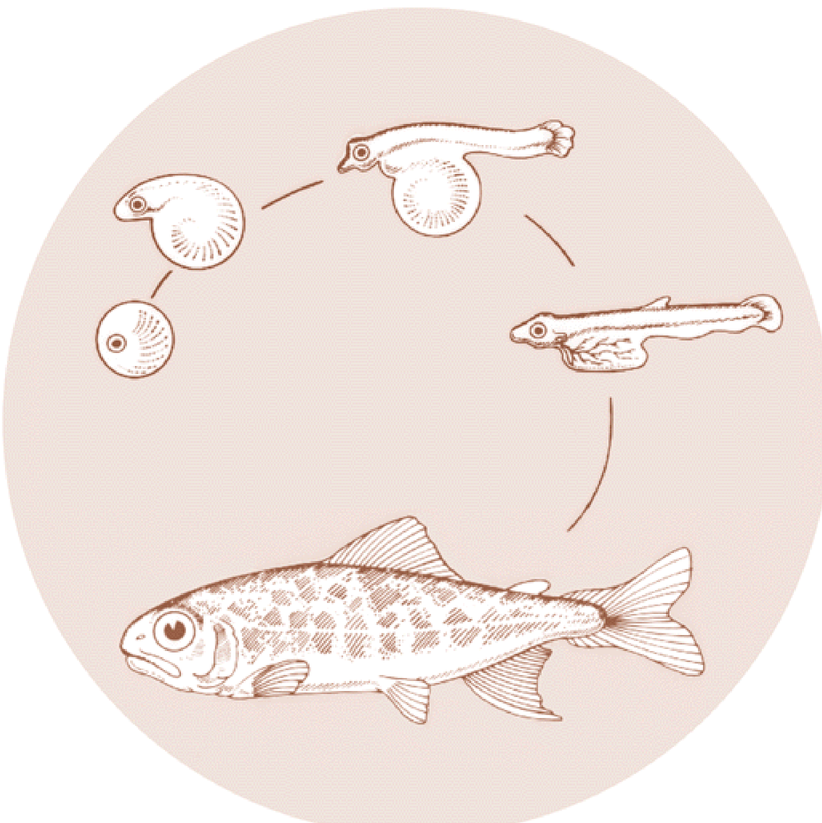
EVALUATION OF PURE OXYGEN SYSTEMS A THE UMATILLA HATCHERY

Task 1 - Review and Evaluation of Supplemental 0_2 Systems

Final Report



DOE/BP-10722-1

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views of this report are the author's and do not necessarily represent the views of BPA.

This document should be cited as follows:

Fish Factory, Evaluation of Pure Oxygen Systems at the Umatilla Hatchery Task 1 - Review and Evaluation of Supplemental 0_2 Systems, Final Report to Bonneville Power Administration, Portland, OR, Contract 90-AP-10722, 180 electronic pages (BPA Report DOE/BP-10722-1)

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Environment, Fish and Wildlife Division
P.O. Box 3621
905 N.E. 11th Avenue
Portland, OR 97208-3621

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EVALUATION OF PURE OXYGEN SYSTEMS
AT THE UMATILLA HATCHERY

Task 1 – Review and Evaluation of Supplemental 0_2 Systems

Final Report

Prepared by:

Fish Factory

Prepared for:

U.S. Department of Energy
Bonneville Power Administration
Environment, Fish and Wildlife
PO Box 3621
Portland, Oregon 97208

Contract No. DE-AP79-90BP10722

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Executive Summary

Based on feed consumption, the oxygen requirement for the Umatilla Hatchery was computed. The oxygen requirement depends strongly on the minimum oxygen criteria. Two oxygen criteria based on effluent concentrations from the raceways were tested: (1) Saturation (depending on elevation and temperature) and (2) 7 mg/L (a criteria commonly used for flow-through salmon hatcheries). The results of the modeliing for the two dissolved oxygen criteria cases are summarized below:

Parameter	Saturation Criteria	7 mg/L Criteria
Absorption Efficiency (%)	44.8	44.6
Yearly Design Oxygen Requirement (lb)	197,000	86,000
Yearly Oxygen Costs ($)		
$0.40/100 ft^3	9,500	4,100
$0.50/100 ft^3	11,900	5,200
$0.60/100 ft^3	14,200	6,200

There is probably little biological basis to support the saturation criteria, although it provides higher dissolved oxygen concentrations and therefore its selection may be more prudent during the experimental phase of the Umatilla Hatchery. While the oxygen requirement for the saturation criteria is significantly larger than for the 7 mg/L criteria, the absolute difference is relatively small compared to the operational cost of the overall hatchery. Increasing the absorption efficiency from the existing value to 90% could reduce annual oxygen costs by $5,959 based on an oxygen cost of $0.50/100 ft^3 and a saturation criteria for dissolved oxygen. Depending on the parameter used, the intensity of the **Michigan** system is 2.9-4.4 times higher than the **Standard Oregon** system.

Introduction

The Northwest Power Planning Council has established a goal of doubling the size of salmon runs in the Columbia River Basin. The achievement of this important goal is largely dependent upon expanding the production of hatchery fish. Pure oxygen has been commonly used to increase the carrying capacity of private sector salmonid hatcheries in the Pacific Northwest (Gowan, 1987; Severson et al., 1987). The use of supplemental oxygen to increase hatchery production is significantly less expensive than the construction of new hatcheries and might save up to $500 million in construction costs.

The Umatilla Fish Hatchery is being constructed (near Irrigon, Oregon) to produce summer steelhead, spring chinook, and fall chinook. Bonneville Power Administration will fund construction, operation, and maintenance of the hatchery and Oregon Department of Fish and Wildlife will operate and manage the facility. Initially, the hatchery was designed to produce 160,000 lb of salmon and steelhead using a 2-pass water reuse system. In 1987, the objectives were modified to allow testing of an oxygen supplementation system which would boost production to 290,000 lb. The use of supplemental oxygen at the Umatilla Hatchery is attractive for three reasons; (1) the increased production would more fully meet smolt requirements for the Umatilla River adult return goals, (2) the cost efficiency of producing smolts at the hatchery would be greatly increased, and (3) it would provide an opportunity to thoroughly test the oxygen system which would have system-wide applications in the Columbia Basin (Umatilla Master Plan, 1989). The pure oxygen columns at the Umatilla Fish Hatchery are based on a design used by the Michigan Department of Natural Resources (Boersen and Chesney, 1987: Westers et al.. 1987).

Because of the lack of long-term experience with oxygen supplementation systems in the Columbia River Basin, Bonneville Power Administration contracted with

Fish Factory (DE-AP79-90BP10722) to perform an independent review and evaluation of the pure oxygen design for the Umatilla Hatchery. This report documents Task 1 - Review and Evaluation of Supplemental Oxygen Systems. Task 2 will conduct an engineering assessment of the existing design, compare the design to recently developed oxygen contact systems, and recommend potential changes to the system to increase reliability and reduce operating costs.

Project Dercription

The Umatilla Hatchery in located on the banks of the Columbia River near the lrrigon Hatchery at Irrigon, Oregon. A groundwater supply will be used for the hatchery. In the event of pump failure, the Umatilla Hatchery can use water from the Irrigon Hatchery for egg incubators.

The hatchery will use two types of outdoor rearing raceways, refened to in this report **as** the **Standard Oregon** raceway and the **Michigan** raceway. The key characteristics of these two raceways and hatchery design approaches are presented below:

Parameter	Standard Oregon Raceway	Michigan Raceway
Volume **(ft^3)**	6200	1890
Water Flow (gpm)	1500	940
Baffles	no	yes
Number of Passes	2	3
Supplemental Oxygen	no	yes
Number of banks	5	**8**
Total Number of Raceways	10	24

The **baffles** in the **Michigan** raceways will increase the water velocity near the bottom of the raceway and are designed to make the raceways essentially self-cleaning. Similar baffles have been recently installed in an experimental system at the Williamette Hatchery near Oakridge, Oregon. Additional information on the project is presented in the following documents:

Umatilla Fish Hatchery- Environmental Assessment

Umatilla Hatchery Master Plan

Umatilla Fish Hatchery - Construction drawings

Detailed citations for these documents are presented in the reference section.

Project Objectives

The Umatilla Hatchery will produce suumer steelhead, spring chinook, and fall chinook. Detailed growth projections on a weekly basis are presented in Table 1 for the three species reared at the Umatilla Hatchery.

The production objectives and scheduling used in this report are based on published information and discussion with Drew Schaeffer and Mike Stratton at Oregon Department of Fish and Wildlife. In this report, only those fish that are actually ponded at the Umatilla Hatchery are considered. Due to operational constraints and the lack of adequate number of broodstock, additional fish will be reared off-site during the initial phases of the restoration of salmon runs in the Umatilla basin.

Table 1 Growth Projections for the Umatilla Hatchery

Date	Day	Summer Steelhead			Spring Chinook			Fall Chinook		
		Weight (g)	#/ pound	Length (in)	Weight (g)	#/ pound	Length (in)	Weight (g)	#/ pound	Length (in)
01-Aug-89	0	1.52		2.14						
08-Aug-89	7	2.06	300.00	2.37						
15-Aug-89	14	2.72	167.29	2.60						
22-Aug-89	21	3.50		2.83						
29-Aug-89	28	5.48	129.73102.63	3.06						
05-Sep-89	35	6.69	67.92 82.90	3.28						
12-Sep-89	42	8.07		3.51						
19-Sep-89	49	9.62	56.35	3.74						
26-Sep-89	56			3.96						
03-Oct-89	63	ii.39	39.90	4.19						
10-Oct-89	70	13.37	33.99	4.42						
17-Oct-89	77	15.57	29.20	4.65						
24-Oct-89	84	17.99	25.26	4.88						
31-Oct-89	91	20.66	22.01	5.11	1.52	300.00	2.24			
07-Nov-89	98	23.39	19.44	s.33	1.98	229.79	2.45			
14-Nov-89	105	26.3s	17.25	5.54	2.53	179.89	2.66			
21-Nov-89	112	29.56	15.38	5.76	3.17	143.4s	2.87			
28-Nov-89	119	33.01	13.77	5.97	3.91	116.23	3.08			
OS-k-89	126	36.26	12.54	6.16	4.65	97.69	3.26			
12-Dec-89	133	39.72	11.44	6.35	5.48	82.90	3.44			
19-Dec-89	140	43.40	10.48	6.54	6.41	70.94	3.63			
26-Dec-89	147	47.29	9.61	6.74	7.43	61.18	3.81			
02-Jan-90	154	51.02	8.91	6.91	8.45	53.81	3.98			
09-Jan-90	161	54.95	8.27	7.08	9.56	4737	4.14			
16-Jan-90	168	59.07	7.70	7.25	10.76	42.26	4.31			
23-Jan-90	175	63.40	7.17	7.43	12.05	37.71	4.48			
30-Jan-90	182	67.93	6.69	7.60	13.4s	33.79	4.64			
06-Feb-90	189	72.18	6.30	7.7s	14.80	30.72	4.79	1.52	300.00	2.24
13-Feb-90	1 %	76.62	5.93	7.91	16.23	28.00	4.94	1.84	247.02	2.39
20-Feb-90	203	81.23	5.60	8.07	17.76	25.60	5.09	2.21	205.82	2.54
27-Feb-90	210	86.02	5.28	8.22	19.37	23.47	5.24	2.62	173.29	2.69
06-Mar-90	217	91.27	4.98	8.39	21.18	21.46	5.40	3.11	145.98	2.85
13-Mar-90	224				23.10	19.68	5.56	3.66	1x13	3.01
20-Mar-90	231				25.13	18.09	5.72	4.27	106.42	3.17
2%Mar-90	238				27.28	16.67	5.88	4.94	91.93	3.33
03-Apr-90	245				29.66	15.32	6.04	5.73	79.39	3.49
10-Apr-90	252							6.59	69.02	3.66
17-Apr-90	259							7.53	60.39	3.83
24-Apr-90	266									
01-May-90	m									
OS-May-90	280									

Modeling Approach

Oxygen projections for the Umatilla Hatchery are based on a feed basis. Approximately 0.25 lb of oxygen is needed to metabolize 1 .OO lb of feed under production feeding levels. To account for postprandial (following feeding) increases in oxygen consumption, a peaking factor of 1.44 is used. All oxygen requirements are based on the peak oxygen consumption rate (1.44 times the average rate). The oxygen required by the fish is computed on a weekly basis for each species.

The actual amount of oxygen that must be supplied to the oxygen contactor depends on the amount required by the fish and the absorption efficiency. The following relationship exists between AE (absorption efficiency) and ADO (change in DO in the oxygen contactor):

$$AE(\%) = 60 - (6)(\Delta DO)$$

This is based on work on similar (but not identical) units at the the Williamette Hatchery (Fish Factory, 1990). The diameter of the discharge pipe from the Williamette oxygen contactors was smaller that the column diameter and therefore produced a vacuum in the range of l00-140 mm Hg. The Umatilla contactors do not have a reduced discharge diameter. There is little published data on the performance of the columns that are planned for use at the Umatilla Hatchery. A significant result of the relationship between AE and ADO is that the absorption efficiency strongly decreases as more oxygen is added:

ADO (mg/L)	Absorption Efficiency (%)
0.5	57
1 .0	53
2.0	48
3.0	42
4.0	36

The amount of oxygen consumed in a raceway will be referred to as oxygen consumption (OC) and the total amount for any bank of raceways, the cumulative oxygen consumption **(COC).** The COC is an important measure of the intensity of a hatchery system and may be relatively independent of water temperature, fish size, and feeding level (Meade, 1985).

The amount of oxygen needed depends strongly on the effluent dissolved oxygen criteria. In typical flow-through salmon systems, the dissolved oxygen in the effluent water is maintained in the range of 5 - 7 mg/L The growth of salmonids will decreases if the dissolved oxygen drops much below this range. Oregon Department of Fish and Wildlife has recommended a much more conservative criteria for the Umatilla Hatchery: the criteria in the effluent water will be equal to the local saturation concentration of dissolved oxygen. To show the impact of the oxygen criteria on oxygen requirements, an effluent criteria of 7 mg/L and saturation will be used.

For presentation purposes, the starting date for all figures and tables is August 1. The corresponding dates and days from August 1st are presented in Table 1. Detailed information on the oxygen model used in this report is presented in Appendix A. Copies of the five Lotus 123 spreadsheets used are included in the inside of the back cover of this report. The five files cover the following cases:

File Name	**Species**	System
STSMICH	Summer Steelhead	Michigan
SCHMICH	Spring Chinook	Michigan
FCHMICH	Fall Chinook	Michigan
SCHOREG	Spring Chinook	Oregon
FCHOREG	Fall Chinook	Oregon

Dissolved Gas Levels

Influent Gas Concentrations

Based on groundwater temperatures at the Irrigon Hatchery, the saturation dissolved oxygen concentrations were computed on a weekly basis (Figure 1). The influent DO ranges from 9-l 1 mg/L over the production cycle.

Effluent Gas Concentrations - Saturation Criteria

The range of influent and effluent DOs in each treatment are presented in Table 2 for an effluent criteria based on local saturation.

Table 2 Influent and Effluent DOs mg/L) for a Saturation **Criteria**

Treatment	FirstPass		second Pass		ThirdPass	
	ifluent	Effluent	Influent	Effluent	Influent	Effluent
STSMICH	10.23-14.71	9.67-11.09	10.23-14.71	9.67-11.09	10.23-14.71	9.67-11.09
SCHMICH	10.76-13.78	10.15-11.09	10.76-13.78	10.15-11.09	10.76-13.78	10.15-11.09
FCHMICH	12.37-14.44	10.80-11.09	12.37-14.44	10.80-11.09	12.37-14.44	10.80-11.09
FCHOREG	10.80-11.09	9.71-10.49	9.15-10.46	7.50-9.84	—	—
SCHOREG	10.15-11.09	9.40-10.29	9.40-10.29	7.99-9.62	—	—

Due to the saturation criteria, the influent and effluent DOs to each unit within a given bank of the **Michigan** raceways are identical. **The** DOs in the **Standard Oregon** raceways decrease as the water passes down through the system. Both the influent and effluent DO in the **Michigan** system are higher than in the **Standard Oregon** systems. The effluent DOs (saturation criteria) for the **Michigan** and **Standard Oregon** raceways are presented in Figure 2 for fall chinook and in Figure 3 for spring

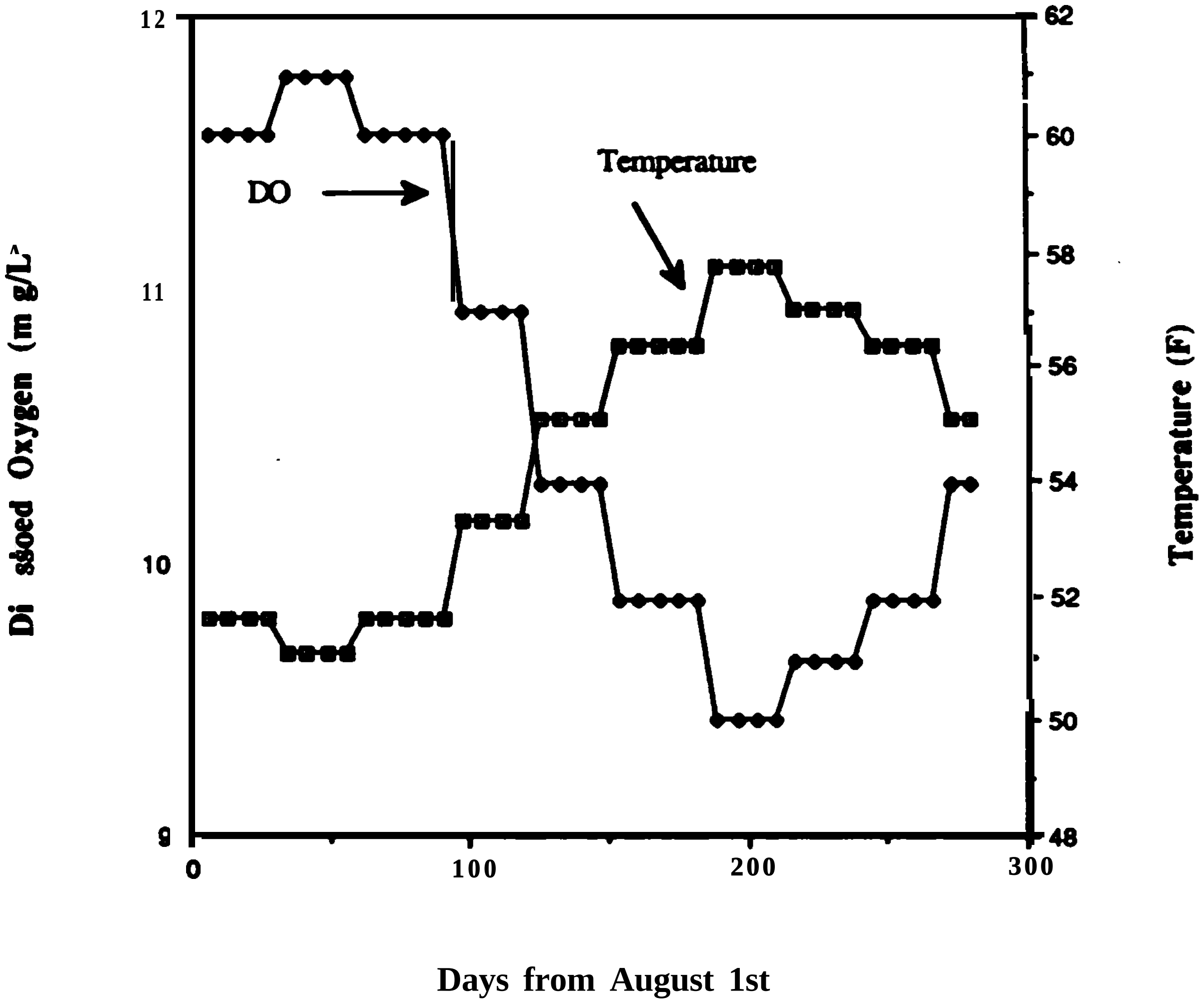

Figure 1 The variation of water temperature (F) and local dissolved oxygen saturation (mg/L) as a function of time at the Irrigon Hatchery. Actual dates corresponding to the days from August 1st are present in Table 1.

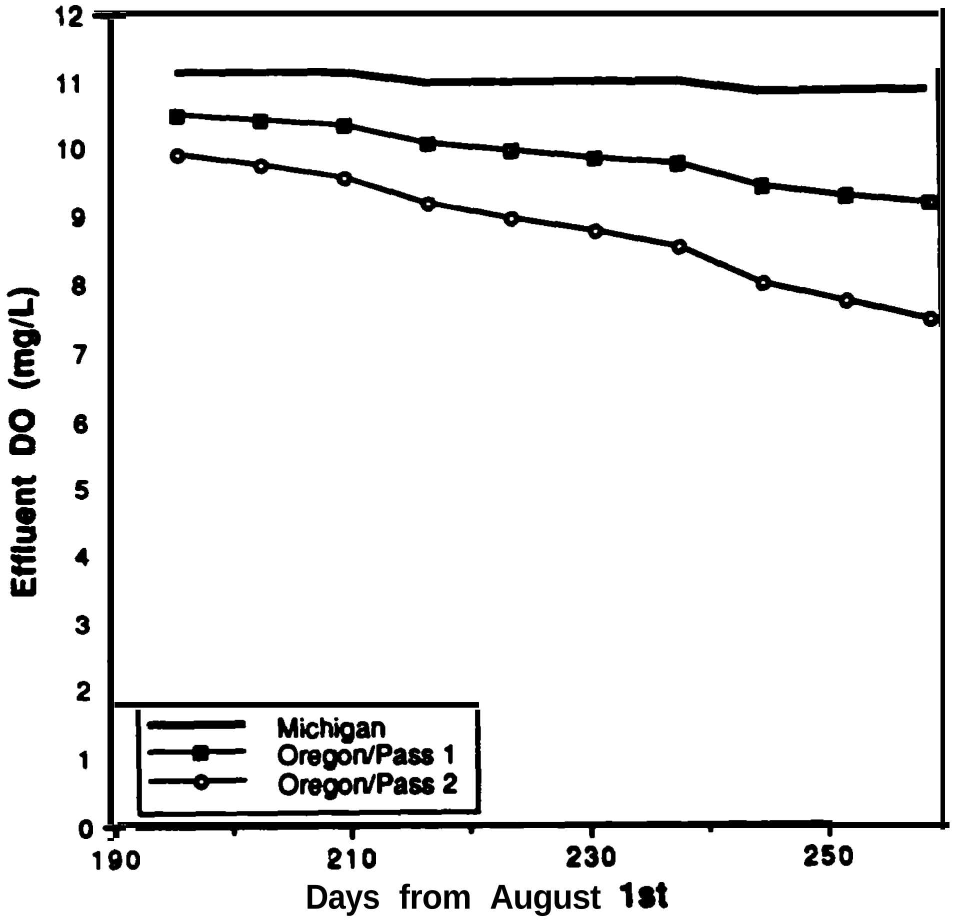

Figure 2 Effluent DOs (mg/L) for fall chinook using a saturated dissolved oxygen criteria. (based on peak oxygen consumption).

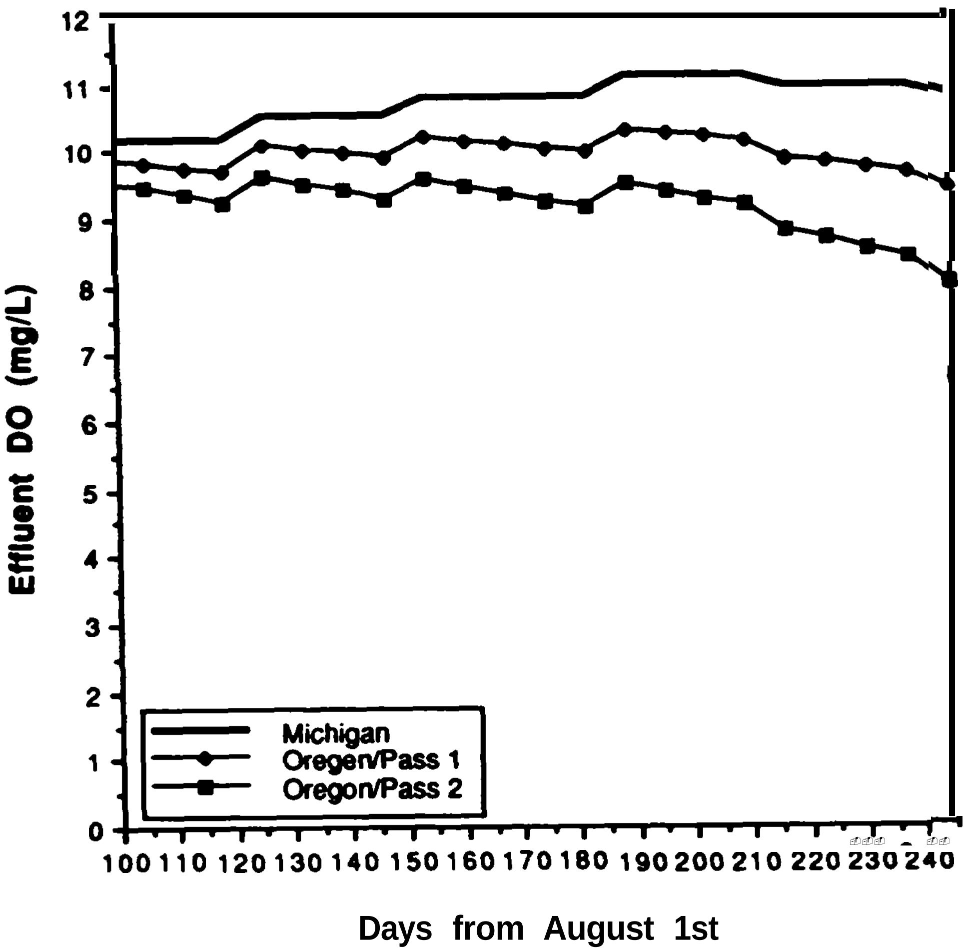

Figure 3 Effluent DOs (mg/L) for spring chinook using **a** saturated dissolved oxygen criteria. (based on peak oxygen consumption).

chinook. The effluent **DOs** in the **Standard Oregon** raceways are less than in the Michigan raceways.

Effluent Gas Concentrations - 7 mg/L Criteria

The range of influent and effluent DOs in each treatment are presented in Table 3 for an effluent criteria based on 7 mg/L criteria.

Table 3 Influent and Effluent DOs for a 7 mg/L **Criteria**

Treatment	First Pass		Second Pass		Third Pass	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
STSMICH	9.67-11.09	7.17-9.34	8.37-10.77	7.00-8.89	7.00-1 0.77	7.00-8.44
SCHMICH	10.15-1 1.09	7.83-9.57	9.04-9.88	7.00-8.91	8.19-9.98	7.00-8.29
FCHMICH	10.80-1 1.09	7.17-9.80	9.03-10.55	7.00-8.41	8.41-1 0.55	7.00-7.07
FCHOREG	10.80-1 1.09	9.71-10.49	9.15-10.46	7.50-9.84	—	—
SCHOREG	10.15-11.09	9.40-10.29	9.40-10.29	7.99-9.62	—	—

Since the **Standard Oregon** raceways do not receive supplemental oxygen, the influent and effluent concentrations for the saturation and 7 mg/L cases are the same. The DOs in both the **Michigan** and **Standard Oregon** raceways decrease as the water passes down through the system. Because of the effluent criteria of 7 mg/L, the minimum **DO** in the **Michigan** system is 7 mg/L. The effluent DOs (7 mg/L criteria) for the **Michigan** and **Standard Oregon** raceways are presented in Figure 4 for fall chinook and in Figure 5 for spring chinook. The effluent DOs in the Michigan raceways are less than in the Standard Oregon raceways. The effluent DO from the second pass of the **Standard Oregon** raceway is very similar to the effluent DO from the first pass of the **Michigan** raceway.

