacteria.

Filter influent and effluent samples were taken at both Dworshak and the Salmon Cultural Lab. The analyses showed that ammonia nitrogen is reduced and that nitrate nitrogen and nitrite nitrogen are increased. In addition, a decrease in suspended solids was noted



Aeration:
Each Aspirator passes 125 GPM at 10 psi
11,400 GPM Requires 92 Aspirators.
Each Aspirator Requires 4 sq. ft. of Area. 92 Aspirator 368 sq. ft. Aeration Tank

Capacity:
1,000,000 Fish at 10/lb. or 4,000,000 Fish at 50/lb. or 5,400,000 Fish at 90/lb.

Ponds:
Twenty 75' Ponds at 600 GPM = 12,000 GPM in Circulating System. 12,000 at 5% = 600 GPM Supplemental Water R'q'd.

Filters:
Each 1,500 sq. ft. Filter Passes 1,500 GPM
Eight Filters at 1,500 GPM = 12,000 GPM.

FIGURE 7. Schematic Drawing of a Typical Controlled Environment System for Rearing Salmonids (4).

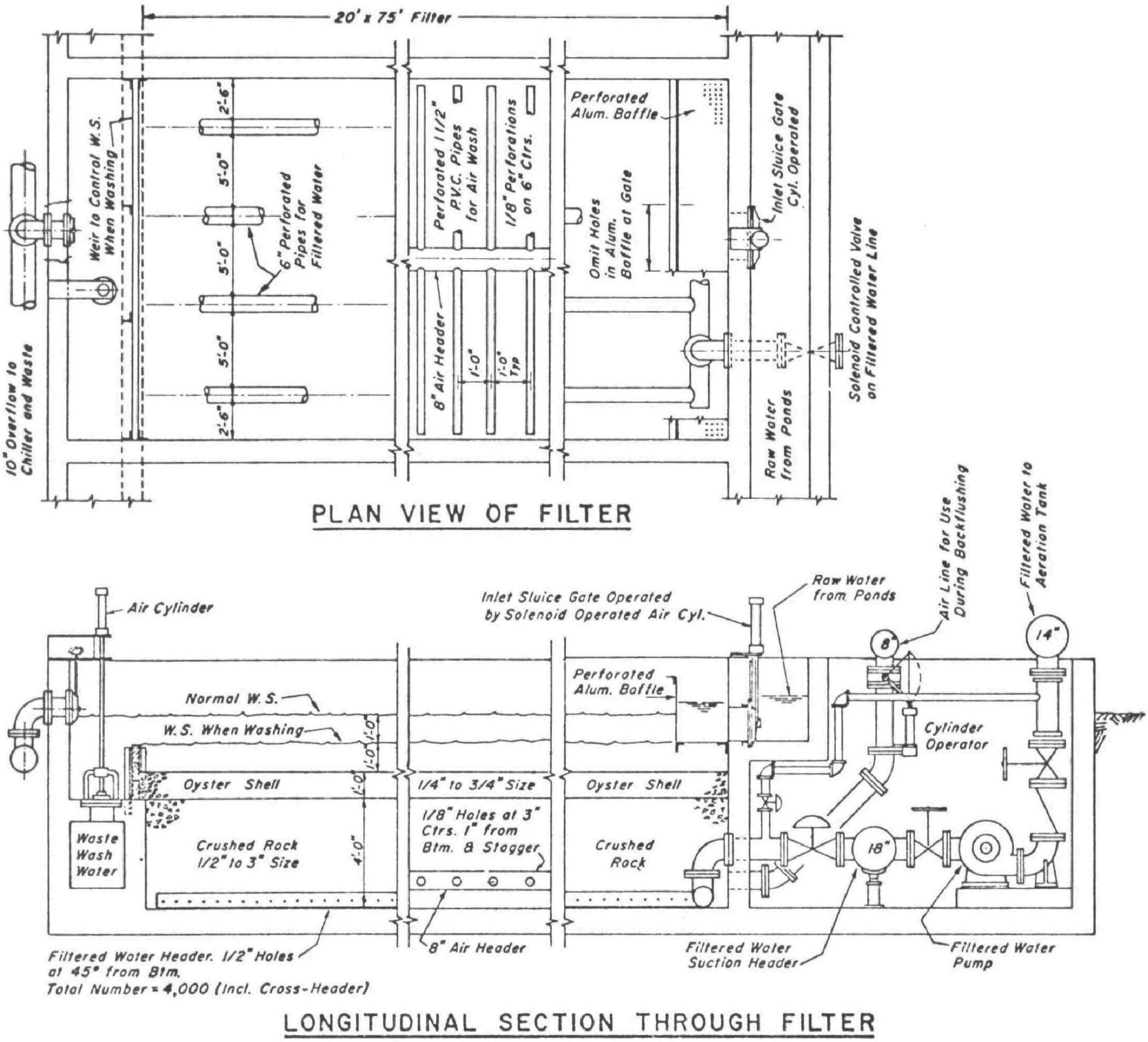


FIGURE 8. Design Drawing of a Water Reclamation Filter (4).

across the filter at Dworshak (Table 8).

TABLE 8

OYSTER SHELL FILTER WASTE TREATMENT

	Salmon Cultural Lab 5/22/69		Dworshak Hatchery 12/17/69	
	Influent	Effluent	Influent	Effluent
Total Solids, mg/l	198	198	227	171
NH_3-N, mg/l	0.11	0.02	0.08	0.05
NO_2-N, mg/l	0.05	0.05	0.03	0.05
NO_3-N, mg/l	3.5	3.7	2.2	2.4
pH	6.2	7.0	-	-
DO, mg/l	7.3	6.7	-	-
BOD, mg/l	2	<2	-	-
COD, mg/l	6	4	-	-

Following the filter, the water is aerated to replace the dissolved oxygen used by the fish and the bacteria. This aeration also strips off any CO_2 gas that is present.

The accumulation of solids and growth of Sphaerotolus necessitate backwashing the filter about once or twice a day under maximum fish loading. This backwash water and the skimming water constitutes the effluent streams for a hatchery using a water reconditioning/reuse system of this type.

Other Treatment Methods

Related studies on hatchery waste problems have led to schemes which differ from those of the water reconditioning/reuse system outlined in the previous section. Parker and Associates' studies of the Rifle Falls Trout Hatchery in Colorado (2) led to the design of a treatment system which includes high-rate trickling filters, chemical additions, final sedimentation, and solids decomposition. The filters were designed for 20 million gallons (MG) per acre per day (.32 gpm/ft^2) without recirculation. Activated carbon and potassium permanganate are added to remove taste and odor, followed by a final settling basin with a 1 to 1½ hr. design detention time. Disposal of solids from the settling basin is accomplished in an aerobic stabilization pond.