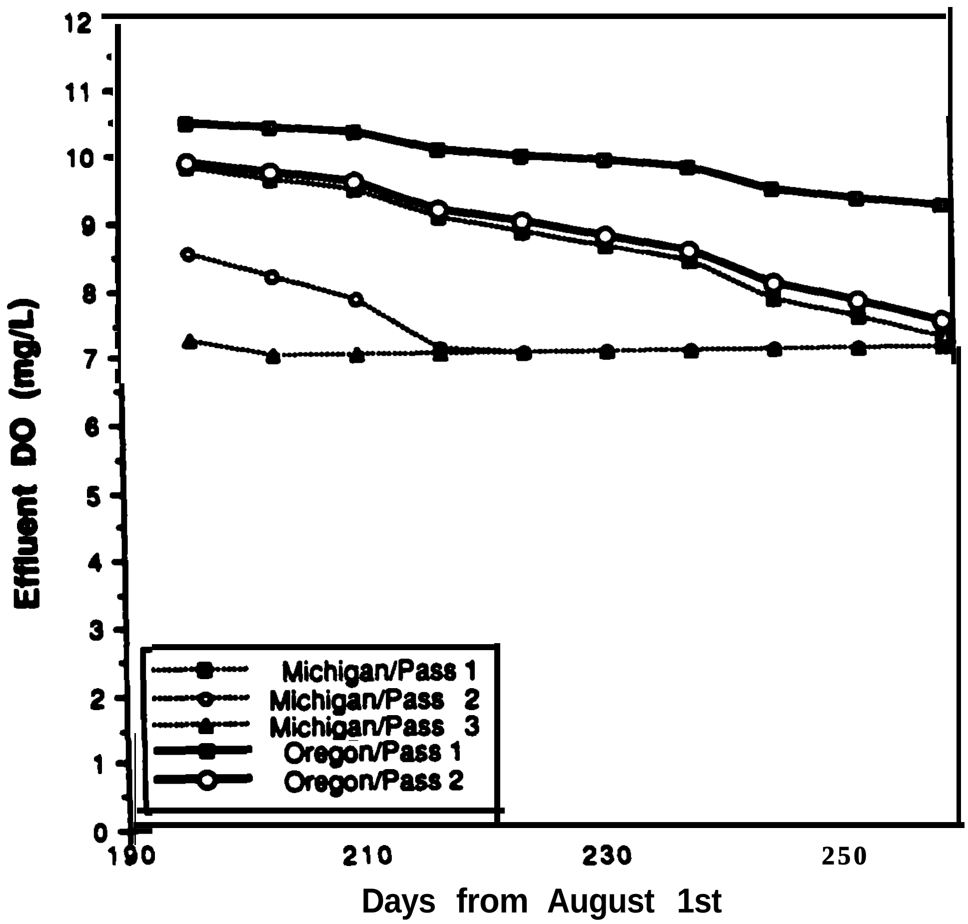

Figure 4 Effluent DOs (mg/L) for fall chinook using a 7 mg/L dissolved oxygen criteria. (based on peak oxygen consumption).

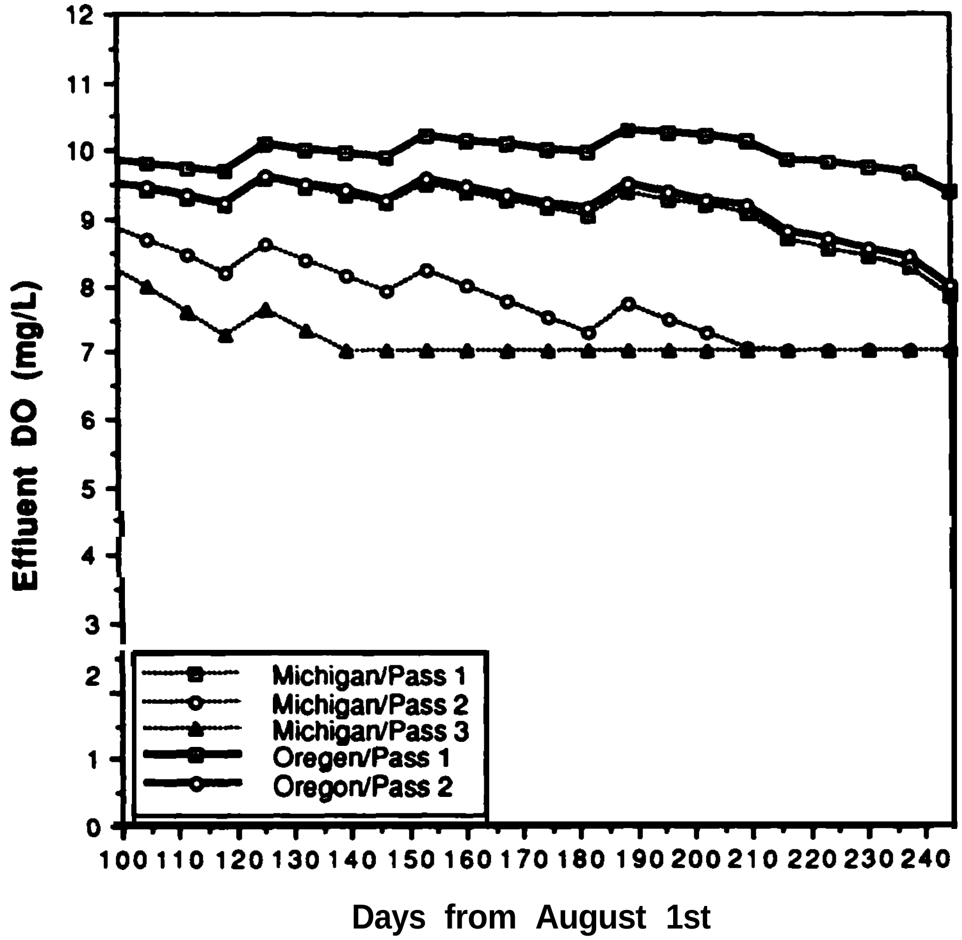

Figure 5 Effluent DOs (mg/L) for spring chinook using a 7 mg/L dissolved oxygen criteria. (based on peak oxygen consumption).

Oxygen Consumption and ADO

The weekly oxygen consumption and **ΔDO** through the oxygen contactors are presented in Appendixes B-F. The range of oxygen consumption rates for the different treatments are presented in Table 4:

Table 4 Raceway Oxygen Consumption (mg/L) and Cumulative Oxygen Consumption (mg/L) for each Treatment

Treatment	First Pass	Second Pass	Third Pass	Total System
STSMICH	0.45-3.77	0.45-3.77	0.45-3.77	1.35-l 1.31
SCHMICH	O-62-2.98	0.62-2.98	0.62-2.98	1.86-8.94
FCHMICH	1.28-3.64	1.28-3.64	1.28-3.64	3.84-l 0.92
FCHOREG	0.60-l .69	0.60-l .69	---	l-20-3.38
SCHOREG	0.29-l .41	0.29-l .41	---	0.58-2.28

The oxygen consumption does not depend on the effluent DO criteria. The maximum **COCs** in the **Michigan** systems range from 9-11 mg/L compared to 2-3 mg/L in the **Standard Oregon** systems.

The ADO through the oxygen contactor units is presented in Table 5 for a saturation criteria and in Table 6 for a 7 mg/L criteria. For the saturation criteria, the ADO is equal to the oxygen consumption rate, i.e., the amount of supplemental oxygen replaces any oxygen consumed by the fish. The ADO for the 7 mg/L criteria is less than for the saturation criteria as a significant amount of oxygen contained in the influent water is used by the fish. For the 7 mg/L criteria, supplemental oxygen is not required in the first pass of the Michigan raceways over the whole production cycle. During the early portions of the production cycle, supplemental oxygen is not required in the second and third passes.

Table 5 ADO (mg/L) through the Oxygen Contactor Units for a Saturation Criteria

Treatment	First Pass	Second Pass	Third Pass
STSMICH	0.45-3.77	o-45-3.77	0.45-3.77
SCHMICH	0.62-2.98	0.62-2.98	0.62-2.98
FCHMICH	1.28-3.64	1.28-3.64	1.28-3.64
FCHOREG	0.00	0.00	----
SCHOREG	0.00	0.00	----

Table 6 ΔDO (mg/L) through the Oxygen Contactor Units for a 7 mg/L Ctiteria

Treatment	First Pass	Second Pass	Third Pass
STSMICH	0.00-0.00	0.00-3.59	0.00-3.77
SCHMICH	0.00-0.00	0.00-2.15	0.00-2.98
FCHMICH	0.00-0.00	0.00-3.47	0.00-3.64
FCHOREG	0.00	0.00	---
SCHOREG	0.00	0.00	----

Absorption Efficiencies

The absorption efficiencies for the two effluent criteria cases range from 43-51% and are presented in the Table 7. The absorption efficiencies for the saturation criteria are the same within each treatment because the ADO are identical. In the 7 mg/L criteria case, the absorption efficiencies decrease through the system. The overall absorption efficiencies for the two dissolved oxygen criteria case are comparable.

Table 7 Absorption Efficiencies (%) for the Michigan Treatments

Treatment	First Pass	Second Pass	Third Pass	Overall
STSMICH/Sat	43.9	43.9	43.9	43.9
SCHMICH/Sat	48.2	48.2	48.2	48.2
FCHMICH/Sat	43.7	43.7	43.7	43.7
STSMICH/7 mg/L	--	46.7	43.3	44.6
SCHMICH/7 mg/L	--	50.7	47.1	47.8
FCHMICH/7 mg/L	---	44.0	42.9	43.3

Oxygen Requirement

Weekly Requirements

Based on the oxygen required by the fish and the absorption efficiency of the oxygen contactor, the overall oxygen requirement was computed weekly.

Criteria Based on Saturation

The overall oxygen requirement is presented in Table 8 for a saturation effluent criteria. The maximum weekly oxygen requirement for the whole system is 10,906 lb and occurs on the week ending on March 6th. The overall oxygen requirement generally increases over the production cycle (Figure 6).

Criteria Based on 7 mg/L

The overall oxygen requirement is presented in Table 9 for a 7 mg/L effluent criteria. The maximum weekly oxygen requirement for the whole system is 9080 lb and occurs on the week ending on April 17th. The overall oxygen requirement generally increases over the production cycle (Figure 7).

Table 8 Overall Weekly Oxygen Requirements for a Saturation Effluent Criteria

Days	Date	Summer Steelhead (per bank	Spring Chinook (per bank	Fall Chinook (per bank)	Summer Steelhead (Species Total)	Spring Chinook (Species Total)	Fall Chinook (Species Total)	System Total
0	01-Aug-89	0	0	0	0	0	0	0
7	08-Aug-89	187	0	0	374	0		374
14	15-Aug-89	227	0	0	454		8	454
21	22-Aug-89	271	0	0	542	8	0	542
28	29-Aug-89	321	0	0	842	0	0	842
35	05-Sep-89	389	0		778	0	0	778
42	12-Sep-89	450	0	8	900	0	0	900
49	19-Sep-89	518		0	1036	0	0	1036
56	26-Sep-89	833	8	0	1288	0	0	1266
63	03-Oct-89	691	0	0	1382		0	1382
70	10-Oct-89	733	0		1488	8	0	1466
77	17-Oct-89	827	0	8	1654	0	0	1654
84	24-Oct-89	929			1858	0	0	1858
91	31-Oct-89	1042	8	8	2084	0	0	2084
98	07-Nov-89	1002	281	0	2004	522	0	2528
105	14-Nov-89	1108	311	0	2218	822	0	2838
112	21-Nov-89	1222	388	0	2444	732	0	3178
119	28-Nov-89	1347	427	0	2694	854	0	3548
126	05-Dec-89	1234	421	0	2488	842	0	3310
133	12-Dec-89	1337	478	0	2874	952	0	3828
140	19-Dec-89	1447	534	0	2894	1068	0	3962
147	26-Dec-89	1565	598	0	3130	1196	0	4328
154	02-Jan-90	1471	591	0	2942	1182	0	4124
161	09-Jan-90	1574	850	0	3148	1300		4448
168	16-Jan-90	1683	712	0	3388	1424	8	4790
175	23-Jan-90	1800	779	0	3800	1558	0	5158
182	30-Jan-90	1925	850	0	3850	1700	0	5550
189	06-Feb-90	1750	808	0	3500	1616	0	[illegible]116
196	13-Feb-90	1853	870	585	3708	1740	2340	[illegible]786
203	20-Feb-90	1961	938	874	3922	1872	2898	[illegible]90
210	27-Feb-90	2078	1006	771	4152	2012	3084	[illegible]248
217	06-Mar-90	2402	1161	945	4804	2322	3780	10906
224	13-Mar-90	0	1252	1082	0	2504	4328	8832
231	20-Mar-90	0	1348	1235	0	2898	4940	7838
238	27-Mar-90	0	1450	1405	0	2900	5820	8520
245	03-Apr-90	0	1683	1729	0	3368	6916	10282
252	10-Apr-90	0	0	1981	0	0	7924	7924
259	17-Apr-90	0	0	2270	0		9080	9080
266	24-Apr-90	0	0	0	0	8	0	0
273	01-May-90	0	0	0	0	0	0	0
280	08-May-90	0	0	0	0	0	0	0

Table 9 Overall Weekly Oxygen Requirements for a 7 mg/L Criteria

Days	Date	Summer Steelhead (per bank	Spring Chinook (per bank	Fall Chinook (per bank	Summer Steelhead (Species Total)	Spring Chinook (Species Total)	Fall Chinook (Species Total)	System Total
0	01-Aug-89	0	0	0	0	0	0	0
7	08-Aug-89	0	0	0	0	0	0	0
14	15-Aug-89	0	0	0	0	0	0	0
21	22-Aug-89	0	0	0	0	0	0	0
28	29-Aug-89	0	0	0	0	0	0	0
35	05-Sep-89	1	0	0	2	0	0	2
42	12-Sep-89	53	0	0	106	0	0	106
49	19-Sep-89	113	0	0	226	0	0	226
56	26-Sep-89	221	0	0	442	0	0	442
63	03-Oct-89	254	0	0	508	0	0	508
70	10-Oct-89	289	0	0	578	0	0	578
77	17-Oct-89	369	0	0	738	0	0	738
84	24-Oct-89	458	0	0	916	0	0	916
91	31-Oct-89	558	0	0	1116	0	0	1116
98	07-Nov-89	462	0	0	924	0	0	924
105	14-Nov-89	552	0	0	1104	0	0	1104
112	21-Nov-89	652	0	0	1304	0	0	1304
119	28-Nov-89	763	0	0	1526	0	0	1526
126	05-Dec-89	594	0	0	1188	0	0	1188
133	12-Dec-89	680	0	0	1360	0	0	1360
140	19-Dec-89	775	4	0	1550	8	0	1558
147	26-Dec-89	878	54	0	1756	108	0	1864
154	02-Jan-90	743	11	0	1486	22	0	1508
161	09-Jan-90	830	57	0	1660	114	0	1774
168	16-Jan-90	924	109	0	1848	218	0	2066
175	23-Jan-90	1026	166	0	2052	332	0	2384
182	30-Jan-90	1138	231	0	2276	462	0	2738
189	06-Feb-90	920	145	0	1840	290	0	2130
196	13-Feb-90	1007	199	585	2014	398	2340	4752
203	20-Feb-90	1101	259	674	2202	518	2696	5416
210	27-Feb-90	1202	326	771	2404	652	3084	6140
217	06-Mar-90	1543	469	945	3086	938	3780	7804
224	13-Mar-90	0	540	1082	0	1080	4328	5408
231	20-Mar-90	0	617	1235	0	1234	4940	6174
238	27-Mar-90	0	700	1405	0	1400	5620	7020
245	03-Apr-90	0	924	1729	0	1848	6916	8764
252	10-Apr-90	0	0	1981	0	0	7924	7924
259	17-Apr-90	0	0	2270	0	0	9080	9080
266	24-Apr-90	0	0	0	0	0	0	0
273	01-May-90	0	0	0	0	0	0	0
280	08-May-90	0	0	0	0	0	0	0

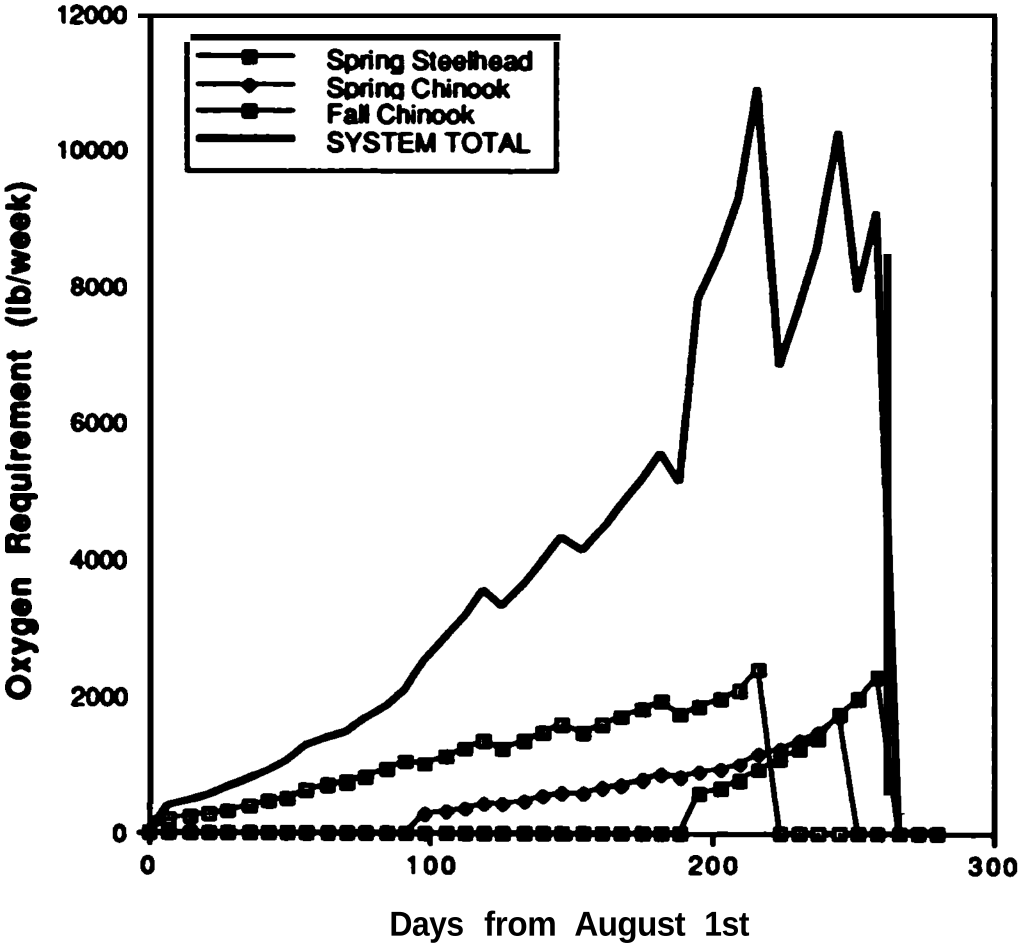

Figure 6 Weekly oxygen requirements (lb/week) for spring steelhead, spring chinook, fall chinook, and total system using a saturated dissolved oxygen criteria. (based on peak oxygen consumption).

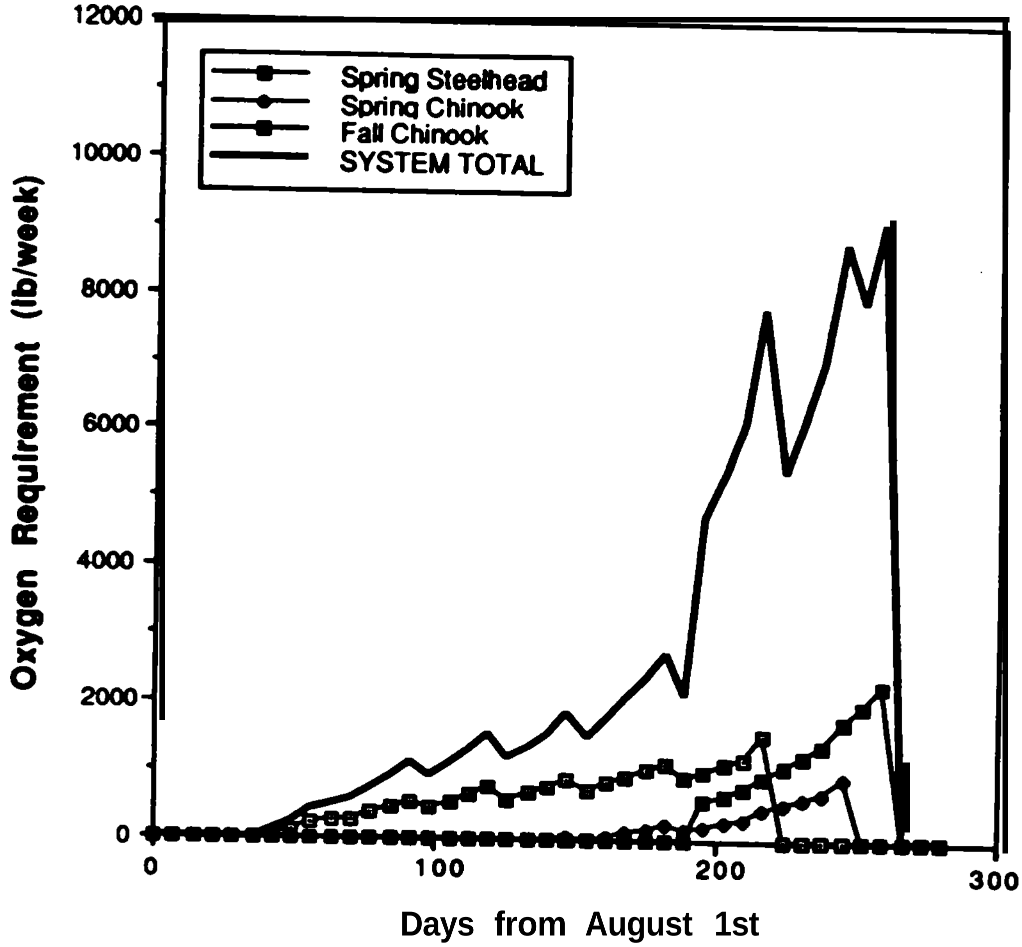

Figure 7 Weekly oxygen requirements (lb/week) for spring steelhead, spring chinook, fall chinook, and total system using a 7 mg/L dissolved oxygen criteria. (based on peak oxygen consumption).

Yearly Requirements

Based on the total of the weekly oxygen requirements for each bank of three raceways, the overall annual oxygen requirements in pounds were computed for each treatment:

Treatment	Saturation Criteria	7 mg/L Criteria
STSMICH	35,975	18,107
SCHMICH	17,492	4810
FCHMICH	12,877	5854
FCHOREG	0	0
SCHOREG	0	0
System Total	157,642	88,450

The system total in the previous table is based on two replicates for the STSMICH and SCHMICH and four replicates for FCHMICH. To more clearly show the impact of dissolved oxygen criteria on oxygen requirement, the oxygen requirement for FCHMICH was computed for a wide range of absolute dissolved oxygen criteria. The oxygen requirement for the saturation criteria is comparable to an absolute criteria of approximately 11 mg/L (Figure 8).

Design Requirements

The design oxygen requirements are needed to size equipment, instrumentation, and piping as well as for economic analysis of the system and alternatives. The oxygen requirements in this report are based on the peak oxygen consumption. If some type of dynamic control is provided to reduce oxygen gas flow to the contactors, it is possible to reduce the oxygen requirements in this report by 30-40%. While this type of control system can significantly reduce oxygen costs, its impact on system complexity and reliability must be carefully evaluated.

The accuracy and frequency of the adjustment of the gas flow rate will significantly effect the oxygen requirement. Operational constraints and reliability

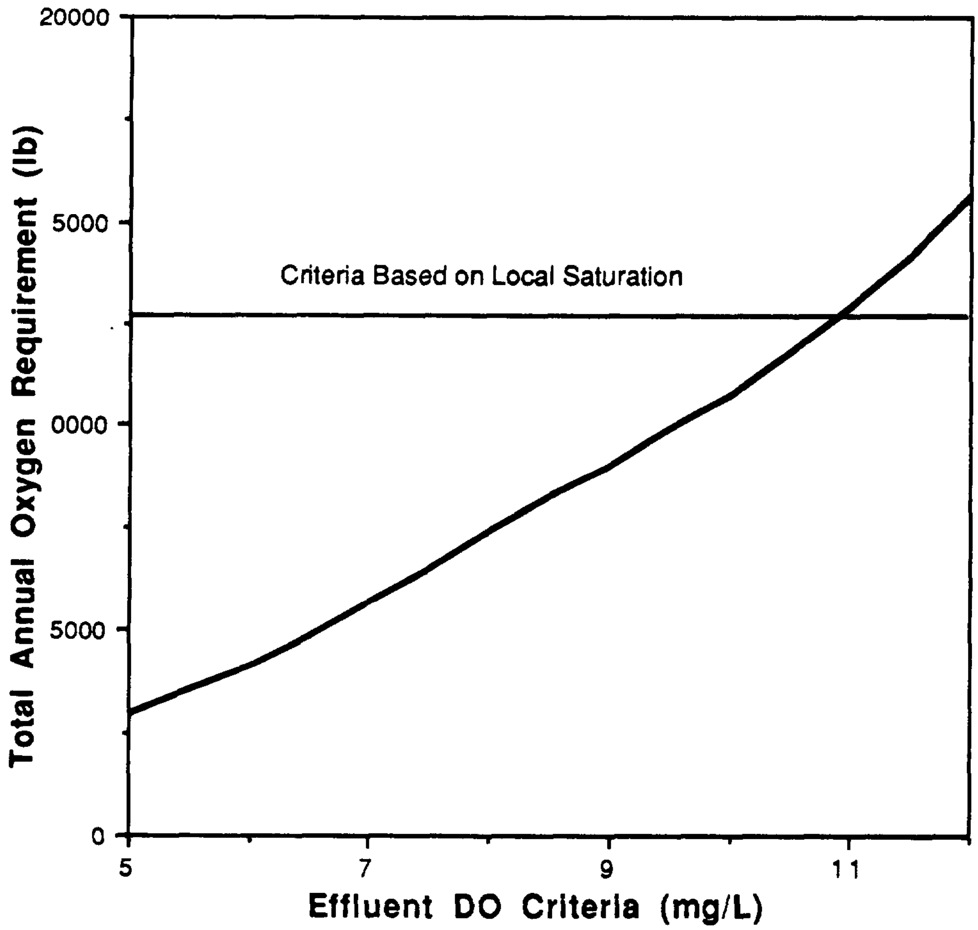

Figure 8 Effect of effluent DO criteria (mg/L) on total annual oxygen requirement for a three-pass Michigan system (based on fall chinook salmon)

considerations will potentially result in a tendency for hatchery personnel to increase the oxygen gas flow rate over what is required. To account for this action and other oxygen losses, a safety factor of 1.25 has been applied to the model results to compute the weekly and yearly design requirements.

Daily

The daily design oxygen requirement was computed from l/7 of the maximum weekly system requirement and a safety factor of 1.50. This safety factor included the gas flow safety factor and an adjustment to correct for daily increases in oxygen consumption over the weekly period.

Daily Design Oxygen Requirements (Saturation)	**2,300 lb**
Daily Design Oxygen Requirements (7 mg/L)	**1,700 lb**

Weekly

Weekly design oxygen requirements were based on the computed values and a safety factor of 1.25.

Weekly Design Oxygen Requirements (Saturation)	**13,600 lb**
Weekly Design Oxygen Requirements (7 mg/l)	**11,400 lb**

Yearly

Yearly design oxygen requirements were based on the computed values and a safety factor of 1.25.

Yearly Design Oxygen Requirements (Saturation)	**197,000 lb**
Yearly Design Oxygen Requirements (7 mg/L)	86,000 **lb**

Oxygen Costs

Oxygen can be generated on-site using pressure-swing absorption (PSA) units or by purchase of liquid oxygen (LOX) (Colt and Watten, 1988). The initial design at Umatilla was based on the use of PSA units. Because of the reliability of a LOX system, consideration is being given for addition of a LOX system as a backup to the designed PSA system.

The cost of LOX depends strongly on the number of plants in the area, transportation charges, and contracting procedures. Because of the uncertainty in the type of system that will be used at the Umatilla Hatchery, yearly oxygen costs are computed for a typical range of oxygen costs. Cost estimates are based on the yearly design oxygen requirements listed in the previous section. Oxygen costs are expressed in terms of $/100 ft^3 of gas at standard conditions (0.08309 lb/ft^3) and are equal to:

Cost/l 00 ft^3	Saturation	**7 mg/L**
$0.40	$9,500	$4,100
$0.50	$11,900	$5,200
SO.60	$14,200	$6,200

While oxygen costs for the saturation criteria are 2.3 times higher than for the 7 mg/L, at an oxygen cost of **$0.50/100 ft^3,** the difference in costs is only $6,700. For an oxygen cost of **$0.50/100 ft^3,** the yearly oxygen costs and savings are presented below for a range of absorption efficiencies for a saturated effluent criteria:

Absorption Efficiency (%)	Annual Costs($)	Annual Saving($)
44.6 (existing)	11,863	----
50	10,629	1,236
60	8,855	3,008
70	7,590	4,273
80	6,642	5,221
90	5,904	5.959

Hatchery Intensity

The intensity of a hatchery may be measured in a number of ways. Some of the most important parameters that measure intensity are cumulative oxygen consumption, volumetric density, and loading. As one of the primary advantages of the use of supplemental oxygen is increased intensity, the intensity of the two rearing systems planned for the Umatilla Hatchery will be compared. Because no spring steelhead will be reared in **Standard Oregon** raceways at the Umatilla Hatchery, comparison will be limited to the two stocks of chinook salmon.

Cumulative Oxygen Consumption (COC)

The comparison of cumulative oxygen consumption (COC) rates are based on the maximum yearly COCs expressed in **mg/L:**

Treatment	Michigan	Standard Oregon	Michigan/Oregon
Spring Chinook	8.94	**2.28**	**3.92**
Fall Chinook	10.92	**3.38**	**3.23**

Based on COC, the intensity of the **Michigan** system is 3-4 times larger than the **Standard Oregon** system.

Volumetric Density (lb/ft^3)

The comparison of volumetric density is based on the maximum **yearly** biomass:

Treatment	Michigan	Standard Oregon	Michigan/Oregon
Spring Chinook	4.2 (0.69)	0.96 (0.16)	4.4
Fall Chinook	3.2 (0.84)	0.73 (0.19)	4.4

Based on volumetric density, the intensity of the **Michigan** system is 4.4 times larger than the **Standard Oregon** system. The numbers within the parenthesis are the density index, which is equal to the density divided by the length of the fish.

Loading (lb/gpm)

The comparison of loading is based on the overall maximum yearfy loadings:

Treatment	Michigan	Standard Oregon	Michigan/Oregon
Spring Chinook	16.8 (2.8)	5.9 (0.98)	2.9
Fall Chinook	13.09 (3.4)	4.5 (1.2)	2.9

Based on Loading, intensity of the **Michigan** system is 2.9 times larger than the **Standard Oregon** system. The numbers within the parenthesis are the loading index, which is equal to the loading divided by the length of the fish.

Conclusions

Based on feed consumption, the oxygen requirement for the Umatilla Hatchery was computed. The oxygen requirement depends strongly on the minimum oxygen criteria. Two oxygen criteria based on effluent concentrations from the raceways were tested:

Saturation (depending on elevation and temperature)

7 mg/L (a criteria commonly used for flow-through salmon hatcheries)

The results of the modelling for the two dissolved oxygen criteria cases are summarized below:

Parameter	Saturation Criteria	7 mg/L Criteria
Absorption Efficiency (%)	44.8	44.6
Design Oxygen Requirement (lb)		
Daily	3,100	2,600
Weekly	13,600	11,400
Yearly	197,000	86,000
Oxygen Costs ($/year)		
$0.40/100 ft^3	9,500	4,100
$0.50/l 00 ft^3	11,900	5,200
$0.60/l 00 ft^3	14,200	6,200

There is probably little biological basis to support the saturation criteria over the 7 mg/L criteria, although it provides higher dissolved oxygen concentrations and therefore its selection may be more prudent during the experimental phase of the Umatilla Hatchery. Because of higher oxygen use for the saturation criteria, the use of this criteria will reduce the dissolved nitrogen gas concentrations in the raceways significantly more than for the 7 mg/L criteria. The reduction in nitrogen gas may have more impact on the fish than the increased dissolved oxygen.

While the oxygen requirement for the saturation criteria is significantly larger than for the 7 mg/L, the absolute difference is relatively small compared to the operational cost of the overall hatchery. Increasing the absorption efficiency from the existing value to 90% could reduce annual oxygen costs by $5,959 based on an oxygen cost of $0.50/100 ft^3.

The intensity of the **MIchigan** system is higher than the **Standard Oregon** system. The intensity ratio (intensity of the Michigan system/intensity of the standard Oregon system) is equal to:

Parameter	Intensity Ratio
Cumulative Oxygen Consumption (CCC)	3.2-3.9
Volumetric Density **(lb/ft^3)**	4.4
Loading (lb/gpm)	2.9

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Westers, H. V. Bennett, and J. Copeland. 1967. Michigan's Experience with Supplemental.Oxygen in **Salmonid** Rearing. Pages 12-16 **in** Papers on the use of supplemental oxygen to increase hatchery rearing capacity in the Pacific Northwest, Bonneville Power Administration, Portland, Oregon.

Appendix A - Spreadsheet Instructions

UMATILLA OXYGEN SUPPLEMENTATION PROJECT

The spreadsheet used tocompute the oxygen requirement for the Umatilla Project is written in Lotus 123 (Version 2.0). The spreadsheet is divided into the following sections:

Summary Page

This page contains summar'es of the influent DOs effluent DOs. density, loading, oxygen requirements, and absorption efficiencies for each species or case tested.

Growth Model

The following length-weight relationship was used:

$$\text{Weight (lb)} = K(\text{Length in inches})^3$$

Where

K =0.0003405 Summer Steelhead

K = 0.0002959 Spring Chinook

K = 0.0002959 Fall Chinook

A ΔL growth model was used:

$$\Delta L \text{ (inches)} = (T - T_0)/TU$$

where

TU = 810/inch Summer Steelhead

TU = 840/inch Spring Chinook

TU = 840/inch Fall Chinook

T = temperature (F)

T_0 = 32 F

The change in length (AL) was computed on a weekly basis.For temperatures ova 59 F, the growth rate was reduced by 5%/degree F.

The HCTU is equal to:

$$HCTU = (300)(FCR)/TU$$

where

FCR = Feed Conversion Ratio (1.00 lb feed/lb fish)

This parameter is used to compute the feeding rate. The working temperatures that the spreadsheet uses are stored in the cells C67-C107.

Mortality Model

A simple linear mortality model is used. Using the fish numbers from the mortality model and and fish weigh from the growth model, the total biomass in each raceway is computed on a weekly basis.

Dissolved Oxygen Criteria

Based on the water temperature, elevation, and assumed percent saturation, the influent DO to the raceways was computed (E164-E204). The working effluent criteria is stored in cells C164-C204. Depending on the desired effluent criteria, either the saturation values (E164-E204) or an absolute criteria (G164-G204) should be copied into C164-C204.

Individual Raceway Information

Five different treatments will be used in this experiment:

Species	System	Number of passes	Supplemental Oxygen	Replicates
Summer Steelhead	Michigan System	3	yes	2
spring Chinook	Michigan system	3	yes	2
Fall Chinook	Michigan System	3	yes	4
spring Chinook	Oregon System	2	m	2
Fall Chinook	Oregon system	2	m	3

The oxygen demand for each treatment is computed on a weekly basis using the following information:

Oxygen-Feed Ratio	Pounds oxygen required/lb feed consumed
Peaking Factor	Ratio of maximum DO requirement/average DO requirement

The oxygen absorption efficiency is computed fmm the following assumed relationship:

$$\text{Absorption Efficiency (decimal fraction)} = 0.60 - 0.006(\Delta DO)$$

where

ΔDO = required change in DO (mg/L) through the column

Detailed information on the computation of each column in the printout is presented below:

Feed (%)	Feed expressed as a percent of body weight; equal to HCTU/L, where L is equal to length of the fish in inches
Feed (lb)	Pounds of feed required per raceway: computed from Feed (%) and biomass of fish

O_2 Avail (lb/d)	Pounds of oxygen available in flow based on a minimum DO of 7.00 mg/L
Peak Demand (lb/d)	Pounds of oxygen needed by fish based on oxygen-feed ratio for peak conditions. The O_2 need are based on the effluent DO criteria computed previously.
Aver Demand (lb/d)	Pounds of oxygen needed by fish based on oxygen-feed ratio far average conditions. The O_2 need are based on the effluent DO criteria computed previously.
Peak DO_{in}	Influent DO to raceways under peak oxygen demand conditions.
Peak DO_{out}	Effluent DO from raceway under peak oxygen demand conditions.
Ava. DO_{in}	Influent DO to raceways under average oxygen demand conditions.
Aver. DO_{out}	Effluent DO from raceway under average oxygen demand conditions.
Oxygen (lb) - Require	Pounds of oxygen required per raceway per week by the fish.
Oxygen (lb) - Purchase	Pounds of oxygen that must be purchased; this is based on the Oxygen Required and the absorption efficiency of the transfer columns
Delta-DO far AU	Required dissolved oxygen increased through the absorber unit in mg/l
Delta-DO for RU	Overall oxygen requirement in the rearing unit in mg/l

Summary of Weekly Oxygen Requirements

The weekly oxygen purchase is listed for each raceway on a weekly basis, along with annual totals for the raceways and treatments.

Appendix B-1 - Summer Steelhead
Michigan System
Effluent DO Criteria: Saturation

SUMMARY OF INFLUENT AND EFFLUENT Don

	Well Water		Effluent from Raceways		
	DOmin	DOmax	DOmin	DOmax	Delta-DO
Mich lrt	9.67	11.09	9.67	12.14	-3.n
Mich 2nd			9.67	13.25	-3.n
Mich fth			9.67	14.10	-3.77

SUMMARY OF FINAL INTENSITY DATA

	Hatchery Intensity				
	Biomass (lb)	Flow (gpm)	Volume (ft3)	Density (lb/ft3)	Loading (lb/gpm)
Mich 1st	14071	940	1890	7.45	14.97
Mich 2nd	14071	940	1890	7.45	29.94
Mich 3th	14071	940	1890	7.45	44.91

SUMMARY OF OXYGEN REQUIREMENTS

	lb/raceway	AE%
Mich 1st	11992	43.9%
Mich 2nd	11992	43.9%
Mich 3th	11992	43.9%
	35975	43.9%

GROWTH MODELLING

C=	0.00034		Init. #/lb	300.00
n	3.00		Init. Length (in)	2.14
TU/inch	810		Init. Wt (g)	1.52
TO	32.00	(F)		
FCR	1.00	(lb feed/lb fish)	Elevation (ft)	500
HCTU	0.37037	(inches,F,day)	BP (mm Hg)	747

Date	Day	Test Temp (F)	Growth Model Weight (g)	Growth Model Weight (#/lb)	Growth Model Length (inch)	Average Temp (F)	Maximum Temp (F)
01-Aug-89	0	60.0	1.52	300.00	2.14	60.0	
08-Aug-89	7	60.0	2.06	220.87	2.37	60.0	
15-Aug-89	14	60.0	2.72	167.29	2.60	60.0	
22-Aug-89	21	60.0	3.50	129.73	2.83	60.0	
29-Aug-89	28	60.0	4.43	102.63	3.06	60.0	
OS-Sep-89	35	61.0	5.48	82.90	3.28	61.0	
12-Sep-89	42	61.0	6.69	67.92	3.51	61.0	
19-Sep-89	49	61.0	8.07	56.35	3.74	61.0	
26-Sep-89	56	61.0	9.62	47.26	3.96	61.0	
03-Oct-89	63	60.0	11.39	39.90	4.19	60.0	
10-Oct-89	70	60.0	13.37	33.99	4.42	60.0	
17-Oct-89	77	60.0	15.57	29.20	4.65	60.0	
24-Oct-89	84	60.0	17.99	25.26	4.88	60.0	
31-Oct-89	91	60.0	20.66	22.01	5.11	60.0	
07-Nov-89	98	57.0	23.39	19.44	5.33	57.0	
14-Nov-89	105	57.0	26.35	17.25	5.54	57.0	
21-Nov-89	112	57.0	29.56	15.38	5.76	57.0	
28-Nov-89	119	57.0	33.01	13.77	5.97	57.0	
05-Dec-89	126	54.0	36.26	12.54	6.16	54.0	
12-Dec-89	133	54.0	39.72	11.44	6.35	54.0	
19-Dec-89	140	54.0	43.40	10.48	6.54	54.0	
26-Dec-89	147	54.0	47.29	9.61	6.74	54.0	
02-Jan-90	154	52.0	51.02	8.91	6.91	52.0	
09-Jan-90	161	52.0	54.95	8.27	7.08	52.0	
16-Jan-90	168	52.0	59.07	7.70	7.25	52.0	
23-Jan-90	175	52.0	63.40	7.17	7.43	52.0	
30-Jan-90	182	52.0	67.93	6.69	7.60	52.0	
06-Feb-90	189	50.0	72.18	6.30	7.n	50.0	
13-Feb-90	1 %	50.0	76.62	5.93	7.91	50.0	
20-Feb-90	203	50.0	81.23	5.60	8.07	50.0	
27-W-90	210	50.0	86.02	5.28	a.22	50.0	
06-Mar-90	217	51.0	91.27	4.98	8.39	51.0	
13-Mar-90		51.0				51.0	
20-Mar-90		51.0				51.0	
27-Mar-90		51.0				51.0	
03-Apr-90		52.0				52.0	
10-Apr-90		52.0				52.0	
17-Apr-90		52.0				52.0	
24-Apr-90		52.0				52.0	

MORTALITY MODEL Mortality/dry (%) 0.0060 Initial Number 71000

Date	MICHIGAN SYSTEM		
	#/lb	Number	Mass(lb)
01-Aug-89	300.00	71000	237
08-Aug-89	220.87	70970	321
15-Aug-89	167.29	70940	424
22-Aug-89	129.73	70911	547
29-Aug-89	102.63	70881	691
05-Sep-89	82.90	70851	855
12-Sep-89	67.92	70821	1043
19-Sep-89	56.35	70792	1256
26-Sep-89	47.26	70762	1497
03-Oct-89	39.90	70732	1773
lo-m-89	33.99	70702	2080
17-Oct-89	29.20	70673	2420
24-Oct-89	25.26	70643	2796
31-Oct-89	22.01	70613	3209
07-Nov-89	19.44	70584	3632
14.Nov.69	17.25	70554	4090
21-Nov-89	15.38	70524	4585
28-Nov-89	13.77	70495	5119
05-Dec-89	12.54	70465	5621
12-Dec-89	11.44	70436	6155
19-Dec-89	10.48	70406	6721
26-Dec-89	9.61	70376	7321
02-Jan-90	8.91	70347	7896
09-Jan-90	a.27	70317	8500
16-Jan-90	7.70	70288	9134
23-Jan-90	7.17	70258	9798
30-Jan-90	6.69	70229	10494
06-Feb-90	6.30	70199	11147
13-Feb-90	5.93	70170	11826
20-Feb-90	5.60	70140	12533
27-Feb-90	5.28	70111	13266
06-Mar-90	4.98	70081	14071
13-Mar-90			
20-Mar-90			
27-Mar-90			
03-Apr-90			
10-Apr-90			
17-Apr-90			
24-Apr-90			
01-May-90			
08-May-90			

DISSOLVED OXYGEN CRITERIA IN EFFLUENT

Influent DO%	100
Oxygen-Feed Ratio	0.25
Peaking Factor	1.44

	Effluent Criteria (mg/l)	Influent DO (mg/l)	Absolute	Sat. et Sealevel (mg/l)	Vapor Press. (mm Hg)	Sat. at Hatchery (mg/l)
01-Aug-89	9.79	9.79	7.00	9.96	13.25	9.79
08-Aug-89	9.79	9.79	7.00	9.96	13.25	9.79
15-Aug-89	9.79	9.79	7.00	9.96	13.25	9.79
22-Aug-89	9.79	9.79	7.00	9.96	13.25	9.79
29-Aug-89	9.79	9.79	7.00	9.96	13.25	9.79
05-Sep-89	9.67	9.67	7.00	9.85	13.73	9.67
12-Sep-89	9.67	9.67	7.00	9.85	13.73	9.67
19-Sep-89	9.67	9.67	7.00	9.85	13.73	9.67
26-Sep-89	9.67	9.67	7.00	9.85	13.73	9.67
03-Oct-89	9.79	9.79	7.00	9.96	13.25	9.79
10-Oct-89	9.79	9.79	7.00	9.96	13.25	9.79
17-Oct-89	9.79	9.79	7.00	9.96	13.25	9.79
24-Oct-89	9.79	9.79	7.00	9.96	13.25	9.79
31-Oct-89	9.79	9.79	7.00	9.96	13.25	9.79
07-Nov-89	10.15	10.15	7.00	10.33	11.90	10.15
14-Nov-89	10.15	10.15	7.00	10.33	11.90	10.15
21-Nov-89	10.15	10.15	7.00	10.33	11.90	10.15
28-Nov-89	10.15	10.15	7.00	10.33	11.90	10.15
OS-Dee-89	10.53	10.53	7.00	10.72	10.67	10.53
12-Dec-89	10.53	10.53	7.00	10.72	10.67	10.53
19-Dec-89	10.53	10.53	7.00	10.72	10.67	10.53
26-Dec-89	10.53	10.53	7.00	10.72	10.67	10.53
02-Jan-90	10.60	10.80	7.00	11.00	9.92	10.80
09-Jan-90	10.80	10.80	7.00	11.00	9.92	10.80
16-Jan-90	10.80	10.80	7.00	11.00	9.92	10.80
U-Jan-90	10.80	10.80	7.00	11.00	9.92	10.80
30-Jan-90	10.80	10.80	7.00	11.00	9.92	10.80
06-Feb-90	11.09	11.09	7.00	11.29	9.21	11.09
13-Feb-90	11.09	11.09	7.00	11.29	9.21	11.09
20-Feb-90	11.09	11.09	7.00	11.29	9.21	11.09
27-Feb-90	11.09	11.09	7.00	11.29	9.21	11.09
06-Mar-90	10.94	10.94	7.00	11.14	9.56	10.94
13-Mar-90	10.94	10.94	7.00	11.14	9.56	10.94
20-Mar-90	10.94	10.94	7.00	11.14	9.56	10.94
27-Mar-90	10.94	10.94	7.00	11.14	9.56	10.94
03-Apr-90	10.80	10.80	7.00	11.00	9.92	10.80
10-Apr-90	10.80	10.80	7.00	11.00	9.92	10.60
17-Apr-90	10.80	10.80	7.00	11.00	9.92	10.60
24-Apr-90	10.80	10.80	7.00	11.00	9.92	10.80
01-May-90	10.53	10.53	7.00	10.72	10.67	10.53
08-May-90	10.53	10.53	7.00	10.72	10.67	10.53
	Minimum	9.67	7.00	9.85	9.21	9.67
	Maximum	11.09	7.00	11.29	13.73	11.09

HIGH DENSITY MICHIGAN SYSTEM (First Pass)

Column Performance Data

Flow (gpm) 940 intercept 0.60

slope 0.06

Date	Feed (%)	Feed (lb)	O2-Avail (lb/d)	Peak Dem (lb/d)	Aver Oem (lb/d)	Peak Conditions DOin	Peak Conditions DOout	Aver. Conditions DOin	Aver. Conditions DOout	Oxygen (lb) Require	Oxygen (lb) Purchase	Delta-DO 02 AU	Delta-DO RU
01-Aug-89													
08-Aug-89	4.38	14.1	0.00	5.06	3.52	10.23	9.79	10.23	9.92	35	62	0.45	-0.45
15-Aug-89	3.99	16.9	0.00	6.09	4.23	10.33	9.79	10.33	9.95	43	76	0.54	-0.54
22-Aug-89	3.67	20.0	0.00	7.21	5.01	10.43	9.79	10.43	9.98	50	90	0.64	-0.64
29-Aug-89	3.39	23.4	0.00	a.43	5.85	10.53	9.79	10.53	10.01	59	107	0.75	-0.75
05-Sep-89	3.27	27.9	0.00	10.06	6.99	10.56	9.67	10.56	9.94	70	130	0.89	-0.89
12-Sep-89	3.06	31.9	0.00	11.49	7.98	10.69	9.67	10.69	9.98	80	150	1.02	-1.02
19-Sep-89	2.88	36.1	0.00	13.00	9.03	10.82	9.67	10.82	10.02	91	173	1.15	-1.15
26-Sep-89	2.88	43.1	0.00	15.50	10.76	11.04	9.67	11.04	10.09	108	211	1.37	-1.37
03-Oct-89	2.62	46.4.	0.00	16.71	11.60	11.27	9.79	11.27	10.24	117	230	1.48	-1.48
10-Oct-89	2.35	48.8	0.00	17.56	12.20	11.34	9.79	11.34	10.26	123	244	1.56	-1.56
17-Oct-89	2.23	54.0	0.00	19.43	13.49	11.51	9.79	11.51	10.31	136	276	1.72	-1.72
24-Oct-89	2.12	59.4	0.00	21.39	14.85	11.68	9.79	11.68	10.37	150	310	1.90	-1.90,
31-Oct-89	2.03	65.1	0.00	23.44	16.28	11.86	9.79	11.86	10.42	164	347	2.08	-2.08
07-Nov-89	1.74	63.1	0.00	22.73	15.78	12.16	10.15	12.16	10.76	159	334	2.01	-2.01
14-Nov-89	1.67	68.3	0.00	24.60	17.08	12.33	10.15	12.33	10.81	172	369	2.18	-2.18
21-Nov-89	1.61	75.7	0.00	26.54	18.43	12.50	10.15	12.50	10.87	186	407	2.35	-2.35
28-Nov-89	1.55	79.3	0.00	28.56	19.83	12.68	10.15	12.68	10.92	200	449	2.53	-2.53
05-Dec-89	1.32	74.3	0.00	26.75	18.57	12.90	10.53	12.90	11.26	187	411	2.37	-2.37
12-Dec-89	1.28	78.9	0.00	28.41	19.73	13.05	10.53	13.05	11.30	199	446	2.52	-2.52
19-Dec-89	1.24	63.7	0.00	30.12	20.92	13.20	10.53	13.20	11.35	211	482	2.67	-2.67
26-Dec-89	1.21	88.6	0.00	31.88	22.14	13.36	10.53	13.36	11.40	223	522	2.83	-2.83
02-Jan-90	1.07	64.7	0.00	30.48	21.17	13.50	10.80	13.50	11.63	213	490	2.70	-2.70
W-Jan-W	1.05	88.9	0.00	32.01	22.23	13.64	10.80	13.64	11.67	224	525	2.84	-2.84
16-Jan-90	1.02	93.3	0.00	33.58	23.32	13.78	10.80	13.78	11.71	235	561	2.98	-2.98
23- Jan-W	.1 .00	97.7	0.00	35.18	24.43	13.92	10.80	13.92	11.76	246	600	3.12	-3.12
30-Jan-W	0.97	102.3	0.00	36.82	25.57	14.07	10.80	14.07	11.80	258	642	3.26	-3.26
06-Feb-90	0.86	95.8	0.00	34.50	23.96	14.15	11.09	14.15	12.02	241	583	3.06	-3.06
13-Feb-90	0.84	99.7	0.00	35.88	24.92	14.27	11.09	14.27	12.06	251	618	3.18	-3.18
20-Feb-90	0.83	103.6	0.00	37.29	25.90	14.39	11.09	14.39	12.10	261	654	3.31	-3.31
27-Feb-90	0.81	107.6	0.00	38.73	26.89	14.52	11.09	14.52	12.14	271	692	3.43	-3.43
06-Mar-90	0.84	118.1	0.00	42.51	29.52	14.71	10.94	14.71	12.09	298	801	3.77	-3.77
13-Mar-90													
20-Mar-90													
27-Mar-90													
03-Apr-90													
10-Apr-90													
17-Apr-90													
24-Apr-90													
OI-May-W													
OS-May-W													
Minimum						10.23	9.67	10.23	9.92	5264	11992	0.45	-3.77
Maximum						14.71	11.09	14.71	12.14			3.77	-0.45

HIGH DENSITY MICHIGAN SYSTEM (Second Pass1

Date	DOin		O2-Avail (lb/d)	Peak Dem (lb/d)	Aver Dem (lb/d)	Peak Conditions		Aver. Conditions		Oxygen (lb)		Delta-DO	
	Peak	Average				DOin	DOout	DOin	DOout	Require	Purchase	02 AU	RU
01-Aug-89													
08-Aug-89	9.79	9.92	0.00	5.06	3.52	10.23	9.79	10.37	10.06	35	62	0.45	-0.45
15-Aug-89	9.79	9.95	0.00	6.09	4.23	10.33	9.79	10.49	10.12	43	76	0.54	-0.54
22-Aug-89	9.79	9.98	0.00	7.21	5.01	10.43	9.79	10.62	10.18	50	90	0.64	-0.64
29-Aug-89	9.79	10.01	0.00	a.43	5.85	10.53	9.79	10.76	10.24	59	107	0.75	-0.75
OS-sep-89	9.67	9.94	0.00	10.06	6.99	10.56	9.67	10.84	10.22	70	130	0.89	-0.89
12-Sep-89	9.67	9.98	0.00	Il.49	7.98	10.69	9.67	11.00	10.29	80	150	1.02	-1.02
19-Sep-89	9.67	10.02	0.00	13.00	9.03	10.82	9.67	11.18	10.38	91	173	1.15	-1.15
26-Sep-89	9.67	10.09	0.00	15.50	10.76	11.04	9.67	11.46	10.51	108	211	1.37	-1.37
03-m-89	9.79	10.24	0.00	16.71	11.60	11.27	9.79	11.72	10.69	117	230	1.48	-1.48
10-Oct-89	9.79	10.26	0.00	17.56	12.20	11.34	9.79	11.82	10.74	123	244	1.56	-1.56
17-Oct-89	9.79	10.31	0.00	19.43	13.49	11.51	9.79	12.03	10.84	136	276	1.72	-1.72
24-Oct-89	9.79	10.37	0.00	21.39	14.85	11.68	9.79	12.26	10.94	150	310	1.90	-1.90
31-Oct-89	9.79	10.42	0.00	23.44	16.28	11.86	9.79	12.50	11.06	164	347	2.08	-2.08
07-Nov-89	10.15	10.76	0.00	22.73	15.78	12.16	10.15	12.78	11.38	159	334	2.01	-2.01
14-Nov-89	10.15	10.81	0.00	24.60	17.08	12.33	10.15	12.99	11.48	172	369	2.18	-2.18
21-Nov-89	10.15	10.87	0.00	26.54	18.43	12.50	10.15	13.22	11.58	186	407	2.35	-2.35
28-Nov-89	10.15	10.92	0.00	28.56	19.83	12.68	10.15	13.45	11.69	200	449	2.53	-2.53
05-Dec-89	10.53	11.26	0.00	26.75	is.57	12.90	10.53	13.63	11.98	187	411	2.37	-2.37
12-Dec-89	10.53	11.30	0.00	28.41	19.73	13.05	10.53	13.82	12.07	199	446	2.52	-2.52
19-Dec-89	10.53	11.35	0.00	30.12	20.92	13.20	10.53	14.02	12.16	211	482	2.67	-2.67
26-Dec-89	10.53	11.40	0.00	31.88	22.14	13.36	10.53	14.22	12.26	223	522	2.83	-2.83
02-Jan-90	10.80	11.63	0.00	30.48	21.17	13.50	10.80	14.33	12.45	213	490	2.70	-2.70
W-Jan-W	10.80	11.67	0.00	32.01	22.23	13.64	10.80	14.51	12.54	224	525	2.64	-2.84
16-Jan-90	10.60	11.71	0.00	33.58	23.32	13.78	10.80	14.69	12.62	235	561	2.98	-2.98
23-Jan-90	10.60	11.76	0.00	35.18	24.43	13.92	10.80	14.87	12.71	246	600	3.12	-3.12
30-Jan-90	10.80	11.80	0.00	36.82	25.57	14.07	10.80	15.06	12.80	258	642	3.26	-3.26
06- Ftb-W	11.09	12.02	0.00	34.50	23.96	14.15	Il.w	15.08	12.96	241	583	3.06	-3.06
13-Feb-90	11.09	12.06	0.00	35.88	24.92	14.27	11.09	15.24	13.03	251	618	3.18	-3.18
20-Feb-90	11.09	12.10	0.00	37.29	25.90	14.39	11.09	15.40	13.11	261	654	3.31	-3.31
27-Feb-90	11.09	12.14	0.00	38.73	26.89	14.52	11.09	15.57	13.18	271	692	3.43	-3.43
06-Mar-90	10.94	12.09	0.00	42.51	29.52	14.71	10.94	15.86	13.25	298	801	3.77	-3.77
13-Mar-90													
20-Mar-90													
27-Mar-90													
03-Apr-90													
10-Apr-90													
17-Apr-90													
24-Apr-90													
01-May-90													
OS-Hay-90													
Minimum						10.23	9.67	10.37	10.06	5264	11992	0.45	-3.77
Maximum						14.71	11.09	15.86	13.25			3.77	-0.45

HIGH DENSITY MICHIGAN SYSTEM (Third Pass)