At the Jordan River National Fish Hatchery in Michigan, a study undertaken by the Lake Michigan Basin Office, FWQA, (formerly FWPCA) (3) recommended a treatment system employing only a settling basin or lagoon for the removal of solids.

As stated earlier, a study by Huber and Valentine (6) at the Lamar National Fish Hatchery in Pennsylvania recommended a settling basin with a detention time of 15 minutes for treatment of the hatchery wastes and an activated sludge system employing only 2 hours of aeration time. Mechanical aerators are recommended for use in the aeration basin, followed by a settling basin.

Design Criteria

The design criteria outlined in this section are for a treatment system incorporating an oyster-shell filter. Although other systems may prove feasible, the oyster-shell filter is presently used and was the only treatment process analysed. In addition, the system provides for the reuse of water which offers many advantages. While doing an adequate job of renovating water for reuse, the system does present some pollution problems through the discharge of backwash and skimming water. For this reason, additional processes are needed in order to provide sufficient treatment for discharges to receiving waters.

An adequate treatment system for a hatchery would consist of three basic steps. These are filtration-aeration, sedimentation, and solids handling.

The filtration-aeration step is explained in detail in a previous section. Burrows and Combs (4) outlined the following design criteria for the process:

Filter

Loading rate: 1 gpm/ft^2

Frequency of Backwash: Every other day @ maximum loading

Duration of Backwash: 40 min. air agitation, 20 min. of flushing

Blower capacity: 1.33 scfm/ft^2 filter

Aerators

Number: 1 aspirator per 125 gpm @ 10 psi

Size: 4 ft^2 of area per aspirator

The filters should be sized to handle the full hydraulic load of the hatchery. This would prevent any solids from raceway flushing entering the receiving water, besides providing the best effluent possible.