Date	DOin		O2-Avail (lb/d)	Peak Da (lb/d)	Aver Da (lb/d)	Peak Conditions		Aver. Conditions		Oxygen (lb)		Delta-00	
	Peak	Average				DOin	DOout	DOin	DOout	Rtquirt	Purchase	02 AU	RU
01-Aug-89													
08-Aug-89	9.79	10.06	0.00	5.06	3.52	10.23	9.79	10.51	10.20	35	62	0.45	-0.45
15-Aug-89	9.79	10.12	0.00	6.09	4.23	10.33	9.79	10.66	10.28	43	76	0.54	-0.54
22-Aug-89	9.79	10.18	0.00	7.21	5.01	10.43	9.79	10.62	10.37	50	90	0.64	-0.64
29-Aug-89	9.79	10.24	0.00	a.43	5.85	10.53	9.79	10.99	10.47	59	107	0.75	-0.75
05-Sep-89	9.67	10.22	0.00	10.06	6.99	10.56	9.67	11.11	10.49	70	130	0.89	-0.89
12-Sep-89	9.67	10.29	0.00	11.49	7.98	10.69	9.67	11.31	10.60	80	150	1.02	-1.02
19-Sep-89	9.67	10.38	0.00	13.00	9.03	10.82	9.67	11.53	10.73	91	173	1.15	-1.15
26-Sep-89	9.67	10.51	0.00	15.50	10.76	11.04	9.67	11.88	10.93	108	211	1.37	-1.37
03-Oct-89	9.79	10.69	0.00	16.71	11.60	11.27	9.79	12.17	11.14	117	230	1.48	-1.48
10-Oct-89	9.79	10.74	0.00	17.56	12.20	11.34	9.79	12.29	11.21	123	244	1.56	-1.56
17-Oct-89	9.79	10.84	0.00	19.43	13.49	11.51	9.79	12.56	11.36	136	276	1.72	-1.72
24-Oct-89	9.79	10.94	0.00	21.39	14.85	11.68	9.79	12.84	11.52	150	310	1.90	-1.90
31-Oct-89	9.79	11.06	0.00	23.44	16.28	11.86	9.79	13.13	11.69	164	347	2.08	-2.08
07-Nov-89	10.15	11.38	0.00	22.73	15.78	12.16	10.15	13.39	11.99	159	334	2.01	-2.01
14-Nov-89	10.15	11.68	0.00	24.60	17.08	12.33	10.15	13.66	12.15	172	369	2.18	-2.18
21-Nov-89	10.15	11.58	0.00	26.54	18.43	12.50	10.15	13.94	12.30	186	407	2.35	-2.35
28-Nov-89	10.15	11.69	0.00	28.56	19.83	12.68	10.15	14.23	12.47	200	449	2.53	-2.53
05-Dec-89	10.53	11.98	0.00	26.75	18.57	12.90	10.53	14.35	12.70	187	411	2.37	-2.37
12-Dec-89	10.53	12.07	0.00	28.41	19.73	13.05	10.53	14.59	12.84	199	446	2.52	-2.52
19-Dec-89	10.53	12.16	0.00	30.12	20.92	13.20	10.53	14.83	12.98	211	482	2.67	-2.67
26-Dec-89	10.53	12.26	0.00	31.88	22.14	13.36	10.53	15.09	13.12	223	522	2.83	-2.83
02-Jan-90	10.80	12.45	0.00	30.48	21.17	13.50	10.80	15.16	13.28	213	490	2.70	-2.70
W-Jan-W	10.80	12.54	0.00	32.01	22.23	13.64	10.80	15.37	13.40	224	525	2.84	-2.84
16-Jan-90	10.80	12.62	0.00	33.58	23.32	13.78	10.80	15.60	13.53	235	561	2.98	-2.98
23-Jan-90	10.80	12.71	0.00	35.18	24.43	13.92	10.80	15.83	13.66	246	600	3.12	-3.12
30-Jan-90	10.00	12.80	0.00	36.82	25.57	14.07	10.80	16.06	13.80	258	642	3.26	-3.26
06-Feb-90	11.09	12.96	0.00	34.50	23.96	14.15	11.09	16.01	13.89	241	583	3.06	-3.06
13-Feb-90	11.09	13.03	0.00	35.88	24.92	14.27	11.09	16.21	14.00	251	618	3.18	-3.18
20-Feb-90	11.09	13.11	0.00	37.29	25.90	14.39	11.09	16.41	14.12	261	654	3.31	-3.31
27-Feb-90	11.09	13.18	0.00	38.73	26.89	14.52	11.09	16.62	14.23	271	692	3.43	-3.43
06-Mar-90	10.94	13.25	0.00	42.51	29.52	14.71	10.94	17.01	14.40	298	801	3.77	-3.77
13-Mar-90													
20-Mar-90													
27-Mar-90													
03-Apr-90													
10-Apr-90													
17-Apr-90													
24-Apr-90													
01-May-90													
08-May-90													
Minimum						10.23	9.67	10.51	10.20	5264	11992	0.45	-3.77
Maximum						14.71	11.09	17.01	14.40			3.77	-0.45

Uttklcy **Oxygen Requirements** (lb/raceway)

Date	Michigan			Oxygen/Treatment
	First	Second	Third	
01-Aug-89	0	0	0	0
08-Aug-89	62	62	62	187
15-Aug-89	76	76	76	227
22-Aug-89	90	90	90	271
29-Aug-89	107	107	107	321
05-Sep-89	130	130	130	389
12-Sep-89	150	150	150	450
19-Sep-89	173	173	173	518
26-Sep-89	211	211	211	633
03-Oct-89	230	230	230	691
10-Oct-89	244	244	244	733
17-Oct-89	276	276	276	827
24-Oct-89	310	310	310	929
31-Oct-89	347	347	347	1042
07-Nov-89	334	334	334	1002
14-Nov-89	369	369	369	1108
21-Nov-89	407	407	407	1222
28-Nov-89	449	449	449	1347
05-Dec-89	411	411	411	1234
12-Dec-89	446	446	446	1337
19-Dec-89	482	482	482	1447
26-Dec-89	522	522	522	1565
02-Jan-90	490	490	490	1471
09-Jan-90	525	525	525	1574
16-Jan-90	561	561	561	1683
23-Jan-90	600	600	600	1800
30-Jan-90	642	642	642	1925
06-Feb-90	583	583	583	1750
13-Feb-90	618	618	618	1853
20-Feb-90	654	654	654	1961
27-Feb-90	692	692	692	2076
06-Mar-90	801	801	801	2402
13-Mar-90	0	0	0	0
20-Mar-90	0	0	0	0
27-Mar-90	0	0	0	0
03-Apr-90	0	0	0	0
10-Apr-90	0	0	0	0
17-Apr-90	0	0	0	0
24-Apr-90	0	0	0	0
01-May-90	0	0	0	0
OS-May-90	0	0	0	0
15-May-90	0	0	0	0
Total	11992	11992	11992	35975 lb
				435748 cubic feet

Appendix B-2 - Summer Steelhead
Michigan System
Effluent DO Criteria: 7 **mg/L**

UMATILLA PROJECT

StS O/Michigan System

John Colt

REV 2 7/24/90

SUMMARY OF INFLUENT AND EFFLUENT DOs

	Well Water		Effluent from Raceways		
	DOmin	DOmax	DOmin	DOmax	Delta-00
Mich 1st	9.67	11.09	7.17	9.47	-3.77
Mich 2nd			7.00	9.90	-3.77
Mich 3th			7.00	10.83	-3.77

SUMMARY OF FINAL INTENSITY DATA

	Hatchery Intensity				
	Biomass (lb)	Flow (gpm)	Volume (ft3)	Density (lb/ft3)	Loading (lb/gpm)
Mich 1st	14071	940	1890	7.45	14.97
Mich 2nd	14071	940	1890	7.45	29.94
Mich 3th	14071	940	1890	7.45	44.91

SUMMARY OF OXYGEN REQUIREMENTS

	lb/raceway	AEX
Mich 1st	0	0.0%
Mich 2nd	6736	46.7%
Mich 5th	11372	43.3%
	....	....
	18107	44.6%

GROWTH MODELLING

C=	0.00034	Init. #/lb	300.00
n	3.00	Init. Length (in)	2.14
TU/inch	810	Init. Wt (g)	1.52
TO	32.00 (F)		
FCR	1.00 (lb feed/lb fish)	Elevation (ft)	500
HCTU	0.37037 (inches,F,day)	BP (mm Hg)	747

Date	Day	Test Temp (F)	Growth Model Utight (g)	Utight (#/lb)	Length (inch)	Avtrtgt Temp (F)	Maximum Temp (F)
ol-Aug-89	D	60.0	1.52	300.00	2.14	60.0	
08-Aug-89	7	60.0	2.06	220.87	2.37	60.0	
15-Aug-89	14	60.0	2.72	167.29	2.60	60.0	
22-Aug-89	21	60.0	3.50	129.73	2.83	60.0	
29-Aug-89	28	60.0	4.43	102.63	3.06	60.0	
05-Sep-89	35	61.0	5.48	82.90	3.28	61.0	
12-Sep-89	42	61.0	6.69	67.92	3.51	61.0	
19-Sep-89	49	61.0	8.07	56.35	3.74	61.0	
26-Sep-89	56	61.0	9.62	47.26	3.96	61.0	
03-Oct-89	63	60.0	11.39	39.90	4.19	60.0	
lo-tit-89	70	60.0	13.37	33.99	4.42	60.0	
17-Oct-89	77	60.0	15.57	29.20	4.65	60.0	
24-Oct-89	84	60.0	17.99	25.26	4.88	60.0	
31-Oct-89	91	60.0	20.66	22.01	5.11	60.0	
07-Nov-89	98	57.0	23.39	19.44	5.33	57.0	
14-Nov-89	105	57.0	26.35	17.25	5.54	57.0	
21-Nov-89	112	57.0	29.56	15.38	5.76	57.0	
28-Nov-89	119	57.0	33.01	13.77	5.97	57.0	
05-Dec-89	126	54.0	36.26	12.54	6.16	54.0	
12-Dec-89	133	54.0	39.72	11.44	6.35	54.0	
19-Dec-89	140	54.0	43.40	10.48	6.54	54.0	
26-Dec-89	147	54.0	47.29	9.61	6.74	54.0	
02-Jan-90	154	52.0	51.02	8.91	6.91	52.0	
09-Jan-90	161	52.0	54.95	a.27	7.08	52.0	
16-Jan-90	168	52.0	59.07	7.70	7.25	52.0	
23-Jan-90	175	52.0	63.40	7.17	7.43	52.0	
30-Jan-90	182	52.0	67.93	6.69	7.60	52.0	
06-Feb-90	189	50.0	72.18	6.30	7.75	50.0	
13-Feb-90	1 %	50.0	76.62	5.93	7.91	50.0	
20-Feb-90	203	50.0	81.23	5.60	8.07	50.0	
27-Feb-90	210	50.0	86.02	5.28	a.22	50.0	
06-Mar-90	217	51.0	91.27	4.98	a.39	51.0	
13-Mar-90		51.0				51.0	
20-Mar-90		51.0				51.0	
27-Mar-90		51.0				51.0	
03-Apr-90		52.0				52.0	
10-Apr-90		52.0				52.0	
17-Apr-90		52.0				52.0	
24-Apr-90		52.0				52.0	

MORTALITY MODEL Mortality/day (%) 0.0060 Initial Number 71000

Date	MICHIGAN SYSTEM		
	#/lb	Number	Mass(lb)
01-Aug-89	300.00	71000	237
08-Aug-89	220.87	70970	321
15-Aug-89	167.29	70940	424
22-Aug-89	129.73	70911	547
29-Aug-89	102.63	70881	691
05-Sep-89	82.90	70851	855
12-Sep-89	67.92	70821	1043
19-Sep-89	56.35	70792	1256
26-Sep-89	47.26	70762	1497
03-Oct-89	39.90	70732	1773
10-Oct-89	33.99	70702	2080
17-Oct-89	29.20	70673	2420
24-Oct-89	25.26	70643	2796
31-Oct-89	22.01	70613	3209
07-Nov-89	19.44	70584	3632
14-Nov-89	17.25	70554	4090
21-Nov-89	15.38	70524	4585
28-Nov-89	13.77	70495	5119
05-Dec-89	12.54	70465	5621
12-m-89	11.44	70436	6155
19-Dec-89	10.48	70406	6721
26-Dec-89	9.61	70376	7321
02-Jan-90	8.91	70347	7896
W-Jan-W	a.27	70317	8500
16-Jan-90	7.70	70288	9134
23-Jan-90	7.17	70258	9798
30-Jan-90	6.69	70229	10494
06-Feb-90	6.30	70199	11147
13-Feb-90	5.93	70170	11826
20-Feb-90	5.60	70140	12533
27-Feb-90	5.28	70111	13266
06-Mar-90	4.98	70081	14071
13-Mar-90			
20-Mar-90			
27-Mar-90			
03-Apr-90			
10-Apr-90			
17-Apr-90			
24-Apr-90			
01-May-W			
08-May-90			

DISSOLVED OXYGEN CRITERIA IN EFFLUENT

Influent 00%	100
Oxygen-Feed Ratio	0.25
Peaking Factor	1.44

	Effluent Criteria (mg/l)	Influent DO (mg/l)	Absolute	Sat. at Sealevel (mg/l)	Vapor Press. (mm Hg)	Sat. at Hatchery (mg/l)
01-Aug-89	7.00	9.79	7.00	9.96	13.25	9.79
08-Aug-89	7.00	9.79	7.00	9.96	13.25	9.79
15-Aug-89	7.00	9.79	7.00	9.96	13.25	9.79
22-Aug-89	7.00	9.79	7.00	9.96	13.25	9.79
29-Aug-89	7.00	9.79	7.00	9.96	13.25	9.79
05-Sep-89	7.00	9.67	7.00	9.85	13.73	9.67
12-Sep-89	7.00	9.67	7.00	9.85	13.73	9.67
19-Sep-89	7.00	9.67	7.00	9.85	13.13	9.67
26-Sep-89	7.00	9.67	7.00	9.85	13.73	9.67
03-Oct-89	7.00	9.79	7.00	9.96	13.25	9.79
10-Oct-89	7.00	9.79	7.00	9.96	13.25	9.79
17-Oct-89	7.00	9.79	7.00	9.96	13.25	9.79
24-Oct-89	7.00	9.79	7.00	9.96	13.25	9.79
31-Oct-89	7.00	9.79	7.00	9.96	13.25	9.79
07-Nov-89	7.00	10.15	7.00	10.33	11.90	10.15
14-Nov-89	7.00	10.15	7.00	10.33	11.90	10.15
21-Nov-89	7.00	10.15	7.00	10.33	11.90	10.15
28-Nov-89	7.00	10.15	7.00	10.33	11.90	10.15
05-Dec-89	7.00	10.53	7.00	10.72	10.67	10.53
12-Dec-89	7.00	10.53	7.00	10.72	10.67	10.53
19-Dec-89	7.00	10.53	7.00	10.72	10.67	10.53
26-Dec-89	7.00	10.53	7.00	10.72	10.67	10.53
02-Jan-90	7.00	10.80	7.00	11.00	9.92	10.80
W-Jan-W	7.00	10.80	7.00	11.00	9.92	10.80
16-Jan-90	7.00	10.00	7.00	11.00	9.92	10.80
23-Jan-90	7.00	10.80	7.00	11.00	9.92	10.80
30-Jan-90	7.00	10.80	7.00	11.00	9.92	10.80
06-Feb-90	7.00	11.09	7.00	11.29	9.21	11.09
13-Feb-90	7.00	11.09	7.00	11.29	9.21	11.09
20-Feb-90	7.00	11.09	7.00	11.29	9.21	11.09
27-Feb-90	7.00	11.09	7.00	11.29	9.21	11.09
06-Mar-90	7.00	10.94	7.00	11.14	9.56	10.94
13-Mar-90	7.00	10.94	7.w	11.14	9.56	10.94
20-Mar-90	7.00	10.94	7.00	11.14	9.56	10.94
27-Mar-90	7.00	10.94	7.00	11.14	9.56	10.94
03-Apr-90	7.00	10.80	7.00	11.00	9.92	10.80
10-Apr-90	7.00	10.80	7.00	11.00	9.92	10.80
17-Apr-90	7.00	10.80	7.00	11.00	9.92	10.80
24-Apr-90	7.00	10.80	7.00	11.00	9.92	10.80
01-May-90	7.00	10.53	7.00	10.72	10.67	10.53
08-May-90	7.00	10.53	7.00	10.72	10.67	10.53
	Minimum	9.67	7.00	9.85	9.21	9.67
	Maximum	11.09	7.00	11.29	13.73	11.09

HIGH DENSITY MICHIGAN SYSTEM (First Pass) ˙

Column Performance Data

Flow (gpm) 940

inttrctpt 0.60

slope 0.06

Date	Fttd (%)	Feed (lb)	O2-Avail Lb/d)	Peak Dem (lb/d)	Aver Dem (lb/d)	Peak Conditions DOin	Peak Conditions DOout	Aver. Conditions DOin	Aver. Conditions DOout	Oxygen (lb) Require	Oxygen (lb) Purchase	Delta-00 02 AU	Delta-00 RU
01-Aug-89													
08-Aug-89	4.38	14.1	31.43	5.06	3.52	9.79	9.34	9.79	9.47	0	0	0.00	-0.4!
15-Aug-89	3.99	16.9	31.43	6.09	4.23	9.79	9.25	9.79	9.41	0	0	0.00	-0.5
22-Aug-89	3.67	20.0	31.43	7.21	5.01	9.79	9.15	9.79	9.34	0	0	0.00	-0.6
29-Aug-89	3.39	23.4	31.43	8.43	5.85	9.79	9.04	9.79	9.27	0	0	0.00	-0.7
05-Sep-89	3.27	27.9	30.13	10.06	6.99	9.67	a.78	9.67	9.05	0	0	0.00	-0.8'
12-Sep-89	3.06	31.9	30.13	11.49	7.98	9.67	8.65	9.67	a.96	0	0	0.00	-1.0
19-Sep-89	2.88	36.1	30.13	13.00	9.03	9.67	a.52	9.67	8.87	0	0	0.00	-1.1'
26-Sep-89	2.88	43.1	30.13	15.50	10.76	9.67	8.30	9.67	a.72	0	0	0.00	-1.3
03-m-89	2.62	46.4	31.43	16.71	11.60	9.79	8.30	9.79	8.76	0	0	0.00	-1.4
10-Oct-89	2.35	48.8	31.43	17.56	12.20	9.79	a.23	9.79	8.70	0	0	0.00	-1.51
17-Oct-89	2.23	54.0	31.43	19.43	13.49	9.79	8.06	9.79	a.59	0	D	0.00	-1.7
24-Oct-89	2.12	59.4	31.43	21.39	14.85	9.79	7.89	9.79	a.47	D	0	0.00	-1.9
31-Oct-89	2.03	65.1	31.43	23.44	16.28	9.79	7.71	9.79	a.34	0	0	0.00	-2.0
07-Nov-89	1.74	63.1	35.50	22.73	15.76	10.15	8.13	10.15	a.75	0	0	0.00	-2.0
14-Nov-89	1.67	68.3	35.50	24.60	17.06	10.15	7.97	10.15	8.63	0	0	0.00	-2.1
21 -Nov-89	1.61	73.7	35.50	26.54	18.43	10.15	7.79	10.15	8.51	0	0	0.00	-2.3'
28-Nov-89	1.55	79.3	35.50	28.56	19.83	10.15	7.61	10.15	a.39	0	0	0.00	-2.5:
OS-Dec.89	1.32	74.3	39.64	26.75	18.57	10.53	8.16	10.53	a.88	0	0	0.00	-2.3'
12-Dec-89	1.28	78.9	39.64	28.41	19.73	10.53	8.01	10.53	8.78	0	0	0.00	-2.5;
19-Dec-89	1.24	83.7	39.84	30.12	20.92	10.53	7.86	10.53	a.68	0	0	0.00	-2.6
26-Dec-89	1.21	88.6	39.84	31.88	22.14	10.53	7.70	10.53	a.57	0	0	0.00	-2.8:
02- Jan-W	1.07	84.7	42.90	30.48	21.17	10.80	8.10	10.80	8.93	0	0	0.00	-2.71
W-Jan-W	1.05	88.9	42.W	32.01	22.23	10.80	7.97	10.80	a.83	0	0	0.00	-2.8
16- Jan-W	1.02	93.3	42.90	33.58	23.32	10.80	7.83	10.80	a.74	0	0	0.00	-2.91
23-Jan-90	1.00	97.7	42.90	35.18	24.43	10.80	7.68	10.80	a.64	0	0	0.00	-3.1
SO-Jan-00	0.97	102.3	42.90	36.82	25.57	10.80	7.54	10.80	8.54	0	0	0.00	-3.2
06-Feb-90	0.86	95.8	46.11	34.50	23.96	11.09	8.03	11.09	8.96	0	0	0.00	-3.0
13-Feb-90	0.84	99.7	46.11	35.88	24.92	11.09	7.91	11.09	a.88	0	0	0.00	-3.1
20-Feb-90	0.83	103.6	46.11	37.29	25.90	11.09	7.78	11.09	a.79	0	0	0.00	-3.31
27-Feb-90	0.81	107.6	46.11	38.73	26.89	11.09	7.65	11.09	8.70	0	0	0.00	-3.4
06-Mar-90	0.84	118.1	44.49	42.51	29.52	10.96	7.17	10.94	a.33	0	0	0.00	-3.7
13-Mar-90													
20-Mar-90													
27-Mar-90													
03-Apr-90													
10-Apr-90													
17-Apr-90													
24-Apr-90													
01 -May-W													
08-May-90													
Minimum						9.67	7.17	9.67	a.33	0	0	0.00	-3.7
Maximum						11.09	9.34	11.09	9.47			0.00	-0.45

HIGH DENSITY MICHIGAN SYSTEM (Second Pass)

Date	DOin		O2-Avail (lb/d)	Peak Dem (lb/d)	Aver Dem (lb/d)	Peak Conditions		Avar. Conditions		Oxygen (lb)		Delta-DO	
	Peak	Average				DOin	DOout	DOin	DOout	Require	Purchase	02 AU	RU
01-Aug-89													
08-Aug-89	9.34	9.47	26.37	5.06	3.52	9.34	8.89	9.92	9.61	0	0	0.00	-0.45
15-Aug-89	9.25	9.41	25.34	6.09	4.23	9.25	8.71	9.95	9.58	0	0	0.00	-0.54
22-Aug-89	9.15	9.34	24.22	7.21	5.01	9.15	8.51	9.98	9.54	0	0	0.00	-0.64
29-Aug-89	9.04	9.27	23.00	8.43	5.85	9.04	8.29	10.01	9.50	0	0	0.00	-0.75
05-Sep-89	8.78	9.05	20.07	10.06	6.99	8.78	7.89	9.94	9.32	0	0	0.00	-0.89
12-Sep-89	8.65	8.96	18.64	11.49	7.98	8.65	7.63	9.98	9.27	0	0	0.00	-1.02
19-Sep-89	8.52	8.87	17.12	13.00	9.03	8.52	7.36	10.02	9.22	0	0	0.00	-1.15
26-Sep-89	8.30	8.72	14.63	15.50	10.76	8.37	7.00	10.09	9.14	6	10	0.08	-1.37
03-Oct-89	8.30	8.76	14.72	16.71	11.60	8.48	7.00	10.24	9.21	14	24	0.18	-1.48
10-Oct-89	8.23	8.70	13.86	17.56	12.20	8.56	7.00	10.26	9.18	26	45	0.33	-1.56
17-Oct-89	8.06	8.59	12.00	19.43	13.49	8.72	7.00	10.31	9.12	52	93	0.66	-1.72
24-Oct-89	7.89	8.47	10.04	21.39	14.85	8.90	7.00	10.37	9.05	79	148	1.01	-1.90
31-Oct-89	7.71	8.34	7.98	23.44	16.28	9.08	7.00	10.42	8.98	108	210	1.37	-2.08
07-Nov-89	8.13	8.75	12.77	22.73	15.78	9.01	7.00	10.76	9.36	70	128	0.88	-2.01
14-Nov-89	7.97	8.63	10.89	24.60	17.08	9.18	7.00	10.81	9.30	96	183	1.21	-2.18
21-Nov-89	7.79	8.51	8.95	26.54	18.43	9.35	7.00	10.87	9.23	123	245	1.56	-2.35
28-Nov-89	7.61	8.39	6.93	28.56	19.83	9.53	7.00	10.92	9.16	151	314	1.92	-2.53
05-Dec-89	8.16	8.88	13.09	26.75	18.57	9.37	7.00	11.26	9.61	96	182	1.21	-2.37
12-Dec-89	8.01	8.78	11.43	28.41	19.73	9.52	7.00	11.30	9.55	119	235	1.51	-2.52
19-Dec-89	7.86	8.68	9.71	30.12	20.92	9.67	7.00	11.35	9.49	143	292	1.81	-2.67
26-Dec-89	7.70	8.57	7.95	31.88	22.14	9.83	7.00	11.40	9.43	168	357	2.12	-2.83
02-Jan-90	8.10	8.93	12.42	30.48	21.17	9.70	7.00	11.63	9.75	126	252	1.60	-2.70
W-Jan-W	7.97	8.83	10.89	32.01	22.23	9.84	7.00	11.67	9.70	148	305	1.87	-2.04
16-Jan-90	7.83	8.74	9.32	33.58	23.32	9.98	7.00	11.71	9.65	170	363	2.15	-2.98
23-Jan-90	7.68	8.66	7.72	35.18	24.43	10.12	7.00	11.76	9.59	192	426	2.44	-3.12
30-Jan-90	7.54	8.54	6.07	36.82	25.57	10.26	7.00	11.80	9.53	215	496	2.73	-3.26
06-Feb-90	8.03	8.96	11.61	34.50	23.96	10.06	7.00	12.02	9.90	160	337	2.03	-3.06
13-Feb-90	7.91	8.88	10.22	35.88	24.92	10.18	7.00	12.06	9.85	180	390	2.27	-3.18
20-Feb-90	7.78	8.79	8.81	37.29	25.90	10.31	7.00	12.10	9.80	199	447	2.52	-3.31
27-Feb-90	7.65	8.70	7.38	38.73	26.89	10.43	7.00	12.14	9.75	219	510	2.78	-3.43
06-Mar-90	7.17	8.33	1.97	42.51	29.52	10.77	7.00	12.09	9.48	284	743	3.59	-3.77
13-Mar-90													
20-Mar-90													
27-Mar-90													
03-Apr-90													
10-Apr-90													
17-Apr-90													
24-Apr-90													
01-May-W													
08-May-90													
Minimum						8.37	7.00	9.92	8.98	3145	6736	0.00	-3.77
Maximum						10.77	8.89	12.14	9.90			3.59	-0.45

HIGH DENSITY MICHIGAN SYSTEM (Third Pass)

Date	DOin		O2-Avail (lb/d)	Peak Dem (lb/d)	Aver Dem (lb/d)	Peak Conditions		Aver. Conditions		Oxygen (lb)		Delta-DO	
	Peak	Average				DOin	DOout	DOin	DOout	Require	Purchase	02 AU	RU
01-Aug-89													
08-Aug-89	8.89	9.61	21.30	5.06	3.52	8.89	8.44	10.06	9.75	0	0	0.00	-0.45
15-Aug-89	8.71	9.58	19.25	6.09	4.23	8.71	8.17	10.12	9.74	0	0	0.00	-0.54
22-Aug-89	8.51	9.54	17.00	7.21	5.01	8.51	7.87	10.18	9.73	0	0	0.00	-0.64
29-Aug-89	8.29	9.50	14.57	8.43	5.85	8.29	7.54	10.24	9.72	0	D	0.00	-0.75
05-Sep-89	7.89	9.32	10.00	10.06	6.99	7.89	7.00	10.22	9.60	0	1	0.01	-0.89
12-Sep-89	7.63	9.27	7.15	11.49	7.98	8.02	7.00	10.29	9.59	30	53	0.38	-1.02
19-Sep-89	7.36	9.22	4.12	13.00	9.03	8.15	7.00	10.38	9.57	62	113	0.79	-1.15
26-Sep-89	7.00	9.14	-0.00	15.50	10.76	8.37	7.00	10.51	9.56	109	211	1.37	-1.37
03-Oct-89	7.00	9.21	-0.00	16.71	11.60	8.48	7.00	10.69	9.66	117	230	1.48	-1.48
10-Oct-89	7.00	9.18	-0.00	17.56	12.20	8.56	7.00	10.74	9.66	123	244	1.56	-1.56
17-Oct-89	7.00	9.12	-0.00	19.43	13.49	8.72	7.00	10.84	9.64	136	276	1.72	-1.72
24-Oct-89	7.00	9.05	-0.00	21.39	14.85	8.90	7.00	10.94	9.63	150	310	1.90	-1.90
31-Oct-89	7.00	8.98	-0.00	23.44	16.28	9.08	7.w	11.06	9.61	164	347	2.08	-2.08
07-Nov-89	7.00	9.36	-0.00	22.73	15.78	9.01	7.00	11.38	9.98	159	334	2.02	-2.01
14-Nov-89	7.00	9.30	-0.00	24.60	17.08	9.18	7.00	11.48	9.96	172	369	2.18	-2.18
21-Nov-89	7.00	9.23	-0.00	26.54	18.43	9.35	7.00	11.58	9.95	186	407	2.35	-2.35
28-Nov-89	7.00	9.16	-0.00	28.56	19.83	9.53	7.00	11.69	9.94	200	449	2.53	-2.53
05-Dec-89	7.00	9.61	-0.00	26.75	18.57	9.37	7.00	11.98	10.33	187	412	2.37	-2.37
12-Dec-89	7.00	9.55	-0.00	28.41	19.73	9.52	7.00	12.07	10.32	199	446	2.52	-2.52
19-Dec-89	7.00	9.49	-0.00	30.12	20.92	9.67	7.00	12.16	10.31	211	482	2.67	-2.67
26-Dec-89	7.00	9.43	-0.00	31.88	22.14	9.83	7.00	12.26	10.30	223	522	2.83	-2.83
02-Jan-90	7.00	9.75	-0.00	30.48	21.17	9.70	7.00	12.45	10.58	213	490	2.70	-2.70
09-Jan-90	7.00	9.70	-0.00	32.01	22.23	9.84	7.00	12.54	10.57	224	525	2.84	-2.84
16-Jan-90	7.00	9.65	-0.00	33.58	23.32	9.98	7.00	12.62	10.55	235	561	2.98	-2.98
23-Jan-90	7.00	9.59	-0.00	35.18	24.43	10.12	7.00	12.71	10.54	246	600	3.12	-3.12
30-Jan-90	7.00	9.53	-0.00	36.82	25.57	10.26	7.00	12.80	10.53	258	642	3.26	-3.26
06-Feb-90	7.00	9.90	-0.00	34.50	23.96	10.06	7.00	12.96	10.83	242	583	3.06	-3.06
13-Feb-90	7.00	9.85	-0.00	35.88	24.92	10.18	7.00	13.03	10.82	251	618	3.18	-3.18
20-Feb-90	7.00	9.80	-0.00	37.29	25.90	10.31	7.00	13.11	10.81	261	654	3.31	-3.31
27-Feb-90	7.00	9.75	-0.00	38.73	26.89	10.43	7.00	13.18	10.80	271	692	3.43	-3.43
06-Mar-90	7.00	9.48	-0.00	42.51	29.52	10.77	7.00	13.25	10.63	298	801	3.77	-3.77
IS-War-90													
20-Mar-90													
27-Mar-90													
03-Apr-90													
10-Apr-90													
17-Apr-90													
24-Apr-90													
01-May-W													
08-May-90													
Minimum						7.89	7.00	10.06	9.56	4927	11372	0.00	-3.n
Maximum						10.77	8.44	13.25	10.83			3.77	-0.45

Weekley Oxygen Requirements (lb/raceway)

Date	Michigan First	Michigan Second	Michigan Third	Oxygen/Treatmen'
01-Aug-89	0	0	0	0
08-Aug-89	0	0	G	0
15-Aug-89	0	0	G	0
22-Aug-89	0	0	C	0
29-Aug-89	0	0	C	0
OS-Scp-89	0	G	1	1
12-Sep-89	0	G	53	53
19-Sep-89	0	0	113	113
26-Sep-89	0	10	211	221
03-Oct-89	0	24	230	254
10-Oct-89	0	45	244	289
17-Oct-89	0	93	276	369
24-Oct-89	0	148	31G	458
31-Oct-89	0	210	347	558
07-Nov-89	0	128	334	462
14-Nov-89	0	183	369	552
21-Nov-89	0	245	407	652
28-Nov-89	0	314	449	763
OS-kc-89	0	182	412	594
12-Dec-89	0	235	446	680
19-Dec-89	0	292	482	775
26-Dec-89	0	357	522	878
02-Jan-90	0	252	490	743
09-Jan-90	0	305	525	830
16-Jan-90	0	363	561	924
23-Jan-90	0	426	600	1026
30-Jan-90	0	496	642	1138
06-Feb-90	0	337	583	920
13-Feb-90	0	390	618	1007
20-Feb-90	0	447	654	1101
27-Feb-90	0	510	692	1202
06-Mar-90	0	743	801	1543
13-Mar-90	0	0	0	0
20-Mar-90	0	0	0	0
27-Mar-90	0	0	0	0
03-Apr-90	0	0	0	C
10-Apr-90	0	0	0	0
17-Apr-90	0	0	0	C
24-Apr-90	0	0	0	C
01-May-90	0	0	0	0
08-May-90	C	0	0	
15-May-9C	C	3	0	
Tota.	C	6736	11372	18107 lt
				219328 cubic fee:

Appendix C-l - Spring Chinook
Michigan System
Effluent DO Criteria: Saturation

SUMMARY OF INFLUENT AND EFFLUENT DOs

	Well Water		Effluent from Raceways		
	DOmin	DOmax	DOmin	DOmax	Delta-DO
Mich 1st	9.67	11.09	10.15	11.76	-2.98
Mich 2nd			10.15	12.62	-2.98
Mich 3th			10.15	13.53	-2.98

SUMMARY OF FINAL INTENSITY DATA

	Hatchery Intensity				
	Biomass (lb)	Flow (gpm)	Volume (ft3)	Density (lb/ft3)	Loading (lb/gpm)
Mich 1st	7888	940	1890	4.17	8.39
Mich 2nd	7888	940	1890	4.17	16.78
Mich 3th	7888	940	1890	4.17	25.17

SUMMARY OF OXYGEN REQUIREMENTS

	lb/raceway	AE%
Mich 1st	5831	48.2%
Mich 2nd	5831	48.2%
Mich 3th	5831	48.2%
	------em-	_-_-_-___
	17492	48.2%

GROWTH MODELLING

C=	0.00030		Init. #/lb	300.00
n	3.00		Init. Length (in)	2.24
TU/inch	840		Init. Wt (g)	1.52
To	32.00	(F)		
FCR	1.00	(lb feed/lb fish)	Elevation (ft)	500
HCTU	0.35714	(inches,F,day)	BP (mm Hg)	747

Date	Day	Test Temp (F)	Growth Model			Average Temp (F)	Maximum Temp (F)
			Weight (g)	Weight (#/lb)	length (inch)		
01-Aug-89		60.0				60.0	
08-Aug-89		60.0				60.0	
15-Aug-89		60.0				60.0	
22-Aug-89		60.0				60.0	
29-Aug-89		60.0				60.0	
05-Sep-89		61.0				61.0	
12-Sep-89		61.0				61.0	
19-Sep-89		61.0				61.0	
26-Sep-89		61 .0				61.0	
03-Oct-89		60.0				60.0	
10-Oct-89		60.0				60.0	
17-Oct-89		60.0				60.0	
24-Oct-89		60.0				60.0	
31-Oct-89	0	60.0	1.52	300.00	2.24	60.0	
07-Nov-89	7	57.0	1.98	229.79	2.45	57.0	
14-Nov-89	14	57.0	2.53	179.w	2.66	57.0	
21-Nov-89	21	57.0	3.17	143.45	2.87	57.0	
28-Nov-89	28	57.0	3.91	116.23	3.08	57.0	
05-Dec-89	35	54.0	4.65	97.69	3.26	54.0	
12-Dec-89	42	54.0	5.48	82.90	3.44	54.0	
19-Dec-89	49	54.0	6.41	70.94	3.63	54.0	
26-Dec-89	56	54.0	7.43	61.18	3.81	54.0	
02-Jan-90	63	52.0	8.45	53.81	3.98	52.0	
09-Jan-90	70	52.0	9.56	47.57	4.14	52.0	
16-Jan-90	77	52.0	10.76	42.26	4.31	52.0	
23-Jan-90	84	52.0	12.05	37.71	4.48	52.0	
30-Jan-90	91	52.0	13.45	33.79	4.64	52.0	
06-Feb-90	98	50.0	14.80	30.72	4.79	50.0	
13-Feb-90	105	50.0	16.23	28.00	4.94	50.0	
20-Feb-90	112	50.0	17.76	25.60	5.09	50.0	
27-Feb-90	119	50.0	19.37	23.47	5.24	50.0	
06-Mar-90	126	51.0	21.18	21.46	5.40	51.0	
13-Mar-90	133	51.0	23.10	19.68	5.56	51.0	
20-Mar-90	140	51.0	25.13	18.09	5.72	51.0	
27-Mar-90	147	51.0	27.28	16.67	5.88	51.0	
03-Apr-90	154	52.0	29.66	15.32	6.04	52.0	
10-Apr-90		52.0				52.0	
17-Apr-90		52.0				52.0	
24-Apr-90		52.0				52.0	

MORTALITY MODEL Mortality/day (%) 0.0060 Initial Number 122000

Date	MICHIGAN SYSTEM		
	#/lb	Number	Mass(lb)
01-Aug-89			
08-Aug-89			
15-Aug-89			
22-Aug-89			
29-Aug-89			
0S-Sep.89			
12-Sep-89			
19-sep-89			
26-Sep-89			
03-Oct-89			
10-Oct-89			
17-Oct-89			
24-Oct-89			
31-Oct-89	300.00	122000	407
07-Nov-89	229.79	121949	531
14-Nov-89	179.89	121898	678
21-Nov-89	143.45	121846	a49
28-Nov-89	116.23	121795	1048
05-Dec-89	97.69	121744	1246
12-Dec-89	82.90	121693	1468
19-Dec-89	70.94	121642	1715
26-Dec-89	61.18	121591	1987
02-Jan-90	53.81	121540	2259
09-Jan-90	47.57	121489	2554
16-Jan-90	42.26	121438	2874
23-Jan-90	37.71	121387	3219
30- Jan-W	33.79	121336	3591
W-Cab-90	30.72	121285	3948
13-Feb-90	28.00	121234	4329
20-Feb-90	25.60	121183	4733
27-Feb-90	23.47	121132	5162
W-Mar-00	21.46	121081	5642
13-Mar-90	19.68	121030	6150
20-Mar-90	18.09	120979	6688
27-Mar-90	16.67	120928	7256
03-Apr-90	15.32	120878	7888
10-Apr-90			
17-Apr-90			
24-Apr-90			
01 -May-90			
08-May-90			

DISSOLVED OXYGEN CRITERIA IN EFFLUENT

Influent DO%	100
Oxygen-Fed Ratio	0.25
Peaking Factor	1.44

	Effluent Criteria (mg/l)	Influent DO (mg/l)	Absolute	Sat. at Sealevel (mg/l)	Vapor Press. (mm Hg)	Sat. at Hatchery (mg/l)
01-Aug-89	9.79	9.79	7.00	9.96	13.25	9.79
08-Aug-89	9.79	9.79	7.00	9.96	13.25	9.79
15-Aug-89	9.79	9.79	7.00	9.96	13.25	9.79
22-Aug-89	9.79	9.79	7.00	9.96	13.25	9.79
29-Aug-89	9.79	9.79	7.00	9.96	13.25	9.79
OS-Stp-89	9.67	9.67	7.00	9.85	13.73	9.67
12-Sep-89	9.67	9.67	7.00	9.85	13.73	9.67
19-Sep-89	9.67	9.67	7.00	9.85	13.73	9.67
26-Sep-89	9.67	9.67	7.00	9.85	13.73	9.67
03-Oct-89	9.79	9.79	7.00	9.96	13.25	9.79
10-Oct-89	9.79	9.79	7.00	9.96	13.25	9.79
17-Oct-89	9.79	9.79	7.00	9.96	13.25	9.79
24-Oct-89	9.79	9.79	7.00	9.96	13.25	9.79
31-Oct-89	9.79	9.79	7.00	9.96	13.25	9.79
07-Nov-89	10.15	10.15	7.00	10.33	11.90	10.15
14-Nov-89	10.15	10.15	7.00	10.33	11.90	10.15
21-Nov-89	10.15	10.15	7.00	10.33	11.90	10.15
28-Nov-89	10.15	10.15	7.00	10.33	11.90	10.15
OS-Dee-89	10.53	10.53	7.00	10.72	10.67	10.53
12-Dec-89	10.53	10.53	7.00	10.72	10.67	10.53
19-Dec-89	10.53	10.53	7.00	10.72	10.67	10.53
26-Dec-89	10.53	10.53	7.00	10.72	10.67	10.53
02-Jan-90	10.80	10.80	7.00	11.00	9.92	10.80
09-Jan-90	10.80	10.80	7.00	11.00	9.92	10.80
16-Jan-90	10.80	10.80	7.00	11.00	9.92	10.80
U-Jan-90	10.80	10.80	7.00	11.00	9.92	10.80
30-Jan-90	10.80	10.80	7.00	11.00	9.92	10.80
06-Feb-90	11.09	11.09	7.00	11.29	9.21	11.09
13-Feb-90	11.09	11.09	7.00	11.29	9.21	11.09
20-Feb-90	11.09	11.09	7.00	11.29	9.21	11.09
27-Feb-90	11.09	11.09	7.00	11.29	9.21	11.09
06-Mar-90	10.94	10.94	7.00	11.14	9.56	10.94
13-Mar-90	10.94	10.94	7.00	11.14	9.56	10.94
20-Mar-90	10.94	10.94	7.00	11.14	9.56	10.94
27-Mar-90	10.94	10.94	7.00	11.14	9.56	10.94
03-Apr-90	10.80	10.80	7.00	11.00	9.92	10.80
10-Apr-90	10.80	10.80	7.00	11.00	9.92	10.80
17-Apr-90	10.80	10.80	7.00	11.00	9.92	10.80
24-Apr-90	10.80	10.80	7.00	11.00	9.92	10.80
01-May-90	10.53	10.53	7.00	10.72	10.67	10.53
08-May-90	10.53	10.53	7.00	10.72	10.67	10.53
	Minimum	9.67	7.00	9.85	9.21	9.67
	Maximum	11.09	7.00	11.29	13.73	11.09

HIGH DENSITY MICHIGAN SYSTEM (First Pass)

Flow (gpm) 940

Column Performance Data
intercept 0.60
slope 0.06

Date	Feed (%)	Fttd (lb)	02-Avail (lb/d)	Peak Dem (lb/d)	Aver Dem (lb/d)	Peak Conditions DOin	Peak Conditions DOout	Aver. Conditions DOin	Aver. Conditions DOout	Oxygen (lb) Require	Oxygen (lb) Purchase	Delta-DO 02 AU	Delta-DO RU
01-Aug-89													
08-Aug-89													
15-Aug-89													
22-Aug-89													
29-Aug-89													
OS-Sap-W													
12-Sep-89													
19-Sep-89													
26-Sep-89													
03-Oct-89													
10-Oct-89													
17-Oct-89													
24-m-89													
31-Oct-89													
07-Nov-89	3.64	19.3	0.00	6.96	4.83	10.76	10.15	10.76	10.33	49	87	0.62	-0.62
14-Nov-89	3.36	22.8	0.00	8.19	5.69	lo.87	10.15	10.87	10.37	57	104	0.73	-0.73
21-Nov-89	3.11	26.5	0.00	9.52	6.61	10.99	10.15	10.99	10.40	67	122	0.84	-0.84
28-Nov-89	2.90	30.4	0.00	10.95	7.61	11.12	10.15	11.12	10.44	77	142	0.97	-0.97
05-Dec-89	2.41	30.1	0.00	10.82	7.51	11.49	10.53	11.49	10.82	76	140	0.96	-0.96
12-Dec-89	2.28	33.5	0.00	12.06	8.38	11.60	10.53	11.60	10.86	84	159	1.07	-1.07
19-Dec-89	2.17	37.2	0.00	13.38	9.29	11.72	10.53	11.72	10.89	94	178	1.19	-1.19
26-Dec-89	2.06	41.0	0.00	14.76	10.25	11.84	10.53	11.84	10.93	103	199	1.31	-1.31
02-Jan-90	1.80	40.6	0.00	14.61	10.15	12.10	10.80	12.10	11.20	102	197	1.30	-1.30
W-Jan-W	1.72	44.0	0.00	15.86	11.01	12.21	10.80	12.21	11.23	111	217	1.41	-1.41
16-Jan-90	1.66	47.6	0.00	17.15	11.91	12.32	10.80	12.32	11.27	120	237	1.52	-1.52
23-Jan-90	1.60	51.4	0.00	la.50	12.84	12.44	10.80	12.44	11.30	129	260	1.64	-1.64
30-Jan-90	1.54	55.3	0.00	19.89	13.81	12.57	10.80	12.57	11.34	139	283	1.76	-1.76
06-Feb-90	1.34	53.0	0.00	19.07	13.24	12.78	11.09	12.78	11.60	133	269	1.69	-1.69
13-Feb-90	1.30	56.3	0.00	20.27	14.08	12.88	11.09	12.88	11.64	142	290	1.80	-1.80
20-Feb-90	1.26	59.8	0.00	21.51	14.94	12.99	11.09	12.99	11.67	151	312	1.91	-1.91
27-Feb-90	1.23	63.3	0.00	22.79	15.83	13.11	11.09	13.11	11.70	160	335	2.02	-2.02
06-Mar-90	1.26	70.9	0.00	25.52	17.72	13.21	10.94	13.21	11.63	179	387	2.26	-2.26
13-Mar-90	1.22	75.1	0.00	27.03	18.77	13.34	10.96	13.34	11.68	189	417	2.40	-2.40
20-Mar-90	1.19	T9.4	0.00	28.58	19.85	13.48	10.94	13.48	11.72	200	449	2.53	-2.53
27-Mar-90	1.16	83.8	0.00	30.17	20.95	13.62	10.94	13.62	11.76	211	483	2.67	-2.67
03-Apr-90	1.18	93.3	0.00	33.57	23.31	13.78	10.80	13.78	11.71	235	561	2.98	-2.98
10-Apr-90													
17-Apr-90													
24-Apr-90													
01-May-90													
08-May-90													
Minimum						10.76	10.15	10.76	10.33	2808	5831	0.62	-2.98
Maximum						13.78	11.09	13.78	11.76			2.98	-0.62

HIGH DENSITY MICHIGAN SYSTEM (Second Pass)

Date	DOin		O2-Avail (lb/d)	Peak Dem (lb/d)	Aver Dem (lb/d)	Peak Conditions		Aver. Conditions		Oxygen (lb)		Delta-DO	
	Peak	Average				DOin	DOout	DOin	DOout	Require	Purchase	02 AU	RU
01-Aug-89													
08-Aug-89													
15-Aug-89													
22-Aug-89													
29-Aug-89													
05-Sep-89													
12-sap-89													
19-Sep-89													
26-Sep-89													
03-Oct-89													
10-Oct-89													
17-Oct-89													
24-Oct-89													
31-Oct-89													
07-Nov-89	10.15	10.33	0.00	6.96	4.83	10.76	10.15	10.95	10.52	49	87	0.62	-0.62
14-Nov-89	10.15	10.37	0.00	8.19	5.69	10.87	10.15	11.09	10.59	57	lo4	0.73	-0.73
21-Nov-89	10.15	10.40	0.00	9.52	6.61	10.99	10.15	11.25	10.66	67	122	0.86	-0.84
28-Nov-89	10.15	10.44	0.00	10.95	7.61	11.12	10.15	11.41	10.74	77	142	0.97	-0.97
OS-Dtc-89	10.53	10.82	0.00	10.82	7.51	11.49	10.53	11.78	11.12	76	140	0.96	-0.96
12-Dec-89	10.53	10.86	0.00	12.06	8.38	11.60	10.53	11.93	11.19	84	159	1.07	-1.07
19-Dtc-89	10.53	10.89	0.00	13.38	9.29	11.72	10.53	12.08	11.26	94	178	1.19	-1.19
26-Dtc-89	10.53	10.93	0.00	14.76	10.25	11.84	10.53	12.24	11.33	103	199	1.31	-1.31
02-Jan-90	10.80	11.20	0.00	14.61	10.15	12.10	10.80	12.49	11.59	102	197	1.30	-1.30
W-Jan-W	10.80	11.23	0.00	15.86	11.01	12.21	10.80	12.64	11.66	111	217	1.41	-1.41
16-Jan-90	10.80	11.27	0.00	17.15	11.91	12.32	10.80	12.79	11.73	120	237	1.52	-1.52
23-Jan-90	10.80	11.30	0.00	18.50	12.84	12.44	10.80	12.94	11.80	129	260	1.64	-1.64
30-Jan-90	10.80	11.34	0.00	19.89	13.81	12.57	10.80	13.11	11.88	139	283	1.76	-1.76
06-Feb-90	11.09	11.60	0.00	19.07	13.24	12.78	11.09	13.29	12.12	133	269	1.69	-1.69
13-w-w	11.09	11.64	0.00	20.27	14.08	12.88	11.09	13.43	12.19	142	290	1.80	-1.80
20-Feb-90	11.09	11.67	0.00	21.51	14.94	12.99	11.09	13.58	12.25	151	312	1.91	-1.91
27-Feb-90	11.09	11.70	0.00	22.79	15.83	13.11	11.09	13.72	12.32	160	335	2.02	-2.02
06-Mar-90	10.94	11.63	0.00	25.52	17.72	13.21	10.94	13.90	12.33	179	387	2.26	-2.26
13-Mar-90	10.94	11.68	0.00	27.03	18.77	13.34	10.94	14.07	12.41	189	417	2.40	-2.40
20-Mar-90	10.94	11.72	0.00	28.58	19.85	13.48	10.94	14.25	12.49	200	449	2.53	-2.53
27-Mar-90	10.94	11.76	0.00	30.17	20.95	13.62	10.94	14.44	12.58	211	483	2.67	-2.67
03-Apr-90	10.80	11.71	0.00	33.57	23.31	13.78	10.80	14.69	12.62	235	561	2.98	-2.98
10-Apr-90													
17-Apr-90													
24-Apr-90													
01-May-90													
08-May-90													
Minimum						10.76	10.15	10.95	10.52	2808	5831	0.62	-2.98
Maximum						13.78	11.09	14.69	12.62			2.98	-0.62

HIGH DENSITY MICHIGAN SYSTEM (Third Pass)

Date	DOin		O2-Avail (lb/d)	Peak Dem (lb/d)	Aver Dem (lb/d)	Peak Conditions		Aver. Conditions		Oxygen (lb)		Delta-DO	
	Peak	Average				DOin	DOout	DOin	DOout	Require	Purchase	02 AU	RU
01-Aug-89													
08-Aug-89													
15-Aug-89													
22-Aug-89													
29-Aug-89													
05-Sep-89													
12-Sep-89													
19-Sep-89													
26-Sep-89													
03-Oct-89													
10-Oct-89													
17-Oct-89													
24-Oct-89													
31-Oct-89													
07-Nov-89	10.15	10.52	0.00	6.96	4.83	10.76	10.15	11.14	10.71	49	87	0.62	-0.62
14-Nov-89	10.15	10.59	0.00	8.19	5.69	10.87	10.15	11.32	10.81	57	104	0.73	-0.73
21-Nov-89	10.15	10.66	0.00	9.52	6.61	10.99	10.15	11.51	10.92	67	122	0.84	-0.84
28-Nov-89	10.15	10.74	0.00	10.95	7.61	11.12	10.15	11.71	11.04	77	142	0.97	-0.97
05-Dec-89	10.53	11.12	0.00	10.82	7.51	11.49	10.53	12.08	11.41	76	140	0.96	-0.96
12-Dec-89	10.53	11.19	0.00	12.06	8.38	11.60	10.53	12.25	11.51	84	159	1.07	-1.07
19-Dec-89	10.53	11.26	0.00	13.38	9.29	11.72	10.53	12.44	11.62	94	178	1.19	-1.19
26-Dec-89	10.53	11.33	0.00	14.76	10.25	11.84	10.53	12.64	11.73	103	199	1.31	-1.31
02-Jan-90	10.80	11.59	0.00	14.61	10.15	12.10	10.80	12.89	11.99	102	197	1.30	-1.30
W-Jan-W	10.80	11.66	0.00	15.86	11.01	12.21	10.80	13.07	12.09	111	217	1.41	-1.41
16-Jan-90	10.80	11.73	0.00	17.15	11.91	12.32	10.80	13.25	12.20	120	237	1.52	-1.52
23-Jan-90	10.80	11.80	0.00	18.50	12.84	12.44	10.80	13.44	12.31	129	260	1.64	-1.64
30-Jan-90	10.80	11.88	0.00	19.89	13.81	12.57	10.80	13.64	12.42	139	283	1.76	-1.76
06-Feb-90	11.09	12.12	0.00	19.07	13.24	12.78	11.09	13.81	12.64	133	269	1.69	-1.69
13-Feb-90	11.09	12.19	0.00	20.27	14.08	12.88	11.09	13.98	12.73	142	290	1.80	-1.80
20-Feb-90	11.09	12.25	0.00	21.51	14.94	12.99	11.09	14.16	12.84	151	312	1.91	-1.91
27-Feb-90	11.09	12.32	0.00	22.79	15.83	13.11	11.09	14.34	12.94	160	335	2.02	-2.02
M-Mar-00	10.94	12.33	0.00	25.52	17.72	13.21	10.94	14.59	13.02	179	387	2.26	-2.26
13-Mar-90	10.94	12.41	0.00	27.03	18.77	13.34	10.94	14.80	13.14	189	417	2.40	-2.40
20-Mar-90	10.94	12.49	0.00	28.58	19.85	13.48	10.94	15.03	13.27	200	449	2.53	-2.53
27-Mar-90	10.94	12.58	0.00	30.17	20.95	13.62	10.94	15.25	13.40	211	483	2.67	-2.67
03-Apr-90	10.80	12.62	0.00	33.57	23.31	13.78	10.80	15.60	13.53	235	561	2.98	-2.98
10-Apr-90													
17-Apr-90													
24-Apr-90													
01-May-W													
W-May-90													
Minimum						10.76	10.15	11.14	10.71	2808	5831	0.62	-2.98
Maximum						13.78	11.09	15.60	13.53			2.98	-0.62

Uttklty Oxygen Requirements (lb/raceway)

Date	Michigan			Oxygen/Treatment
	First	Second	Third	
01-Aug-89	0	0	0	0
08-Aug-89	0	0	0	0
15-Aug-89	0	0	0	0
22-Aug-89	0	0	0	0
29-Aug-89	0	0	0	0
05-Sep-89	0	0	0	0
12-Sep-89	0	0	0	0
19-Sep-89	0	0	0	0
26-Sep-89	0	0	0	0
03-Oct-89	0	0	0	0
10-Oct-89	0	0	0	0
17-Oct-89	0	0	0	0
24-Oct-89	0	0	0	0
31-Oct-89	0	0	0	0
07-Nov-89	87	87	87	261
14-Nov-89	104	104	104	311
21-Nov-89	122	122	122	366
28-Nov-89	142	142	142	427
OS-Dac-89	140	140	140	421
12-Dec-89	159	159	159	476
19-Dec-89	178	178	178	534
26-Dec-89	199	199	199	598
02-Jan-90	197	197	197	591
09-Jan-90	217	217	217	650
16-Jan-90	237	237	237	712
23-Jan-90	260	260	260	779
30-Jan-90	283	283	283	850
06-Feb-90	269	269	269	808
13-Feb-90	290	290	290	870
20-Feb-90	312	312	312	936
27-Feb-90	335	335	335	1006
06-Mar-90	387	387	387	1161
13-Mar-90	417	417	417	1252
20-Mar-90	449	449	449	1348
27-Mar-90	483	483	483	1450
03-Apr-90	561	561	561	1683
10-Apr-90	0	0	0	0
17-Apr-90	0	0	0	0
24-Apr-90	0	0	0	0
01-May-90	0	0	0	0
08-May-90	0	0	0	0
B-May-00	0	0	0	0
Total	5831	5831	5831	17492 Lb
				211874 cubic feet

Appendix C-2 - Spring Chinook
Michigan System
Effluent DO Criteria: 7 **mg/L**

UMATILLA PROJECT John Colt

SCh O/Michigan System REV 2 7/24/90

SUMMARY OF INFLUENT AND EFFLUENT DOs

	Well water		Effluent from Raceways		
	DOmin	DDmax	DDmin	DOmax	Delta-DO
Mich 1st	9.67	11.09	7.83	9.91	-2.98
Mich 2nd			7.00	10.43	-2.98
Mich 3th			7.00	10.95	-2.98

SUMMARY OF FINAL INTENSITY DATA

	Hatchery Intensity				
	Biomass (lb)	FIow (gpm)	Volume (ft3)	Density (lb/ft3)	Loading (lb/gpm)
Mich 1st	7888	940	1890	4.17	8.39
Mich 2nd	7888	940	1890	4.17	16.78
Mich 3th	7888	940	1890	4.17	25.17

SUMMARY OF OXYGEN REQUIREMENTS

	lb/raceway	AE%
Mich 1st	0	0.0%
Mich 2nd	951	50.7%
Mich 3th	3858	47.1%
	4810	47.8%

GROWTH MODELLING

C=	0.00030		Init. #/lb	300.00
n	3.00		Init. Length (in)	2.24
TU/inch	840		Init. Wt (g)	1.52
To	32.00	(F)		
FCR	1.00	(lb feed/lb fish)	Elevation (ft)	500
HCTU	0.35714	(inches,F,day)	BP (mm Hg)	747

Date	Day	Test Temp (F)	Growth Model Utight (g)	Growth Model Utight (#/lb)	Growth Model Length (inch)	Average Temp (F)	Maximum Temp (F)
01-Aug-89		60.0				60.0	
08-Aug-89		60.0				60.0	
15-Aug-89		60.0				60.0	
22-Aug-89		60.0				60.0	
29-Aug-89		60.0				60.0	
05-Sep-89		61.0				61.0	
12-Sep-89		61.0				61.0	
19-Sep-89		61.0				61.0	
26-Sep-89		61.0				61.0	
03-Oct-89		60.0				60.0	
10-Oct-89		60.0				60.0	
17-Oct-89		60.0				60.0	
24-Oct-89		60.0				60.0	
31-Oct-89	0	60.0	1.52	300.00	2.24	60.0	
07-Nov-89	7	57.0	1.98	229.79	2.45	57.0	
14-Nov-89	14	57.0	2.53	179.89	2.66	57.0	
21-Nov-89	21	57.0	3.17	143.45	2.87	57.0	
28-Nov-89	28	57.0	3.91	116.23	3.08	57.0	
05-Dec-89	35	54.0	4.65	97.69	3.26	54.0	
12-Dec-89	42	54.0	5.48	82.90	3.44	54.0	
19-Dec-89	49	54.0	6.41	70.94	3.63	54.0	
26-Dec-89	56	54.0	7.43	61.18	3.81	54.0	
02-Jan-90	63	52.0	8.45	53.81	3.98	52.0	
W-Jan-W	70	52.0	9.56	47.57	4.14	52.0	
16- Jan-W	77	52.0	10.76	42.26	4.31	52.0	
23- Jan-W	a4	52.0	12.05	37.71	4.48	52.0	
30- Jan-W	91	52.0	13.45	33.79	4.64	52.0	
06-Feb-90	98	50.0	14.80	30.72	4.79	50.0	
13-Feb-90	105	50.0	16.23	28.00	4.94	50.0	
20-Feb-90	112	50.0	17.76	25.60	5.09	50.0	
27-Feb-90	119	50.0	19.37	23.47	5.24	50.0	
W-Mar-W	126	51.0	21.18	21.46	5.40	51.0	
13-Mar-90	133	51.0	23.10	19.68	5.56	51.0	
20-Mar-90	140	51.0	25.13	18.09	5.R	51.0	
27-Mar-90	147	51.0	27.28	16.67	5.88	51.0	
03-Apr-90	154	52.0	29.66	15.32	6.04	52.0	
10-Apr-90		52.0				52.0	
17-Apr-90		52.0				52.0	
24-Apr-90		52.0				52.0	