The sedimentation step would be used for treatment of backwash and skimming water from the filter. The sedimentation system could be batch or continuous, depending on the size of the hatchery, frequency of backwashing, space limitations, etc. As determined by the settling tests explained previously, a detention time of 30 to 60 minutes is needed for a continuous system. Surface settling rates for this settling basin should be from 700 to 900 gallons per day per square foot.

The disposal of solids from the sedimentation step is the third phase of treatment. This step can present the most difficult problems. Many possibilities for treatment or disposal exist such as:

Land disposal

Insertion into domestic treatment system

Aerobic or Anaerobic Digestion

Concentration and Incineration

Land disposal, either at the hatchery or some other place, is a relatively cheap and trouble-free method for disposing of solids.

Being high in nutrients, these solids might be disposed of by spreading them on the hatchery grounds.

If the hatchery is large enough to warrant a domestic treatment system, the solids could be disposed of in this manner. The solids are highly amenable to treatment and no problems should be encountered with this method as long as the domestic system is designed hydraulically to handle the total flow.

Another method of disposal is some type of digestion system. Parker (2) recommends an aerobic system; however, an anaerobic system, such as a septic tank, could be used.

Incineration of solids, while effective, should be used only when other methods are not available. It will offer the most problems in terms of operation and maintenance as well as being the most expensive to build.

DEFINITION OF TERMS

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

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.

COD -- Chemical Oxygen Demand. A measure in terms of the amount of oxygen required to chemically oxidize all organic compounds, with a few exceptions, and some reduced inorganic compounds.

DO -- Dissolved Oxygen.

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

SS -- Suspended Solids. Solids that float on the surface or are in suspension in water, sewage or other liquids.

TKN -- 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-).

TOC -- Total Organic Carbon. Reported as carbon (C).

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

TS -- Total Solids. The sum of the suspended and dissolved solids.

BIBLIOGRAPHY

1. Anonymous, "A Study of the Pollutional Effects of Salmonid Hatcheries," Kramer, Chin & Mayo, Consulting Engineers, Seattle, Washington, June 1969.

2. Anonymous, "Preliminary Report for Treatment Facilities, Rifle Falls Trout Hatchery," Parker & Associates, Consulting Engineers, Greeley, Colorado, August 1968.

3. Anonymous, "Water Quality Conditions at the Jordan River National Fish Hatchery, Elmira, Michigan, Department of the Interior, FWPCA, Lake Michigan Basin Office, Great Lakes Region, February 1969.

4. Burrows, Roger E. and Combs, Bobby D. "Controlled Environments for Salmon Propagation," The Progressive Fish-Culturist, Vol. 30, No. 3, July 1968.

5. Burrows, Roger E. Effects of Accumulated Excretory Products on Hatchery-Reared Salmonids, Department of the Interior, Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, Research Report 66, 1964.

6. Huber, Richard T. and Valentine, Joseph J. Analysis and Treatment of Fish Hatchery Effluents, Lamar National Fish Hatchery Development Center, Lamar, Pennsylvania, 1968.

APPENDIX

Letter of Request

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES
COLUMBIA FISHERIES PROGRAM OFFICE
811 N. E. OREGON STREET
P. O. BOX 4332, PORTLAND 8, OREGON 97208

December 24, 1968

Mr. James L. Agee, Regional Director
Federal Water Pollution Control Administration
501 Pittock Block
Portland, Oregon 97205

Dear Mr. Agee:

The wastes that are discharged from some of the fish hatcheries that are operated with Federal funds on the lower Columbia River have become nuisances during low flow in summer.

We believe that objectionable discharges should be corrected, and would like to obtain your advice on how this might be best accomplished.

Could we meet with you or appropriate members of your staff to discuss this problem?

Sincerely yours,

Fred Cleaver
Program Director

As the Nation's principal conservation agency, the Department of the Interior has basic responsibilities for water, fish, wildlife, mineral, land, park, and recreational resources. Indian and Territorial affairs are other major concerns of America's "Department of Natural Resources."

The Department works to assure the wisest choice in managing all our resources so each will make its full contribution to a better United States—now and in the future.