MORTALITY MODEL Mortality/day (%) 0.0060 Initial Number 122000

Date	MICHIGAN SYSTEM		
	#/lb	Number	Mass(lb)
01-Aug-89			
08-Aug-89			
15-Aug-89			
22-Aug-89			
29-Aug-89			
05-Sep-89			
12-Sep-89			
19-Sep-89			
26-Sep-89			
03-Oct-89			
10-Oct-89			
17-Oct-89			
24-Oct-89			
31-Oct-89	300.00	122000	407
07-Nov-89	229.79	121949	531
14-Nov-89	179.89	121898	678
21-Nov-89	143.45	121846	849
28-Nov-89	116.23	121795	1048
05-Dec-89	97.69	121744	1246
12-Dec-89	82.90	121693	1468
19-Dec-89	70.94	121642	1715
26-Dec-89	61.18	121591	1987
02-Jan-90	53.81	121540	2259
09-Jan-90	47.57	121489	2554
16-Jan-90	42.26	121438	2874
23-Jan-90	37.71	121387	3219
30-Jan-90	33.79	121336	3591
06-Feb-90	30.72	121285	3948
13-Feb-90	28.00	121234	4329
20-Feb-90	25.60	121183	4733
27-Feb-90	23.47	121132	5162
06-Mar-90	21.46	121081	5642
13-Mar-90	19.68	121030	6150
20-Mar-90	18.09	120979	6688
27-Mar-90	16.67	120928	7256
03-Apr-90	15.32	120878	7888
10-Apr-90			
17-Apr-90			
24-Apr-90			
01-May-90			
08-May-90			

DISSOLVED OXYGEN CRITERIA IN EFFLUENT

Influent DO%	100
Oxygen-Feed Retio	0.25
Peaking Factor	1.44

	Effluent Criteria (mg/l)	Influent DO (mg/l)	Absolute	Sat. at Sealevel (mg/l)	Vapor Press. (mm Hg)	Sat. at Hatchery (mg/l)
01-Aug-89	7.00	9.79	7.00	9.96	13.25	9.79
08-Aug-89	7.00	9.79	7.00	9.96	13.25	9.79
15-Aug-89	7.00	9.79	7.00	9.96	13.25	9.79
22-Aug-89	7.00	9.79	7.00	9.96	13.25	9.79
29-Aug-89	7.00	9.79	7.00	9.96	13.25	9.79
05-Sep-89	7.00	9.67	7.00	9.85	13.73	9.67
12-Sep-89	7.00	9.67	7.00	9.85	13.73	9.67
19-Sep-89	7.00	9.67	7.00	9.85	13.73	9.67
26-Sep-89	7.00	9.67	7.00	9.85	13.73	9.67
03-Oct-89	7.00	9.79	7.00	9.96	13.25	9.79
10-Oct-89	7.00	9.79	7.00	9.96	13.25	9.79
17-Oct-89	7.00	9.79	7.00	9.96	13.25	9.79
24-Oct-89	7.00	9.79	7.00	9.96	13.25	9.79
31-Oct-89	7.00	9.79	7.00	9.96	13.25	9.79
07-Nov-89	7.00	10.15	7.00	10.33	11.90	10.15
14-Nov-89	7.00	10.15	7.00	10.33	11.90	10.15
21-Nov-89	7.00	10.15	7.00	10.33	11.90	10.15
28-Nov-89	7.00	10.15	7.00	10.33	11.90	10.15
05-Dec-89	7.00	10.53	7.w	10.72	10.67	10.53
12-Dec-89	7.00	10.53	7.00	10.72	10.67	10.53
19-Dec-89	7.00	10.53	7.00	10.72	10.67	10.53
26-Dec-89	7.00	10.53	7.00	10.72	10.67	10.53
02-Jan-90	7.00	10.80	7.00	11.00	9.92	10.80
09-Jan-90	7.00	10.80	7.00	11.00	9.92	10.80
16-Jan-90	7.00	10.80	7.00	11.00	9.92	10.80
U-Jell-90	7.00	10.80	7.00	11.00	9.92	10.80
30-Jan-90	7.00	10.80	7.00	11.00	9.92	10.80
06-Feb-90	7.00	11.09	7.00	11.29	9.21	11.09
13-Feb-90	7.00	11.09	7.00	11.29	9.21	11.09
20-Feb-90	7.00	11.09	7.00	11.29	9.21	11.09
27-Feb-90	7.00	11.09	7.00	11.29	9.21	11.09
06-Mar-90	7.00	10.94	7.00	11.14	9.56	10.94
13-Mar-90	7.00	10.94	7.00	11.14	9.56	10.94
20-Mar-90	7.00	10.94	7.00	11.14	9.56	10.94
27-Mar-90	7.w	10.94	7.00	11.14	9.56	10.94
03-Apr-90	7.00	10.80	7.00	11.00	9.92	10.80
10-Apr-90	7.00	10.80	7.00	11.00	9.92	10.80
17-Apr-90	7.00	10.80	7.00	11.00	9.92	10.80
24-Apr-90	7.00	10.80	7.00	11.00	9.92	10.80
01-May-90	7.00	10.53	7.00	10.72	10.67	10.53
08-May-90	7.00	10.53	7.00	10.72	10.67	10.53
	Minim	9.67	7.00	9.85	9.21	9.67
	Maximum	11.09	7.00	11.29	13.73	11.09

HIGH DENSITY MICHIGAN SYSTEM (First Pass)

Flow (gpm) 940

Column Performance Data
intercept 0.60
slope 0.06

Date	Feed (%)	Feed (lb)	O2-Avail (lb/d)	Peak Dem (lb/d)	Aver Dem (lb/d)	Peak Conditions DOin	Peak Conditions DOout	Aver. Conditions DOin	Aver. Conditions DOout	Oxygen (lb) Require	Oxygen (lb) Purchase	Delta-DO O2 AU	Delta-DO RU
01-Aug-89													
08-Aug-89													
15-Aug-89													
22-Aug-89													
29-Aug-89													
05-Sep-89													
12-Sep-89													
19-Sep-89													
26-Sep-89													
03-Oct-89													
10-Oct-89													
17-Oct-89													
24-Oct-89													
31-Oct-89													
07-Nov-89	3.64	19.3	35.50	6.96	4.83	10.15	9.53	10.15	9.72	0	0	0.00	-0.62
14-Nov-89	3.34	22.8	35.50	8.19	5.69	10.15	9.42	10.15	9.64	0	0	0.00	-0.73
21-Nov-89	3.11	26.5	35.50	9.52	6.61	10.15	9.30	10.15	9.56	0	0	0.00	-0.84
28-Nov-89	2.90	30.4	35.50	10.95	7.61	10.15	9.18	10.15	9.47	0	0	0.00	-0.97
OS-Dee-89	2.41	30.1	39.64	10.82	7.51	10.53	9.57	10.53	9.87	0	0	0.00	-0.96
12-Dec-89	2.28	33.5	39.84	12.06	8.38	10.53	9.46	10.53	9.79	0	0	0.00	-1.07
19-Dec-89	2.17	37.2	39.84	13.38	9.29	10.53	9.35	10.53	9.71	0	0	0.00	-1.19
26-Dec-89	2.06	41.0	39.84	14.76	10.25	10.53	9.22	10.53	9.62	0	0	0.00	-1.31
02-Jan-90	1.80	40.6	42.90	14.61	10.15	10.80	9.51	10.80	9.90	0	0	0.00	-1.30
09-Jan-90	1.72	44.0	42.90	15.86	11.01	10.80	9.40	10.80	9.83	0	0	0.00	-1.41
16-Jan-90	1.66	47.6	42.90	17.15	11.91	10.80	9.28	10.80	9.75	0	0	0.00	-1.52
23-Jan-90	1.60	51.4	42.90	18.50	12.84	10.80	9.16	10.80	9.66	0	0	0.00	-1.64
30-Jan-90	1.54	55.3	42.90	19.89	13.81	10.80	9.04	10.80	9.58	0	0	0.00	-1.76
06-Feb-90	1.34	53.0	46.11	19.07	13.24	11.09	9.40	11.09	9.91	0	0	0.00	-1.69
13-Feb-90	1.30	56.3	46.11	20.27	14.08	11.09	9.29	11.09	9.84	0	0	0.00	-1.80
20-Feb-90	1.26	59.8	46.11	21.51	14.94	11.09	9.18	11.09	9.76	0	0	0.00	-1.91
27-Feb-90	1.23	63.3	46.11	22.79	15.83	11.09	9.07	11.09	9.68	0	0	0.00	-2.02
W-War-W	1.26	70.9	44.49	25.52	17.72	10.94	8.68	10.94	9.37	0	0	0.00	-2.26
13-Mar-90	1.22	15.1	44.49	27.03	18.77	10.94	8.55	10.94	9.28	0	0	0.00	-2.40
20-Mar-90	1.19	to.4	44.49	28.58	19.85	10.96	8.41	10.94	9.18	0	0	0.00	-2.53
27-Mar-90	1.16	63.8	44.49	30.17	20.95	10.94	8.27	10.94	9.09	0	0	0.00	-2.67
03-Apr-90	1.16	93.3	42.90	33.57	23.31	10.80	7.83	10.80	8.74	0	0	0.00	-2.98
10-Apr-90													
17-Apr-90													
24-Apr-90													
01 -May-W													
08-May-90													
Minimum						10.15	7.83	10.15	8.74	0	0	0.00	-2.98
Maximum						11.09	9.57	11.09	9.91			0.00	-0.62

HIGH DENSITY MICHIGAN SYSTEM (Second Pass)

Date	DOin		O2-Avail (lb/d)	Peek Dan (lb/d)	Aver Dem (lb/d)	Peak Conditions		Aver. Conditions		Oxygen (lb)		Delta-DO	
	Peak	Average				DOin	DOout	DOin	DOout	Require	Purchase	02 AU	RU
01-Aug-89													
08-Aug-89													
15-Aug-89													
22-Aug-89													
29-Aug-89													
05-Sep-89													
12-Sep-89													
19-Sep-89													
26-Sep-89													
03-Oct-89													
10-Oct-89													
17-Oct-89													
24-Oct-89													
31-Oct-89													
07-Nov-89	9.53	9.72	28.53	6.96	4.83	9.53	8.91	10.33	9.91	0	0	0.00	-0.62
14-Nov-89	9.42	9.64	27.30	8.19	5.69	9.42	8.69	10.37	9.86	0	0	0.00	-0.73
21-Nov-89	9.30	9.56	25.97	9.52	6.61	9.30	8.46	10.40	9.82	0	0	0.00	-0.84
28-Nov-89	9.18	9.47	24.54	10.95	7.61	9.18	8.20	10.44	9.77	0	0	0.00	-0.97
05-Dec-89	9.57	9.87	29.02	10.82	7.51	9.57	8.61	10.82	10.16	0	0	0.00	-0.96
12-Dec-89	9.46	9.79	27.78	12.06	8.38	9.46	8.39	10.86	10.12	0	0	0.00	-1.07
19-Dec-89	9.35	9.71	26.46	13.38	9.29	9.35	8.16	10.89	10.07	0	0	0.00	-1.19
26-Dec-89	9.22	9.62	25.08	14.76	10.25	9.22	7.91	10.93	10.02	0	0	0.00	-1.31
02-Jan-90	9.51	9.90	28.29	14.61	10.15	9.51	8.21	11.20	10.30	0	0	0.00	-1.30
W-Jan-W	9.40	9.83	27.05	15.86	11.01	9.40	7.99	11.23	10.26	0	0	0.00	-1.41
16-Jan-90	9.28	9.75	25.75	17.15	11.91	9.28	7.76	11.27	10.21	0	0	0.00	-1.52
23-Jan-90	9.16	9.66	24.41	18.50	12.84	9.16	7.52	11.30	10.17	0	0	0.00	-1.64
30-Jan-90	9.04	9.58	23.01	19.89	13.81	9.04	7.28	11.34	10.12	0	0	0.00	-1.76
06-Feb-90	9.40	9.91	27.04	19.07	13.24	9.40	7.71	11.60	10.43	0	0	0.00	-1.69
13-Feb-90	9.29	9.84	25.03	20.27	14.08	9.29	7.49	11.64	10.39	0	0	0.00	-1.80
20-Feb-90	9.18	9.76	24.59	21.51	14.94	9.18	7.27	11.67	10.35	0	0	0.00	-1.91
27-Feb-90	9.07	9.68	23.31	22.79	15.83	9.07	7.05	11.70	10.30	0	0	0.00	-2.02
06-Mar-90	8.68	9.37	18.96	25.52	17.72	9.26	7.00	11.63	10.06	46	82	0.58	-2.26
13-Mar-90	8.55	9.28	17.46	27.03	18.77	9.40	7.00	11.68	10.01	67	123	0.85	-2.40
20-Mar-90	8.41	9.18	15.90	28.58	19.85	9.53	7.00	11.72	9.96	89	168	1.12	-2.53
27-Mar-90	8.27	9.09	14.31	30.17	20.95	9.67	7.00	11.76	9.90	111	217	1.41	-2.67
03-Apr-90	7.83	8.74	9.33	33.57	23.31	9.98	7.00	11.71	9.65	170	362	2.15	-2.98
10-Apr-90													
17-Apr-90													
24-Apr-90													
01-May-90													
08-May-90													
Minimum						9.04	7.00	10.33	9.65	482	951	0.00	-2.98
Maximum						9.98	8.91	11.76	10.43			2.15	-0.62

HIGH DENSITY MICHIGAN SYSTEM (Third Pass)

Date	DOin		O2-Avail (lb/d)	Peak Dem (lb/d)	Aver Dem (lb/d)	Peek Conditions		Aver. Conditions		Oxygen (lb)		Del te-DO	
	Peek	Average				W i n	DOout	DOin	DOout	Require	Purchase	02 AU	RU
01-Aug-89													
08-Aug-89													
15-Aug-89													
22-Aug-89													
29-Aug-89													
05-Sep-89													
12-Sep-89													
19-Sep-89													
26-Sep-89													
03-Oct-89													
10-Oct-89													
17-Oct-89													
24-Oct-89													
31-Oct-89													
07-Nov-89	8.91	9.91	21.57	6.96	4.83	8.91	8.29	10.52	10.09	0	0	0.00	-0.62
14-Nov-89	8.69	9.86	19.11	8.19	5.69	8.69	7.97	10.59	10.09	0	0	0.00	-0.73
21-Nov-89	8.46	9.82	16.45	9.52	6.61	8.46	7.61	10.66	10.08	D	D	0.00	-0.84
28-Nov-89	8.20	9.77	13.59	10.95	7.61	a.20	7.23	10.74	10.07	0	0	0.00	-0.97
05-Dec-89	8.61	10.16	18.20	10.82	7.51	6.61	7.65	11.12	10.45	0	0	0.00	-0.96
12-Dec-89	8.39	10.12	15.71	12.06	8.38	8.39	7.32	11.19	10.44	0	0	0.00	-1.07
19-Dec-89	8.16	10.07	13.08	13.38	9.29	8.19	7.00	11.26	10.43	2	4	0.03	-1.19
26-Dec-89	7.91	10.02	10.32	14.76	10.25	8.31	7.00	11.33	10.42	31	54	0.39	-1.31
02-Jan-90	8.21	10.30	13.67	14.61	10.15	8.30	7.00	11.59	10.69	7	11	0.08	-1.30
09-Jan-90	7.99	10.26	11.19	15.86	11.01	a.41	7.00	11.66	10.69	33	57	0.41	-1.41
16-Jan-90	7.76	10.21	8.60	17.15	11.91	6.52	7.00	11.73	10.68	60	109	0.76	-1.52
23-Jan-90	7.52	10.17	5.91	18.50	12.84	8.64	7.00	11.80	10.67	88	166	1.12	-1.64
30-Jan-90	7.28	10.12	3.12	19.89	13.81	8.76	7.00	11.88	10.66	117	231	1.49	-1.76
06-Feb-90	7.71	10.43	7.96	19.07	13.24	8.69	7.00	12.12	10.95	78	145	0.98	-1.69
13-Feb-90	7.49	10.39	5.55	20.27	14.08	8.80	7.00	12.19	10.94	103	199	1.30	-1.80
20-Feb-90	7.27	10.35	3.07	21.51	14.94	8.91	7.00	12.25	10.93	129	259	1.63	-1.91
27-Feb-90	7 . M	10.30	0.52	22.79	15.83	9.02	7.00	12.32	10.92	156	326	1.97	-2.02
06-Mar-90	7.00	10.06	-0.00	25.52	17.72	9.26	7.00	12.33	10.75	179	387	2.26	-2.26
13-Mar-90	7.00	10.01	-0.00	27.03	18.77	9.40	7.00	12.41	10.74	189	417	2.40	-2.40
20-Mar-90	7.00	9.96	-0.00	28.58	19.85	9.53	7.00	12.49	10.73	200	449	2.53	-2.53
27-Mar-90	7.00	9.90	-0.00	30.17	20.95	9.67	7.00	12.58	10.72	211	483	2.67	-2.67
03-Apr-90	7.00	9.65	-0.00	33.57	23.31	9.98	7.00	12.62	10.55	235	561	2.98	-2.98
10-Apr-90													
17-Apr-90													
24-Apr-90													
01-May-W													
08-May-90													
Minimum						8.19	7.00	10.52	10.07	1818	3858	0.00	-2.98
Maximum						9.98	8.29	12.62	10.95			2.98	-0.62

Weekley Oxygen Requirements (lb/raceway)

Date	Michigan			Oxygen/Treatment
	First	Second	Third	
01-Aug-89	0	0	0	0
08-Aug-89	0	0	0	0
15-Aug-89	0	0	0	0
22-Aug-89	0	0	0	0
29-Aug-W	0	0	0	0
05-Sep-89	0	0	0	0
12-Sep-89	0	0	0	0
19-Sep-89	0	0	0	0
26-Sep-89	0	0	0	0
03-Oct-89	0	0	0	0
10-Oct-89	0	0	0	0
17-Oct-89	0	0	0	0
24-Oct-89	0	0	0	0
31-Oct-89	0	0	0	0
07-Nov-89	0	0	0	0
14-Nov-89	0	0	0	0
21-Nov-89	0	0	0	0
28-Nov-89	0	0	0	0
05-Dec-89	0	0	0	0
12-Dec-89	0	0	0	0
19-Dec-89	0	0	4	4
26-Dec-89	0	0	54	54
02-Jan-90	0	0	11	11
W-Jan-W	D	0	57	57
16-Jan-90	0	0	109	109
23- Jan-W	0	0	166	166
30- Jan-W	0	0	231	231
06-Feb-90	0	0	145	145
13-Feb-90	0	0	199	199
20-Feb-90	0	0	259	259
27-Feb-90	0	0	326	326
06-Mar-90	0	82	387	469
13-Mar-90	0	123	417	540
20-Mar-90	0	168	449	617
27-Mar-90	0	217	483	700
03-Apr-90	0	362	M l	924
10-Apr-90	0	0	0	0
17-Apr-90	0	0	0	0
24-Apr-90	0	0	0	0
01 -May-W	0	0	0	0
08-May-90	0	0	0	0
15-May-90	0	0	0	0
Total	*0*	951	3858	4810 lb
				58257 cubic feet

Appendix D-l - Fall Chinook
Michigan System
Effluent DO Criteria: Saturation

UMATILLA PROJECT John Colt

FCh O/Michigan System REV 2 7/24/90

SUMMARY OF INFLUENT AND EFFLUENT DOs

	Well Water		Effluent fran Raceways		
	DOmin	DOmax	DOmin	DOmax	Delta-DO
Mich 1st	9.67	11.09	10.80	11.91	-3.64
Mich 2nd			10.80	13.02	-3.64
Mich 3th			10.80	14.14	-3.64

SUMMARY OF FINAL INTENSITY DATA

	Hatchery Intensity				
	Biomass (lb)	Flow (gpm)	Volume (ft3)	Density (lb/ft3)	Loading (lb/gpm)
Mich 1st	5340	940	1890	2.83	5.68
Mich 2nd	5340	940	1890	2.83	11.36
Mich 3th	5340	940	1890	2.83	17.04

SUMMARY OF OXYGEN REQUIREMENTS

	lb/raceway	AEX
Mich 1st	4226	43.7%
Mich 2nd	4226	43.7%
Mich 3th	4226	43.7%
	12677	43.7%

GROWTH MODELLING

C=	0.00030		Init. #/lb	300.00
n	3.00		Init. Length (in)	2.24
TU/inch	840		Init. Wt (g)	1.52
To	32.00 (F)			
FCR	1.00	(lb feed/lb fish)	Elevetion (ft)	500
HCTU	0.35714	(inches,F,day)	BP (mm Hg)	747

Date	Day	Test Temp (F)	Growth Model Weight (g)	Growth Model Weight (#/lb)	Growth Model Length (inch)	Averege Temp (F)	Maximum Temp (F)
01-Aug-89		60.0				60.0	
08-Aug-89		60.0				60.0	
15-Aug-89		60.0				60.0	
22-Aug-89		60.0				60.0	
29-Aug-89		60.0				60.0	
OS-Sep.89		61.0				61.0	
12-Sep-89		61.0				61.0	
19-Sep-89		61.0				61.0	
26-Sep-89		61.0				61.0	
03-Oct-89		60.0				60.0	
10-Oct-89		60.0				60.0	
17-Oct-89		60.0				60.0	
24-Oct-89		60.0				60.0	
31-Oct-89		60.0				60.0	
07-Nov-W		57.0				57.0	
14-Nov-89		57.0				57.0	
21-Nov-89		57.0				57.0	
28-Nov-89		57.0				57.0	
05-Dec-89		54.0				54.0	
12-Dec-89		54.0				54.0	
19-Dec-89		54.0				54.0	
26-Dec-89		54.0				54.0	
02-Jan-90		52.0				52.0	
09-Jan-90		52.0				52.0	
16-Jan-90		52.0				52.0	
23-Jan-90		52.0				52.0	
30-Jan-90		52.0				52.0	
06-Feb-90	0	50.0	1.52	300.00	2.24	50.0	
13-Feb-90	7	50.0	1.84	247.02	2.39	50.0	
20-Feb-90	14	50.0	2.21	205.82	2.54	50.0	
27-Feb-90	21	50.0	2.62	173.29	2.69	50.0	
W-Nor-90	28	51.0	3.11	145.98	2.85	51.0	
13-Mar-90	35	51.0	3.66	124.13	3.01	51.0	
20-Mar-90	42	51.0	4.27	106.42	3.17	51.0	
27-Mar-90	49	51.0	4.94	91.93	3.33	51.0	
03-Apr-90	56	52.0	5.73	79.39	3.49	52.0	
10-Apr-90	63	52.0	6.59	69.02	3.66	52.0	
17-Apr-90	70	52.0	7.53	60.39	3.83	52.0	
24-Apr-90		52.0				52.0	

MORTALITY MODEL Mortality/day (%) 0.0060 Initial Number 370000

Date	MICHIGAN SYSTEM #/lb	Number	Mass(lb)
01-Aug-89			
08-Aug-89			
15-Aug-89			
22-Aug-89			
29-Aug-89			
05-Sep-89			
12-Sep-89			
19-Sep-89			
26-Sep-89			
03-Oct-89			
10-Oct-89			
17-Oct-89			
24-Oct-89			
31-Oct-89			
07-Nov-89			
14-Nov-89			
21-Nov-89			
28-Nov-89			
05-Dec-89			
12-Dec-89			
19-Dec-89			
26-Dec-89			
02-Jan-90			
09-Jan-90			
16-Jan-90			
23-Jan-90			
30-Jan-90			
06-Feb-90	300.00	370000	1233
13-Feb-90	247.02	369845	1497
20-Feb-90	205.82	369689	1796
27-Feb-90	173.29	369534	2132
06-Mar-90	145.98	369379	2530
13-Mar-90	124.13	369224	2975
20-Mar-90	106.42	369069	3468
27-Mar-90	91.93	368914	4013
03-Apr-90	79.39	368759	4645
10-Apr-90	69.02	368604	5340
17-Apr-90	60.39	368449	6101
24-Apr-90			
01-May-90			
08-May-90			

DISSOLVED OXYGEN CRITERIA IN EFFLUENT

Influent DO%	100
Oxygen-Feed Retio	0.25
Peaking Factor	1.44

	Effluent Criteria (mg/l)	Influent DO (mg/l)	Absolute	Set. et Sealevel (mg/l)	Vepor Press. (mm Hg)	Sat. et Hatchery (mg/l)
01-Aug-89	9.79	9.79	7.00	9.96	13.25	9.79
08-Aug-89	9.79	9.79	7.00	9.96	13.25	9.79
15-Aug-89	9.79	9.79	7.00	9.96	13.25	9.79
22-Aug-89	9.79	9.79	7.00	9.96	13.25	9.79
29-Aug-89	9.79	9.79	7.00	9.96	13.25	9.79
OS-Sap-89	9.67	9.67	7.00	9.85	13.73	9.67
12-Sep-89	9.67	9.67	7.00	9.85	13.73	9.67
19-Sep-89	9.67	9.67	7.00	9.85	13.73	9.67
26-Sep-89	9.67	9.67	7.00	9.85	13.73	9.67
03-Oct-89	9.79	9.79	7.00	9.96	13.25	9.79
10-Oct-89	9.79	9.79	7.00	9.96	13.25	9.79
17-Oct-89	9.79	9.79	7.00	9.96	13.25	9.79
24-Oct-89	9.79	9.79	7.00	9.96	13.25	9.79
31-Oct-89	9.79	9.79	7.00	9.96	13.25	9.79
07-Nov-89	10.15	10.15	7.00	10.33	11.90	10.15
14-Nov-89	10.15	10.15	7 . w	10.33	11.90	10.15
21-Nov-89	10.15	10.15	7.00	10.33	11.90	10.15
28-Nov-89	10.15	10.15	7.00	10.33	11.90	10.15
05-Dec-89	10.53	10.53	7.00	10.72	10.67	10.53
12-Dec-89	10.53	10.53	7.00	10.72	10.67	10.53
19-Dec-89	10.53	10.53	7.00	10.72	10.67	10.53
26-Dec-89	10.53	10.53	7.00	10.72	10.67	10.53
02-Jan-90	10.80	10.80	7.00	11.00	9.92	10.80
09-Jan-90	10.80	10.80	7.00	11.00	9.92	10.80
16-Jan-90	10.80	10.80	7.00	11.00	9.92	10.80
23-Jan-90	10.80	10.80	7.00	11.00	9.92	10.80
30-Jan-90	10.80	10.80	7.00	11.00	9.92	10.80
06-Feb-90	11.09	11.09	7.00	11.29	9.21	11.09
13-Feb-90	11.09	11.09	7.00	11.29	9.21	11.09
20-Feb-90	11.09	11.09	7.00	11.29	9.21	11.09
27-Feb-90	11.09	11.09	7.00	11.29	9.21	11.09
06-Mar-90	10.94	10.94	7.00	11.14	9.56	10.94
13-Mar-90	10.94	10.94	7.00	11.14	9.56	10.94
20-Mar-90	10.94	10.94	7.00	11.14	9.56	10.94
27-Mar-90	10.94	10.94	7.00	11.14	9.56	10.94
03-Apr-90	10.80	10.80	7.00	11.00	9.92	10.80
10-Apr-90	10.80	10.80	7.00	11.00	9.92	10.80
17-Apr-90	10.80	10.80	7.00	11.00	9.92	10.80
24-Apr-90	10.80	10.80	7.00	11.00	9.92	10.80
01-May-90	10.53	10.53	7.00	10.72	10.67	10.53
08-May-90	10.53	10.53	7.00	10.72	10.67	10.53
		9.67	7.00	9.85	9.21	9.67
		11.09	7.00	11.29	13.73	11.09

HIGH DENSITY MICHIGAN SYSTEM (First Pess)

Column Performance Data

Flow (gpm) 940 intercept 0.60

slope 0.06

Date	Feed (%)	Feed (lb)	O2-Avail (lb/d)	Peek Dem (lb/d)	Aver Dem (lb/d)	Peek Conditions DOin	Peek Conditions DOout	Aver. Conditions DOin	Aver. Conditions DOout	Oxygen (lb) Require	Oxygen (lb) Purchase	Delta-DO O2 AU	Delta-DO RU
01-Aug-89													
08-Aug-89													
15-Aug-89													
22-Aug-89													
29-Aug-89													
05-Sep-89													
12-Sep-89													
19-Sep-89													
26-Sep-89													
03-Oct-89													
10-Oct-89													
17-Oct-89													
24-Oct-89													
31-Oct-89													
07-Nov-89													
14-Nov-89													
21-Nov-89													
28-Nov-89													
05-Dec-89													
12-Dec-89													
19-Dec-89													
26-Dec-89													
02-Jan-90													
09-Jan-90													
16-Jan-90													
23-Jan-90													
30-Jan-90													
06-Feb-90													
13-Feb-90	2.69	40.2	0.00	14.49	10.06	12.37	11.09	12.37	11.48	101	195	1.28	-1.28
20-Feb-90	2.53	45.4	0.00	16.35	11.36	12.54	11.09	12.54	11.53	114	225	1.45	-1.45
27-Feb-90	2.39	so.9	0.00	18.33	12.73	12.71	11.09	12.71	11.58	128	257	1.63	-1.63
06-Mar-90	2.38	60.2	0.00	21.69	15.06	12.87	10.94	12.87	11.53	152	315	1.92	-1.92
13-Mar-90	2.26	67.1	0.00	24.15	16.77	13.011	10.96	13.08	11.60	169	361	2.14	-2.14
20-Mar-90	2.14	74.3	0.00	26.75	18.58	13.31	10.94	13.31	11.67	187	412	2.37	-2.37
27-Mar-90	2.04	61.9	0.00	29.48	20.47	13.56	10.94	13.56	11.74	206	468	2.61	-2.61
03-Apr-90	2.05	95.0	0.00	34.21	23.76	13.84	10.80	13.84	11.7)	239	576	3.03	-3.03
10-Apr-90	1.95	104.3	0.00	37.54	26.07	14.13	10.80	14.13	11.82	263	660	3.33	-3.33
17-Apr-90	1.87	173.9	0.00	41.02	28.48	14.44	10.80	14.44	11.91	287	757	3.64	-3.64
24-Apr-90													
01-May-90													
08-May-90													
Minimum						12.37	10.80	12.37	11.48	1848	4226	1.28	-3.64
Maximum						14.44	11.09	14.44	11.91			3.64	-1.28

HIGH DENSITY MICHIGAN SYSTEM (Second Pass)

Date	Win		O2-Avail (lb/d)	Perk Dem (lb/d)	Aver Dem (lb/d)	Peek Conditions		Aver. Conditions		Oxygen (lb)		Delta-DO	
	Peek	Average				DOin	DOout	DOin	DOout	Require	Purchase	02 AU	RU
01-Aug-89													
08-Aug-89													
15-Aug-89													
22-Aug-89													
29-Aug-89													
05-Sep-89													
12-Sep-89													
19-Sep-89													
26-Sep-89													
03-Oct-89													
10-Oct-89													
17-Oct-89													
24-Oct-89													
31-Oct-89													
07-Nov-89													
lb-NOV.89													
21-Nov-89													
28-Nov-89													
05-Dec-89													
12-Dec-89													
19-Dec-89													
26-Dec-89													
02-Jan-90													
W- Jan-90													
16-Jan-90													
23-Jan-90													
30- Jan-W													
06-Feb-90													
13-Feb-90	11.09	11.48	0.00	14.49	10.06	12.37	11.09	12.76	11.87	101	195	1.28	-1.28
20-Feb-90	11.09	11.53	0.00	16.35	11.36	12.54	11.09	12.98	11.97	114	225	1.45	-1.45
27-Feb-90	11.09	11.58	0.00	18.33	12.73	12.71	11.09	13.21	12.08	128	257	1.63	-1.63
06-Mar-90	10.06	11.53	0.00	21.69	15.06	12.87	10.94	13.45	12.12	152	315	1.92	-1.92
13-Mar-90	10.94	11.60	0.00	24.15	16.77	13.08	10.94	13.74	12.25	169	361	2.14	-2.14
20-Mar-90	10.94	11.67	0.00	26.75	18.58	13.31	10.94	14.04	12.39	187	412	2.37	-2.37
27-Mar-90	10.94	11.74	0.00	29.48	20.47	13.56	10.94	14.36	12.54	206	468	2.61	-2.61
03-Apr-90	10.80	11.73	0.00	34.21	23.76	13.84	10.80	14.76	12.66	239	576	3.03	-3.03
10-Apr-90	10.80	11.82	0.00	37.54	26.07	14.13	10.80	15.15	12.84	263	660	3.33	-3.33
17-Apr-90	10.80	11.91	0.00	41.02	28.48	14.44	10.80	15.55	13.02	287	757	3.64	-3.64
24-Apr-90													
01-May-90													
08-May-90													
Minimum						12.37	10.80	12.76	11.87	1848	4226	1.28	-3.64
Maximum						14.44	11.09	15.55	13.02			3.64	-1.28

HIGH DENSITY MICHIGAN SYSTEM (Third Pass)

Date	DOin		O2-Avail (lb/d)	Peak Dem (lb/d)	Aver Dem (lb/d)	Peak Conditions		Aver. Conditions		Oxygen (lb)		Delta-DO	
	Peek	Average				DOin	DOout	DOin	DOout	Require	Purchase	02 AU	RU
01-Aug-89													
08-Aug-89													
15-Aug-89													
22-Aug-89													
29-Aug-89													
05-Sep-89													
12-Sep-89													
19-Sep-89													
26-Sep-89													
03-Oct-89													
10-Oct-89													
17-Oct-89													
24-Oct-89													
31-Oct-89													
07-Nov-89													
14-Nov-89													
21-Nov-89													
28-Nov-89													
05-Dec-89													
12-Dec-89													
19-Dec-89													
26-Dec-89													
02-Jan-90													
W-Jan-W													
16-Jan-90													
23-Jan-90													
30- Jan-W													
W-Fob-W													
13-Feb-90	11.09	11.87	0.00	14.49	10.06	12.37	11.09	13.16	12.26	101	1 %	1.28	-1.28
20-Feb-90	11.09	11.97	0.00	16.35	11.36	12.54	11.09	13.42	12.42	114	225	1.45	-1.45
27-Feb-90	11.09	12.08	0.00	18.33	12.73	12.71	11.09	13.71	12.58	128	257	1.63	-1.63
06-Mar-90	10.94	12.12	0.00	21.69	15.06	12.87	10.94	14.04	12.71	152	315	1.92	-1.92
13-Mar-90	10.94	12.25	0.00	24.15	16.77	13.08	10.94	14.39	12.91	169	361	2.14	-2.14
20-Mar-90	10.94	12.39	0.00	26.75	18.58	13.31	10.94	14.76	13.12	187	412	2.37	-2.37
27-Mar-90	10.94	12.54	0.00	29.48	20.47	13.56	10.94	15.15	13.34	206	468	2.61	-2.61
03-Apr-90	10.80	12.66	0.00	34.21	23.76	13.84	10.80	15.69	13.58	239	576	3.03	-3.03
10-Apr-90	10.80	12.84	0.00	37.54	26.07	14.13	10.80	16.16	13.85	263	660	3.33	-3.33
17-Apr-90	10.80	13.02	0.00	41.02	28.48	14.44	10.80	16.66	14.14	287	757	3.64	-3.64
24-Apr-90													
Ol-Hay-W													
08-May-90													
Minimum						12.37	10.80	13.16	12.26	1848	4226	1.28	-3.64
Maximum						14.44	11.09	16.66	14.14			3.64	-1.28

Weekley Oxygen Requirements (lb/raceway)

Date	Michigan			Oxygen/Treatment
	First	Second	Third	
01-Aug-89	0	0	0	0
08-Aug-89	0	0	0	0
15-Aug-89	0	0	0	0
22-Aug-89	0	0	0	0
29-Aug-89	0	0	0	0
05-Sep-89	0	0	0	0
12-Sep-89	0	0	0	0
19-Sep-89	0	0	0	0
26-Sep-89	0	0	0	0
03-Oct-89	0	0	0	0
10-Oct-89	0	0	0	0
17-Oct-89	0	0	0	0
24-Oct-89	0	0	0	0
31-Oct-89	0	0	0	0
07-Nov-89	0	0	0	0
14-Nov-89	0	0	0	0
21-Nov-89	0	0	0	0
28-Nov-89	0	0	0	0
(H-WC-89	0	0	0	0
12-Dec-89	0	0	0	0
19-Dec-89	0	0	0	0
26-Dec-89	0	0	0	0
02-Jan-90	0	0	0	0
09-Jan-90	0	0	0	0
16-Jan-90	0	0	0	0
23-Jan-90	0	0	0	0
30-Jan-90	0	0	0	0
06-Feb-90	0	0	0	0
13-Feb-90	1 %	195	1 %	585
20-Feb-90	225	225	225	674
27-Feb-90	257	257	257	771
06-Mar-90	315	315	315	945
13-Mar-90	361	361	361	1082
20-Mar-90	412	412	412	1235
27-Mar-90	468	468	468	1405
03-Apr-90	576	576	576	1729
10-Apr-90	660	660	660	1981
17-Apr-90	757	757	757	2270
24-Apr-90	0	0	0	0
01-May-90	0	0	0	0
08-May-90	0	0	0	0
15-May-90	0	0	0	0
Total	4226	4226	4226	12677 lb
				153551 cubic feet

Appendix D-2 - Fall Chinook
Michigan System
Effluent DO Criteria: 7 mg/L

UMATILLA PROJECT John Colt

FCh O/Michigan System REV 2 7/24/90

SUMMARY OF INFLUENT AND EFFLUENT DOs

	Well Water		Effluent from Raceways		
	DOmin	DOmax	DOmin	DOmax	Delta-DO
Mich 1st	9.67	11.09	7.17	10.20	-3.64
Mich 2nd			7.00	10.59	-3.64
Mich 3th			7.00	10.98	-3.64

SUMMARY OF FINAL INTENSITY DATA

	Hatchery Intensity				
	Biomass (lb)	Flow (gpm)	Volume (ft3)	Density (lb/ft3)	Loading (lb/gpm)
Mich 1st	5340	940	1890	2.83	5.68
Mich 2nd	5340	940	1890	2.83	11.36
Mich 3th	5340	940	1890	2.83	17.04

SUMMARY OF OXYGEN REQUIREMENTS

	lb/raceway	AEX
Mich 1st	0	0.0%
Mich 2nd	1975	44.0%
Mich 3th	3679	42.9%
	---------	---------
	5654	43.3%

GROWTH MODELLING

C=	0.00030		Init. #/lb	300.00
n	3.00		Init. Length (in)	2.24
TU/inch	840		Init. Wt (g)	1.52
To	32.00	(F)		
FCR	1.00	(lb feed/lb fish)	Elevation (ft)	500
HCTU	0.35714	(inches,F,day)	BP (mm Hg)	747

Date	Day	Test Temp (F)	Growth Model Weight (g)	Yeight (#/lb)	Length (inch)	Average Temp (F)	Maximum Temp (F)
01-Aug-89		60.0				60.0	
08-Aug-89		60.0				60.0	
15-Aug-89		60.0				60.0	
22-Aug-89		60.0				60.0	
29-Aug-89		60.0				60.0	
05-Sep-89		61.0				61.0	
12-Sep-89		61.0				61.0	
19-Sep-89		61.0				61.0	
26-Sep-89		61.0				61.0	
03-Oct-89		60.0				60.0	
10-Oct-89		60.0				60.0	
17-Oct-89		60.0				60.0	
24-Oct-89		60.0				60.0	
31-Oct-89		60.0				60.0	
07-Nov-89		57.0				57.0	
14-Nov-89		57.0				57.0	
21-Nov-89		57.0				57.0	
28-Nov-89		57.0				57.0	
05-Dec-89		54.0				54.0	
12-Dee-89		54.0				54.0	
19-Dec-89		54.0				54.0	
26-Dec-89		54.0				54.0	
02-Jan-90		52.0				52.0	
09-Jan-90		52.0				52.0	
16-Jan-90		52.0				52.0	
U-Jan-90		52.0				52.0	
30-Jan-W		52.0				52.0	
06-Feb-90	0	50.0	1.52	300.00	2.24	50.0	
13-Feb-90	7	50.0	1.84	247.02	2.39	50.0	
20-Feb-90	14	50.0	2.21	205.82	2.54	50.0	
27-Feb-90	21	50.0	2.62	173.29	2.69	50.0	
W-Mar-90	28	51.0	3.11	145.98	2.85	51.0	
13-Mar-90	35	51.0	3 . w	124.13	3.01	51.0	
20-Mar-90	42	51.0	4.27	106.42	3.17	51.0	
27-Mar-90	49	51.0	4.94	91.93	3.33	51.0	
03-Apr-90	56	52.0	5.73	79.39	3.49	52.0	
10-Apr-90	63	52.0	6.59	69.02	3.66	52.0	
17-Apr-90	70	52.0	7.53	60.39	3.83	52.0	
24-Apr-90		52.0				52.0	

MORTALITY MODEL Mortality/day (%) 0.0060 Initial Number 370000

Date	MICHIGAN SYSTEM d/lb	Number	Mass(lb)
01-Aug-89			
08-Aug-89			
15-Aug-89			
22-Aug-89			
29-Aug-89			
05-Sep-89			
12-sap-89			
19-Sep-89			
26-Sep-89			
03-Oct-89			
10-Oct-89			
17-Oct-89			
24-Oct-89			
31-Oct-89			
07-Nov-89			
14-Nov-89			
21-Nov-89			
28-Nov-89			
05-Dec-89			
12-Dec-89			
19-Dec-89			
26-Dec-89			
02-Jan-90			
W-Jan-W			
16-Jan-90			
23-Jan-90			
30-Jan-90			
06-Feb-90	300.00	370000	1233
13-Feb-90	247.02	369845	1497
20-Feb-90	205.82	369689	1796
27-Feb-90	173.29	369534	2132
06-Mar-90	145.98	369379	2530
13-Mar-90	124.13	369224	2975
20-Mar-90	106.42	369069	3468
27-Mar-90	91.93	368914	4013
03-Apr-90	79.39	368759	4645
10-Apr-90	69.02	368604	5340
17-Apr-90	60.39	368449	6101
24-Apr-90			
01 -May-W			
08-May-90			

DISSOLVED OXYGEN CRITERIA IN EFFLUENT

Influent DO%	100
Oxygen-Feed Ratio	0.25
Peaking Factor	1.44

	Effluent Criteria (mg/l)	Influent DO (mg/l)	Absolute	Sat. at Sealevel (mg/l)	Vapor Press. (mm Hg)	Sat. at Hatchery (mg/l)
01-Aug-89	7.00	9.79	7.00	9.96	13.25	9.79
08-Aug-89	7.00	9.79	7.00	9 - w	13.25	9.79
15-hug-89	7.00	9.79	7.00	9.96	13.25	9.79
22-Aug-89	7.00	9.79	7.00	9.96	13.25	9.79
29-Aug-89	7.00	9.79	7.00	9.96	13.25	9.79
05-Sep-89	7.00	9.67	7.00	9.85	13.73	9.67
12-Sep-89	7.00	9.67	7.00	'9.85	13.73	9.67
19-Sep-89	7.00	9.67	7 . w	9.85	13.73	9.67
26-Sep-89	7.00	9.67	7.00	9.85	13.73	9.67
03-Oct-89	7.00	9.79	7.00	9.96	13.25	9.79
10-Oct-89	7.00	9.79	7.00	9.96	13.25	9.79
17-Oct-89	7.00	9.79	7.00	9.96	13.25	9.79
24-Oct-89	7.00	9.79	7.00	9.96	13.25	9.79
31-Oct-89	7.00	9.79	7.00	9.96	13.25	9.79
07-Nov-89	7.00	10.15	7.00	10.33	11.90	10.15
14-Nov-89	7.00	10.15	7.00	10.33	11.90	10.15
21-Nov-89	7.00	10.15	7.00	10.33	11.w	10.15
28-Nov-89	7.00	10.15	7.00	10.33	11.90	10.15
05-Dec-89	7.00	10.53	7.00	10.72	10.67	10.53
12-Dec-89	7.00	10.53	7.00	10.72	10.67	10.53
19-Dec-89	7.00	10.53	7.00	10.72	10.67	10.53
26-Dec-89	7.00	10.53	7.00	10.72	10.67	10.53
02-Jan-90	7.00	10.80	7.00	11.00	9.92	10.80
W-Jan-W	7.00	10.80	7.00	11.00	9.92	10.80
16- Jan-W	7.00	10.80	7.00	11.00	9.92	10.80
23-Jan-90	7.00	10.80	7.00	11.00	9.92	10.80
30-Jan-90	7.00	10.80	7.00	11.00	9.92	10.80
06-Feb-90	7.00	11.09	7.00	11.29	9.21	11.09
13-Feb-90	7.00	11.09	7.00	11.29	9.21	11.09
20-Feb-90	7.00	11.09	7.00	11.29	9.21	11.09
27-Feb-90	7.00	11.09	7.00	11.29	9.21	11.09
W-War-90	7.00	10.94	7.00	11.14	9.56	10.94
13-Mar-90	7.00	10.94	7.00	11.14	9.56	10.94
20-Mar-90	7.00	10.94	7.00	11.14	9.56	10.94
27-Mar-90	7.00	10.94	7.00	11.14	9.56	10.94
03-Apr-90	7.00	10.80	7.00	11.00	9.92	10.80
10-Apr-90	7.00	10.80	7.00	11.00	9.92	10.80
17-Apr-90	7.00	10.80	7.00	11.00	9.92	10.80
24-Apr-90	7.00	10.80	7.00	11.00	9.92	10.80
01 -May-W	7.00	10.53	7.00	10.72	10.67	10.53
08-May-90	7.00	10.53	7.00	10.72	10.67	10.53
		9.67	7.00	9.85	9.21	9.67
		11.09	7.00	11.29	13.73	11.09

HIGH DENSITY MICHIGAN SYSTEM (First Pass)

Flow (gpm) 940

. Column Performance Data
intercept 0.60
slope 0.06

Dote	Feed (%)	Feed (lb)	O2-Avail (lb/d)	Peak Dem (lb/d)	Aver Dem (lb/d)	Peak Conditions DOin	Peak Conditions DOout	Aver. Conditions DOin	Aver. Conditions DOout	Oxygen (lb) Require	Oxygen (lb) Purchase	Delta-DO O2 AU	Delta-DO RU
01-hug-89													
08-Aug-89													
15-Aug-89													
22-Aug-89													
29-Aug-89													
05-Sep-89													
12-Sep-89													
19-Sep-89													
26-Sep-89													
03-Oct-89													
10-Oct-89													
17-Oct-89													
24-Oct-89													
31-Oct-89													
07-Nov-89													
14-Nov-89													
21-Nov-89													
28-Nov-89													
05-Dec-89													
12-Dec-89													
19-Dec-89													
26-Dec-89													
02-Jan-90													
W-Jon-W													
16-Jan-90													
23-Jan-90													
30-Jan-90													
06-Feb-90													
13-Feb-90	2.69	40.2	46.11	14.49	10.06	11.09	9.80	11.09	10.20	0	0	0.00	-1.20
20-Feb-90	2.53	45.4	46.11	16.35	11.36	11.09	9.64	11.09	10.08	0	0	0.00	-1.45
27-Feb-90	2.39	50.9	46.11	18.33	12.73	11.09	9.46	11.09	9.96	0	0	0.00	-1.63
06-Mar-90	2.38	60.2	44.49	21.69	15.06	10.94	9.02	10.94	9.61	0	0	0.00	-1.92
13-Mar-90	2.26	67.1	44.49	24.15	16.77	10.94	8.80	10.94	9.46	0	0	0.00	-2.14
20-Mar-90	2.14	74.3	44.49	26.75	18.58	10.94	8.57	10.94	9.30	0	0	0.00	-2.37
27-Mar-90	2.04	81.9	44.49	29.48	20.47	10.94	8.33	10.94	9.13	0	0	0.00	-2.61
03-Apr-90	2.05	95.0	42.90	34.21	23.76	10.80	7.77	10.80	8.70	0	0	0.00	-3.03
10-Apr-90	1.95	104.3	42.90	37.54	26.07	10.80	7.48	10.80	8.49	0	0	0.00	-3.33
17-Apr-90	1.87	113.9	42.90	41.02	28.48	10.80	7.17	10.80	8.28	0	0	0.00	-3.64
24-Apr-90													
01-May-W													
08-May-90													
Minimum						10.80	7.17	10.80	8.28	0	0	0.00	-3.64
Maximum						11.09	9.80	11.09	10.20			0.00	-1.28

HIGH DENSITY MICHIGAN SYSTEM (Second Pass)

Date	DOin		O2-Avail (lb/d)	Peak Dem (lb/d)	Aver Dan (lb/d)	Perk Conditions		Aver. Conditions		Oxygen (lb)		Delta-DO	
	Peak	Average				DOin	DOout	DOin	DOout	Require	Purchase	02 AU	RU
01-Aug-89													
08-Aug-89													
15-Aug-89													
22-Aug-89													
29-Aug-89													
05-Sep-89													
12-Sep-89													
19-Sep-89													
26-Sep-89													
03-Oct-89													
10-Oct-89													
17-Oct-89													
24-Oct-89													
31-Oct-89													
07-Nov-89													
14-Nov-89													
21-Nov-89													
28-Nov-89													
OS-Dee-89													
12-Dec-89													
19-Dec-89													
26-Dec-89													
02-Jan-90													
09-Jan-90													
16-Jan-90													
U-Jon-90													
30-Jan-90													
06-Feb-90													
13-Feb-90	9.80	10.20	31.62	14.49	10.06	9.80	8.52	11.48	10.59	0	0	0.00	-1.28
20-Feb-90	9.64	10.08	29.75	16.35	11.36	9.64	8.19	11.53	10.52	0	0	0.00	-1.45
27-Feb-90	9.46	9.96	27.77	18.33	12.73	9.46	7.84	11.58	10.45	0	0	0.00	-1.63
06-Mar-90	9.02	9.61	22.80	21.69	15.06	9.02	7.10	11.53	10.20	0	0	0.00	-1.92
13-Mar-90	8.80	9.46	20.33	24.15	16.77	9.14	7.00	11.60	10.11	27	46	0.34	-2.14
20-Mar-90	8.57	9.30	17.73	26.75	18.58	9.37	7.00	11.67	10.02	63	115	0.80	-2.37
27-Mar-90	8.33	9.13	15.00	29.48	20.47	9.61	7.00	11.74	9.93	101	195	1.28	-2.61
03-Apr-90	7.77	8.70	8.69	34.21	23.76	10.03	7.00	11.73	9.62	179	387	2.26	-3.03
10-Apr-90	7.48	8.49	5.36	37.54	26.07	10.33	7.00	11.82	9.51	225	528	2.85	-3.33
17-Apr-90	7.17	8.28	1.88	41.02	28.48	10.64	7.00	11.91	9.39	274	703	3.47	-3.64
24-Apr-90													
01-May-90													
08-May-90													
Minimum						9.02	7.00	11.48	9.39	869	1975	0.00	-3.64
Maximum						10.64	8.52	11.91	10.59			3.47	-1.28

HIGH DENSITY MICHIGAN SYSTEM (Third Pass)

Date	DOin		O2-Avail (lb/d)	Peak Dam (lb/d)	Aver Dem (lb/d)	Peak Conditions		Aver. Condition8		Oxygen (lb)		Delta-DO	
	Peek	Average				DOin	DOout	DOin	DOout	Rquire	Purchase	02 AU	RU
01-hug-89													
08-Aug-89													
15-Aug-89													
22-Aug-89													
29-Aug-89													
05-Sep-89													
12-Sep-89													
19-Sep-89													
26-Sep-89													
03-Oct-89													
10-Oct-89													
17-Oct-89													
24-Oct-89													
31-Oct-89													
07-Nov-89													
14-Nov-89													
21-Nov-89													
28-Nov-89													
05-Dec-89													
12-Dec-89													
19-Dec-89													
26-Dec-89													
02-Jan-90													
W-Jan-W													
16-Jan-90													
23-Jan-90													
30- Jon-W													
06-Feb-90													
13-Feb-90	8.52	10.59	17.13	14.49	10.06	8.52	7.23	11.87	10.98	0	0	0.00	-1.28
20-Feb-90	8.19	10.52	13.39	16.35	11.36	8.45	7.00	11.97	10.97	21	36	0.26	-1.45
27-Feb-90	7.84	10.45	9.43	18.33	12.73	8.63	7.00	12.08	10.95	62	113	0.79	-1.63
IX-Nor-00	7.10	10.20	1.11	21.69	15.06	8.92	7.00	12.12	10.78	144	2 %	1.82	-1.92
13-Mar-90	7.00	10.11	-0.00	24.15	16.77	9.14	7.00	12.25	10.76	169	361	2.14	-2.14
20-Mar-90	7.00	10.02	-0.00	26.75	18.58	9.37	7.00	12.39	10.75	187	412	2.37	-2.37
27-Mar-90	7.00	9.93	-0.00	29.48	20.47	9.61	7.00	12.54	10.75	206	469	2.61	-2.61
03-Apr-90	7.00	9.62	-0.00	34.21	23.76	10.03	7.00	12.66	10.55	239	576	3.03	-3.03
10-Apr-90	7.00	9.51	-0.00	37.54	26.07	10.33	7.00	12.84	10.53	263	660	3.33	-3.33
17-Apr-90	7.00	9.39	-0.00	41.02	28.48	10.64	7.00	13.02	10.50	287	757	3.64	-3.64
24-Apr-90													
01 -May-W													
08-May-90													
Minimum						8.45	7.00	11.87	10.50	1579	3679	0.00	-3.64
Maximum						10.64	7.23	13.02	10.98			3.64	-1.28

Weekley Oxygen Requirements (lb/raceway)

Date	Michigan First	Michigan second	Michigan Third	Oxygen/Treatment
01-Aug-89	0	0	0	0
08-Aug-89	0	0	0	0
15-Aug-89	0	0	0	0
22-Aug-89	0	0	0	0
29-Aug-89	0	0	0	0
05-Sep-89	0	0	0	0
12-Sep-89	0	0	0	0
19-Sep-89	0	0	0	0
26-Sep-89	0	0	0	0
03-Oct-89	0	0	0	0
10-Oct-89	0	0	0	0
17-Oct-89	0	0	0	0
24-Oct-89	0	0	0	0
31-Oct-89	0	0	0	0
07-Nov-89	0	0	0	0
14-Nov-89	0	0	0	0
21-Nov-89	0	0	0	0
28-Nov-89	0	0	0	0
05-Dec-89	0	0	0	0
12-Dec-89	0	0	0	0
19-Dec-89	0	0	0	0
26-Dec-89	0	0	0	0
02-Jan-90	0	0	0	0
W-Jan-W	0	0	0	0
16-Jan-90	0	0	0	0
U-Jan-90	0	0	0	0
30-Jan-90	0	0	0	0
06-Feb-90	0	0	0	0
13-Feb-90	0	0	0	0
20-Feb-90	0	0	36	36
27-Feb-90	0	0	113	113
W-Mar-90	0	0	295	295
13-Mar-90	0	46	361	407
20-Mar-90	0	115	412	527
27-Mar-90	0	1 %	469	664
03-Apr-90	0	387	576	963
10-Apr-90	0	528	660	1189
17-Apr-90	0	703	757	1460
24-Apr-90	0	0	0	0
01-wry-w	0	0	0	0
08-May-90	0	0	0	0
15-May-90	0	0	0	0
Total	0	1975	3679	5654 lb
				68486 cubic feet

Appendix E - Spring Chinook
Oregon System
Effluent DO Criteria: None

UMATILLA PROJECT John Colt

SCh 0/Oregon System REV 2 7/24/90

SUMMARY OF INFLUENT AND EFFLUENT DOs

	Yell Voter		Effluent from Raceways		
	DOmin	DOmax	DOmin	DOmax	Delta-DO
Oreg 1st	9.67	11.09	9.40	10.53	-1.41
Oreg 2nd			7.99	10.78	-1.41

SUMMARY OF FINAL INTENSITY DATA

	Hatchery Intensity				
	Bicfness (lb)	Flow (gpm)	Volume (ft3)	Density (lb/ft3)	Loading (lb/gpm)
Oreg 1st	5948	1500	6200	0.96	3.97
Oreg 2nd	5948	1500	6200	0.96	7.93

SUMMARY OF OXYGEN REQUIREMENTS

	lb/raceway	AE%
Oreg 1st	0	0.0%
Oreg 2nd	0	0.0%
	....	....
	0	0.0%

GROWTH MODELLING

C=	0.00030	Init. #/lb	300.00
n	3.00	Init. Length (in)	2.24
TU/inch	840	Init. Wt (g)	1.52
To	32.00 (F)		
FCR	1.00 (Lb feed/lb fish)	Elevation (ft)	500
HCTU	0.35714 (inches,F,day)	BP (mm Hg)	747

Dote	Day	Test Temp (F)	Growth Model Weight (g)	Growth Model Ueight (#/lb)	Growth Model Length (inch)	Average Temp (F)	Maximum Temp (F)
01-Aug-89		60.0				60.0	
08-Aug-89		60.0				60.0	
15-Aug-89		60.0				60.0	
22-Aug-89		60.0				60.0	
29-Aug-89		60.0				60.0	
05-Sep-89		61.0				61.0	
12-Sep-89		61.0				61.0	
19-Sep-89		61.0				61.0	
26-Sep-89		61.0				61.0	
03-Oct-89		60.0				60.0	
10-Oct-89		60.0				60.0	
17-Oct-89		60.0				60.0	
24-Oct-89		60.0				60.0	
31-Oct-89	0	60.0	1.52	300.00	2.24	60.0	
07-Nov-89	7	57.0	1.98	229.79	2.45	57.0	
14-Nov-89	14	57.0	2.53	179.89	2.66	57.0	
21-Nov-89	21	57.0	3.17	143.45	2.87	57.0	
28-Nov-89	28	57.0	3.91	116.23	3.08	57.0	
05-Dec-89	35	54.0	4.65	97.69	3.26	54.0	
12-Dec-89	42	54.0	5.48	82.90	3.44	54.0	
19-Dec-89	49	54.0	6.41	70.94	3.63	54.0	
26-Dec-89	56	54.0	7.43	61.18	3.81	54.0	
02-Jan-90	63	52.0	8.45	53.81	3.98	52.0	
W-Jon-W	70	52.0	9.56	47.57	4.14	52.0	
16-Jan-90	77	52.0	10.76	42.26	4.31	52.0	
U-Jan-90	84	52.0	12.05	37.71	4.48	52.0	
30-Jan-90	91	52.0	13.45	33.79	4.64	52.0	
06-Feb-90	98	50.0	14.80	30.72	4.79	50.0	
13-Feb-90	105	50.0	16.23	28.00	4.94	50.0	
20-Feb-90	112	50.0	17.76	25.60	5.09	50.0	
27-Feb-90	119	50.0	19.37	23.47	5.24	50.0	
06-Mar-90	126	51.0	21.18	21.44	5.40	51.0	
13-Mar-90	133	51.0	23.10	19.68	5.56	51.0	
20-Mar-90	140	51.0	25.13	18.09	5.72	51.0	
27-Mar-90	147	51.0	27.28	16.67	5.88	51.0	
03-Apr-90	154	52.0	29.66	15.32	6.04	52.0	
10-Apr-90		52.0				52.0	
17-Apr-90		52.0				52.0	
24-Apr-90		52.0				52.0	

MORTALITY MODEL   Mortality/day (%) 0.0060   Initial Nuder 92000

Date	MICHIGAN SYSTEM #/lb	Number	Mass(lb)
01-Aug-89			
08-Aug-89			
15-Aug-89			
22-Aug-89			
29-Aug-89			
0S-Sap-89			
12-Sep-89			
19-Sep-89			
26-Sep-89			
03-Oct-89			
10-Oct-89			
17-Oct-89			
24-Oct-89			
31-Oct-89	300.00	92000	307
07-Nov-89	229.79	91961	400
14-Nov-89	179.89	91923	511
21-Nov-89	143.45	91884	641
28-Nov-89	116.23	91846	790
05-Dec-89	97.69	91807	940
12-Dec-89	82.90	91768	1107
19-Dec-89	70.94	91730	1293
26-Dec-89	61.18	91691	1499
02-Jan-90	53.81	91653	1703
09-Jan-90	47.57	91614	1926
16-Jan-90	42.26	91576	2167
23-Jan-90	37.71	91537	2427
30-Jan-90	33.79	91499	2708
06-Feb-90	30.72	91461	2977
13-Feb-90	28.00	91422	3265
20-Feb-90	25.60	91384	3569
27-Feb-90	23.47	91345	3893
06-Mar-90	21.46	91307	4254
13-Mar-90	19.68	91269	4638
20-Mar-90	18.09	91230	5043
27-Mar-90	16.67	91192	5472
03-Apr-90	15.32	91154	5948
10-Apr-90			
17-Apr-90			
24-Apr-90			
01-May-90			
08-May-90			

DISSOLVED OXYGEN CRITERIA IN EFFLUENT

Influent DO%	100
Oxygen-Feed Ratio	0.25
Peaking Factor	1.44

	Effluent Criteria (mg/l)	Influent DO (mg/l)	Absolute	Sat. at Sealevel (mg/l)	Vapor Press. (mm Hg)	Sat. at Hatchery (mg/l)
01-Aug-89	4.00	9.79	4.00	9.96	13.25	9.79
08-Aug-89	4.00	9.79	4.00	9.96	13.25	9.79
15-Aug-89	4.00	9.79	4.00	9.96	13.25	9.79
22-Aug-89	4.00	9.79	4.00	9.96	13.25	9.79
29-Aug-89	4.00	9.79	4.00	9.96	13.25	9.79
05-Sep-89	4.00	9.67	4.00	9.85	13.73	9.67
12-Sep-89	4.00	9.67	4.00	9.85	13.73	9.67
19-Sep-89	4.00	9.67	4.00	9.85	13.73	9.67
26-Sep-89	4.00	9.67	4.00	9.85	13.73	9.67
03-Oct-89	4.00	9.79	4.00	9.96	13.25	9.79
10-Oct-89	4.00	9.79	4.00	9.96	13.25	9.79
17-Oct-89	4.00	9.79	4.00	9.96	13.25	9.79
24-Oct-89	4.00	9.79	4.00	9.96	13.25	9.79
31-Oct-89	4.00	9.79	4.00	9.96	13.25	9.79
07-Nov-89	4.00	10.15	4.00	10.33	11.90	10.15
14-Nov-89	4.00	10.15	4.00	10.33	11.90	10.15
21-Nov-89	4.00	10.15	4.00	10.33	11.90	10.15
28-Nov-89	4.00	10.15	4.00	10.33	11.90	10.15
OS-Dtc-89	4.00	10.53	4.00	10.72	10.67	10.53
12-Dec-89	4.00	10.53	4.00	10.72	10.67	10.53
19-Dec-89	4.00	10.53	4.00	10.72	10.67	10.53
26-Dec-89	4.00	10.53	4.00	10.72	10.67	10.53
02-Jan-90	4.00	10.80	4.00	11.00	9.92	10.80
09-Jan-90	4.00	10.80	4.00	11.00	9.92	10.80
16-Jan-90	4.00	10.80	4.00	11.00	9.92	10.80
23-Jan-W	4.00	10.80	4.00	11.00	9.92	10.80
30-Jan-90	4.00	10.80	4.00	11.00	9.92	10.80
06-Feb-90	4.00	19.09	4.00	11.29	9.21	11.09
13-Feb-90	4.00	11.09	4.00	11.29	9.21	11.09
20-Feb-90	4.00	11.09	4.00	11.29	9.21	11.09
27-Feb-90	4.00	11.09	4.00	11.29	9.21	11.09
%-Mar-W	4.00	10.94	4.00	11.14	9.56	10.94
13-Mar-90	4.00	10.94	4.00	11.14	9.56	10.94
20-Mar-W	4.00	10.94	4.00	11.14	9.56	10.94
27-Mar-W	4.00	10.94	4.00	11.14	9.56	10.94
03-Apr-90	4.00	10.80	4.00	11.00	9.92	10.80
10-Apr-90	4.00	10.80	4.00	11.00	9.92	10.80
17-Apr-90	4.00	10.80	4.00	11.00	9.92	10.80
24-Apr-90	4.00	10.80	4.00	11.00	9.92	10.80
01-May-90	4.00	10.53	4.00	10.72	10.67	10.53
08-May-90	4.00	10.53	4.00	10.72	10.67	10.53
	Minimun	9.67	4.00	9.85	9.21	9.67
	Maximum	11.09	4.00	11.29	13.73	11.09

OREGON SYSTEM (First Pass)

Column Performance Data

Flow (gpm) 1500 intercept 0.60

slope 0.06

Date	Feed (%)	Feed (lb)	O2-Avail (lb/d)	Peak Dem (lb/d)	Aver Dem (lb/d)	Peak Conditions DOin	Peak Conditions DOout	Aver. Conditions DOin	Aver. Conditions DOout	Oxygen (lb) Require	Oxygen (lb) Purchase	Delta-DO 02 AU	Delta-DO RU
01-Aug-89													
08-Aug-89													
15-Aug-89													
22-Aug-89													
29-Aug-89													
OS-sep-89													
12-Sep-89													
19-Sep-89													
26-Sep-89													
03-Oct-89													
10-Oct-89													
17-Oct-89													
24-Oct-89													
31-Oct-89													
07-Nov-89	3.64	14.6	110.66	5.25	3.65	10.15	9.85	10.15	9.94	0	0	0.00	-0.29
14-Nov-89	3.36	17.2	110.66	6.18	4.29	10.15	9.80	10.15	9.91	0	0	0.00	-0.34
21-Nov-89	3.11	19.9	110.66	7.18	4.99	10.15	9.75	10.15	9.87	0	0	0.00	-0.40
28-Nov-89	2.90	22.9	110.66	8.26	5.74	10.15	9.69	10.15	9.83	D	0	0.00	-0.46
OS-Dee-89	2.41	22.7	117.59	8.16	5.67	10.53	10.08	10.53	10.22	0	0	0.00	-0.45
12-Dec-89	2.28	25.3	117.59	9.10	6.32	10.53	10.03	10.53	10.18	0	0	0.00	-0.51
19-Dec-89	2.17	28.0	117.59	10.09	7.01	10.53	9.97	10.53	113.14	0	0	0.00	-0.56
26-Dec-89	2.06	30.9	117.59	11.13	7.75	10.53	9.91	10.53	10.10	0	0	0.00	-0.62
02-Jan-90	1.80	30.6	122.47	11.02	7.65	10.80	10.19	10.80	10.38	0	0	0.00	-0.61
09-Jan-90	1.72	33.2	122.47	11.96	8.30	10.80	10.14	10.80	10.34	0	0	0.00	-0.66
16-Jan-90	1.66	35.9	122.47	12.93	8.98	10.80	10.08	10.80	10.30	0	0	0.00	-0.72
23-Jan-90	1.60	38.7	122.47	13.95	9.69	10.80	10.03	10.80	10.26	0	0	0.00	-0.77
30-Jan-90	1.54	41.7	122.47	15.00	10.42	10.80	9.97	10.80	10.22	0	0	0.00	-0.83
06-Feb-90	1.34	39.9	127.59	14.38	9.99	11.09	10.29	11.09	10.53	0	0	0.00	-0.80
13-Feb-90	1.30	42.5	127.59	15.29	10.62	11.09	10.24	11.09	10.50	0	D	0.00	-0.85
20-Feb-90	1.26	45.1	127.59	16.22	11.27	11.09	10.19	11.09	10.46	0	D	0.00	-0.90
27-Feb-90	1.23	47.7	127.59	17.19	11.94	11.09	10.13	11.09	10.42	0	0	0.00	-0.95
06-Mar-90	1.26	53.5	125.00	19.25	13.37	10.94	9.87	10.94	10.20	0	0	0.00	-1.07
13-Mar-90	1.22	56.6	125.00	20.38	14.15	10.94	9.81	10.94	10.16	0	0	0.00	-1.13
20-Mar-90	1.19	59.9	125.00	21.55	14.97	10.94	9.75	10.94	10.11	0	0	0.00	-1.20
27-Mar-90	1.16	63.2	125.00	22.75	15.80	10.94	9.68	10.94	10.07	0	0	0.00	-1.26
03-Apr-90	1.18	70.3	122.47	25.32	17.58	10.80	9.40	10.80	9.83	0	0	0.00	-1.41
10-Apr-90													
17-Apr-90													
24-Apr-90													
01-May-W													
08-May-90													
Minimum						10.15	9.40	10.15	9.83	0.00	0.00	0.00	-1.41
Maximum						11.09	10.29	11.09	10.53			0.00	-0.29

OREGON SYSTEM (Second Pass)

Dote	DOin Peak	DOin Average	O2-Avail (lb/d)	Peak Dem (lb/d)	Aver Dem (lb/d)	Peak Conditions DOin	Peak Conditions DOout	Aver. Conditions DOin	Aver. Conditions DOout	Oxygen (lb) Require	Oxygen (lb) Purchase	Delta-DO 02 AU	Delta-DO RU
01-Aug-89													
08-Aug-89													
15-Aug-89													
22-Aug-89													
29-Aug-89													
05-Sep-89													
12-Sep-89													
19-Sep-89													
26-Sep-89													
03-Oct-89													
IO-Dct-89													
17-Oct-89													
24-Oct-89													
31-Oct-89													
07-Nov-89	9.85	9.94	105.40	5.25	3.65	9.85	9.56	10.24	10.03	0	0	0.00	-0.29
14-Nov-89	9.80	9.91	104.48	6.18	4.29	9.80	9.46	10.25	10.01	0	0	0.00	-0.34
21-Nov-89	9.75	9.87	103.47	7.18	4.99	9.75	9.35	10.27	9.99	0	0	0.00	-0.40
28-Nov-89	9.69	9.83	102.39	8.26	5.74	9.69	9.23	10.29	9.97	0	0	0.00	-0.46
OS-Dee-89	10.08	10.22	109.43	8.16	5.67	10.08	9.62	10.67	10.36	0	0	0.00	-0.45
12-Dec-89	10.03	10.18	108.49	9.10	6.32	10.03	9.52	10.69	10.33	0	0	0.00	-0.51
19-Dec-89	9.97	10.14	107.50	10.09	7.01	9.97	9.41	10.70	10.31	0	0	0.00	-0.56
26-Dec-89	9.91	10.10	106.46	11.13	7.73	9.91	9.29	10.72	10.29	0	0	0.00	-0.62
02-Jan-90	10.19	10.38	111.45	11.02	7.65	10.19	9.58	10.99	10.56	0	0	0.00	-0.61
W-Jon-W	10.14	10.34	110.52	11.96	8.30	10.14	9.47	11.01	10.54	0	0	0.00	-0.66
16-Jan-90	10.08	10.30	109.54	12.93	8.98	10.08	9.37	11.02	10.52	0	0	0.00	-0.72
23-Jan-90	10.03	10.26	108.52	13.95	9.69	10.03	9.25	11.04	10.50	0	0	0.00	-0.77
30-Jan-90	9.97	10.22	107.47	15.00	10.42	9.97	9.14	11.06	10.48	0	0	0.00	-0.83
06-Feb-90	10.29	10.53	113.21	14.38	9.99	10.29	9.49	11.33	10.78	0	0	0.00	-0.80
13-Feb-90	10.24	10.50	112.30	15.29	10.62	10.24	9.39	11.35	10.76	0	0	0.00	-0.85
20-Feb-90	10.19	10.46	111.36	16.22	11.27	10.19	9.28	11.36	10.74	0	0	0.00	-0.90
27-Feb-90	10.13	10.42	110.40	17.19	11.94	10.13	9.18	11.38	10.72	0	0	0.00	-0.95
06-Mar-90	9.87	10.20	ID5.75	19.25	13.37	9.87	8.80	11.27	10.53	0	0	0.00	-1.07
13-Mar-90	9.81	10.16	104.62	20.38	14.15	9.81	8.68	11.29	10.50	0	0	0.00	-1.13
20-Mar-90	9.75	10.11	103.45	21.55	14.97	9.75	8.55	11.31	10.48	0	0	0.00	-1.20
27-Mar-90	9.68	10.07	102.25	22.75	15.80	9.68	8.42	11.33	10.45	0	0	0.00	-1.26
03-Apr-90	9.40	9.83	97.15	25.32	17.58	9.40	7.99	11.23	10.26	0	0	0.00	-1.41
10-Apr-90													
17-Apr-90													
24-Apr-90													
01-May-90													
08-May-90													
Minimum						9.40	7.99	10.24	9.97	0.00	0.00	0.00	-1.41
Maximum						10.29	9.62	11.38	10.78			0.00	-0.61

Weekley Oxygen Requirements (lb/raceway)

Date	OREGON First	OREGON second	Oxygen/Treatment
01-Aug-89	0	0	0
08-Aug-89	0	0	0
IS-Aug-89	0	0	0
22-Aug-89	0	0	0
29-Aug-89	D	0	0
OS-sep-89	0	D	0
12-Sep-89	0	0	0
19-Sep-89	0	0	0
26-Sep-89	0	0	0
03-Oct-89	0	0	0
10-Oct-89	0	0	0
IT-OH-89	0	0	0
24-Oct-89	0	0	0
31-Oct-89	D	0	D
07-Nov-89	0'	0	0
14-Nov-89	0	0	0
21-Nov-89	D	0	D
28-Nov-89	0	0	0
05-Dec-89	0	0	0
12-Dec-89	0	0	0
19-Dec-89	0	0	0
26-Dec-89	0	0	0
02-Jan-90	0	0	0
W-Jan-W	0	0	0
16-Jan-90	0	0	0
23-Jan-90	D	0	0
30-Jan-90	0	0	0
06-Feb-90	0	0	0
13-Feb-90	0	D	0
20-Feb-90	0	0	0
27-Feb-90	0	0	0
06-Mar-90	0	0	0
13-Mar-90	0	0	0
20-Mar-90	0	0	0
27-Mar-90	0	0	0
03-Apr-90	0	0	0
10-Apr-90	0	0	0
17-Apr-90	0	0	0
24-Apr-90	0	D	0
01-May-90	0	0	0
08-May-90	D	0	0
15-May-90	0	0	0
Total	0	0	0 lb

Appendix F - Fall Chinook

Oregon System

Effluent DO Criteria: None

SUMMARY OF INFLUENT AND EFFLUENT DOs

	Yell Voter		Effluent from Raceways		
	DOmin	DOmax	DOmin	DOmax	Delta-DO
Oreg 1st	9.67	11.09	9.11	10.67	-1.69
Oreg 2nd			7.42	10.85	-1.69

SUMMARY OF FINAL INTENSITY DATA

	Hatchery Intensity				
	Biomass (lb)	Flow (gpm)	Volume (ft3)	Density (lb/ft3)	Loading (lb/gpm)
Oreg 1st	3969	1500	6200	0.64	2.65
Oreg 2nd	3969	1500	6200	0.64	5.29

SUMMARY OF OXYGEN REWIREMENTS

	lb/raceway	AEX
Oreg 1st	0	0.0%
Oreg 2nd	0	0.0%
	....	....
	0	0.0%

GROWTH MODELLING

C=	0.00030	Init. #/lb	300.00
n	3.00	Init. Length (in)	2.24
TU/inch	840	Init. Wt (g)	1.52
To	32.00 (F)		
FCR	1.00 (lb feed/lb fish)	Elevation (ft)	500
HCTU	0.35714 (inches,F,day)	BP (mm Hg)	747

Date	Day	Test Temp (F)	Growth Model			Average	Maximum
			Ueight (g)	Weight (#/lb)	Length (inch)	Temp (F)	Temp (F)
01-Aug-89		60.0				60.0	
08-Aug-89		60.0				60.0	
15-Aug-89		60.0				60.0	
22-Aug-89		60.0				60.0	
29-Aug-89		60.0				60.0	
05-Sep-89		61.0				61.0	
12-Sep-89		61.0				61.0	
19-Sep-89		61.0				61.0	
26-Sep-89		61.0				61.0	
03-Oct-89		60.0				60.0	
IO-Oct.89		60.0				60.0	
17-Oct-89		60.0				60.0	
24-Oct-89		60.0				60.0	
31-Oct-89		60.0				60.0	
07-Nov-89		57.0				57.0	
14-Nov-89		57.0				57.0	
21-Nov-89		57.0				57.0	
28-Nov-89		57.0				57.0	
OS-Du-89		54.0				54.0	
12-Dec-89		54.0				54.0	
19-Dec-89		54.0				54.0	
26-Dec-89		54.0				54.0	
02- Jon-W		52-0				52.0	
W-Jon-W		52.0				52.0	
16-Jan-90		52.0				52.0	
23- Jon-W		52.0				52.0	
30-Jan-90		52.0				52.0	
06-Feb-90	0	50.0	1.52	300.00	2.24	50.0	
13-Feb-90	7	50.0	1.84	247.02	2.39	50.0	
20-Feb-90	14	50.0	2.21	205.82	2.54	50.0	
27-Feb-90	21	50.0	2.62	173.29	2.69	50.0	
06-Mar-90	28	51.0	3.11	145.98	2.85	51.0	
13-Mar-90	35	51.0	3.66	124.13	3.01	51.0	
20-Mar-90	42	51.0	4.27	106.42	3.17	51.0	
27-Mar-90	49	51.0	4.94	91.93	3.33	51.0	
03-Apr-90	56	52.0	5.73	79.39	3.49	52.0	
10-Apr-90	63	52.0	6.59	69.02	3.66	52.0	
17-Apr-90	70	52.0	7.53	60.39	3.83	52.0	
24-Apr-90		52.0				52.0	

MORTALITY MDDEL Mortality/day (%) 0.0060 Initial Number 275000

Dote	MICHIGAN SYSTEM		
	#/lb	Number	Mass(lb)
01-Aug-89			
08-Aug-89			
15-Aug-89			
22-Aug-89			
29-Aug-89			
05-Sep-89			
12-Sep-89			
19-Sep-89			
26-Sep-89			
03-Oct-89			
IO-cm-89			
17-Oct-89			
24-Oct-89			
31-Oct-89			
07-Nov-89			
14-Nov-89			
21-Nov-89			
28-Nov-89			
OS-Du-89			
12-Dec-89			
19-Dec-89			
26-Dec-89			
02-Jan-90			
W-Jon-W			
16-Jan-90			
U-Jon-90			
30- Jon-W			
06-Feb-90	300.00	275000	917
13-Feb-90	247.02	274885	1113
20-Feb-90	205.82	274769	1335
27-Feb-90	173.29	274654	1585
06-Mar-90	145.98	274538	1881
13-Mar-90	124.13	274423	2211
20-Mar-90	106.42	274308	2578
27-Mar-90	91.93	274193	2983
03-Apr-90	79.39	274077	3452
10-Apr-90	69.02	273962	3969
17-Apr-90	60.39	273847	4535
24-Apr-90			
01-May-90			
08-May-90			

DISSOLVED OXYGEN CRITERIA IN EFFLUENT

Influent DO%	100
Oxygen-Feed Ratio	0.25
Peaking Factor	1.44

	Effluent Criteria (mg/l)	Influent DO (mg/l)	Absolute	[illegible] Sealevel (mg/l)	Vapor Press. (mm Hg)	[illegible] at Hatchery (mg/l)
01-Aug-89	4.00	9.79	4.00	9.96	13.25	9.79
08-Aug-89	4.00	9.79	4.00	9.96	13.25	9.79
15-Aug-89	4.00	9.79	4.w	9.96	13.25	9.79
22-Aug-89	4.00	9.79	4.00	9.96	13.25	9.79
29-Aug-89	4.00	9.79	4.00	9.96	13.25	9.79
05-Sep-89	4.00	9.67	4.00	9.85	13.73	9.67
12-Sep-89	4.00	9.67	4.00	9.85	13.73	9.67
19-Sep-89	4.00	9.67	4.00	9.85	13.73	9.67
26-Sep-89	4.00	9.67	4.00	9.85	13.73	9.67
03-Oct-89	4.00	9.79	4.00	9.96	13.25	9.79
10-Oct-89	4.00	9.79	4.00	9.96	13.25	9.79
17-Oct-89	4.00	9.79	4.00	9.96	13.25	9.79
24-Oct-89	4.00	9.79	4.00	9.96	13.25	9.79
31-Oct-89	4.00	9.79	4.00	9.96	13.25	9.79
07-Nov-89	4.00	10.15	4.00	10.33	11.90	10.15
14-Nov-89	4.00	10.15	4.00	10.33	11.90	10.15
21-Nov-89	4.00	10.15	4.00	10.33	11.90	10.15
28-Nov-89	4.00	10.15	4.00	10.33	11.90	10.15
OS-Du-89	4.00	10.53	4.00	10.72	IO.67	10.53
12-Dec-89	4.00	10.53	4.00	10.72	10.67	10.53
19-Dec-89	4.00	10.53	4.00	10.72	10.67	10.53
26-Dec-89	4.00	10.53	4.00	10.72	10.67	10.53
02-Jan-90	4.00	10.80	4.00	11.00	9.92	10.80
09-Jan-90	4.00	10.80	4.00	11.00	9.92	10.80
16-Jan-90	4.00	10.80	4.00	11.00	9.92	10.80
U-Jon-90	4.00	10.80	4.00	11.00	9.92	10.80
30-Jan-90	4.00	10.80	4.00	11.00	9.92	10.80
06-Feb-90	4.00	11.09	4.00	11.29	9.21	11.09
13-Feb-90	4.00	11.09	4.00	11.29	9.21	11.09
20-Feb-90	4.00	11.09	4.00	11.29	9.21	11.09
27-Feb-90	4.00	11.09	4.00	11.29	9.21	11.09
06-Mar-90	4.00	10.94	4.00	11.14	9.56	10.94
13-Mar-90	4.00	10.94	4.00	11.14	9.56	10.94
20-Mar-90	4.00	10.94	4.00	11.14	9.56	10.94
27-Mar-90	4.00	10.94	4.00	11.14	9.56	10.94
03-Apr-90	4.00	10.80	4.00	11.00	9.92	10.80
10-Apr-90	4.00	10.80	4.00	11.00	9.92	10.80
17-Apr-90	4.00	10.80	4.00	11.00	9.92	10.80
24-Apr-90	4.00	10.80	4.00	11.00	9.92	10.80
01-May-90	4.00	10.53	4.00	10.72	10.67	10.53
08-May-90	4.00	10.53	4.00	10.72	10.67	10.53
		9.67	4.00	9.85	9.21	9.67
		11.09	4.00	11.29	13.73	11.09

OREGON SYSTEM (First Pass)

Column Preformance Data

Flow (gpm) 1500 intercept 0.60

slope 0.06

Dote	Feed (%)	Feed (lb)	O2-Avail (lb/d)	Peek Dem (lb/d)	Aver Dem (lb/d)	Perk Conditions DOin	Perk Conditions DOout	Aver. Conditions DOin	Aver. Conditions DOout	Oxygen (lb) Require	Oxygen (lb) Purchase	Delta-DO 02 AU	Delta-DO RU
01-Aug-89													
08-Aug-89													
15-Aug-89													
22-Aug-89													
29-Aug-89													
05-Sep-89													
12-Sep-89													
19-Sep-89													
26-Sep-89													
03-Oct-89													
IO-Dct-89													
17-Oct-89													
24-Oct-89													
31-Oct-89													
07-Nov-89													
14-Nov-89													
21-Nov-89													
28-Nov-89													
05-Dec-89													
12-Dec-89													
19-Dec-89													
26-Dec-89													
02-Jan-90													
W-Jan-00													
16-Jan-90													
23-Jan-90													
30-Jan-90													
06-Feb-90													
13-Feb-90	2.69	29.9	127.59	10.77	7.48	11.09	10.49	11.09	10.67	0	0	0.00	-0.60
20-Feb-90	2.53	33.8	127.59	12.16	8.44	11.09	10.41	11.09	10.62	0	0	0.00	-0.68
27-Feb-90	2.39	37.9	127.59	13.63	9.46	11.09	10.33	11.09	10.56	0	0	0.00	-0.76
W-Mar-90	2.38	44.8	125.00	16.12	11.19	10.94	10.05	10.94	10.32	0	0	0.00	-0.90
13-Mar-90	2.26	49.9	125.00	17.95	12.47	10.94	9.95	10.94	10.25	0	0	0.00	-1.00
20-Mar-90	2.14	55.2	125.00	19.88	13.81	10.94	9.84	10.94	10.18	0	0	0.00	-1.10
27-Mar-90	2.04	60.9	125.00	21.91	15.22	10.94	9.73	10.94	10.10	0	0	0.00	-1.22
03-Apr-90	2.05	70.6	122.47	25.43	17.66	10.80	9.39	10.80	9.82	0	0	0.00	-1.41
10-Apr-90	1.95	77.5	122.47	27.90	19.37	10.80	9.25	10.80	9.73	0	D	0.00	-1.55
17-Apr-90	1.87	84.7	122.47	30.49	21.17	10.80	9.11	10.80	9.63	0	0	0.00	-1.69
24-Apr-90													
01-May-90													
08-May-90													
Minimum						10.80	9.11	10.80	9.63	0.00	0.00	0.00	-1.69
Maximum						11.09	10.49	11.09	10.67			0.00	-0.60

OREGON SYSTEM (Second Pass)

Dote	Win		O2-Avail (lb/d)	Peak Dem (lb/d)	Aver Dan (lb/d)	Perk Conditions		Aver. Conditions		Oxygen (lb)		Delta-DO	
	Perk	Average				DOin	DOout	DOin	DOout	Require	Purchase	02 AU	RU
01-Aug-89													
08-Aug-89													
15-Aug-89													
22-Aug-89													
29-Aug-89													
05-Sep-89													
12-Sep-89													
19-Sep-89													
26-Sep-89													
03-Oct-89													
I0-Oct.89													
17-Oct-89													
24-Oct-89													
31-Oct-89													
07-Nov-89													
14-Nov-89													
21-Nov-89													
28-Nov-89													
05-Dec-89													
12-Dec-89													
19-Dec-89													
26-Dec-89													
02-Jan-90													
W-Jan-90													
16-Jan-90													
23- Jan-W													
30-Jan-90													
06-Feb-90													
13-Feb-90	10.49	10.67	116.82	10.77	7.48	10.49	9.89	11.27	10.85	D	0	0.00	-0.60
20-Feb-90	10.41	10.62	115.43	12.16	8.44	10.41	9.74	11.29	10.82	0	0	0.00	-0.68
27-Feb-90	10.33	10.56	113.96	13.63	9.46	10.33	9.57	11.32	10.79	0	0	0.00	-0.76
06-Mar-90	10.05	10.32	108.88	16.12	11.19	10.05	9.15	11.22	10.60	0	0	0.00	-0.90
13-Mar-90	9.95	10.25	107.05	17.95	12.47	9.95	8.95	11.25	10.56	0	0	0.00	-1.00
20-Mar-90	9.04	10.18	105.12	19.88	13.81	9.84	8.73	11.28	10.51	0	0	0.00	-1.10
27-Mar-90	9.73	10.10	103.09	21.91	15.22	9.73	8.51	11.32	10.47	0	0	0.00	-1.22
03-Apr-90	9.39	9.82	97.05	25.43	17.66	9.39	7.98	11.23	10.25	0	0	0.00	-1.41
10-Apr-90	9.25	9.73	94.57	27.90	19.37	9.25	7.70	11.28	10.20	0	0	0.00	-1.55
17-Apr-90	9.11	9.63	91.98	30.49	21.17	9.11	7.42	11.32	10.14	0	0	0.00	-1.69
24-Apr-90													
01-May-90													
08-May-90													
Minimum						9.11	7.42	11.22	10.14	0.00	0.00	0.00	-1.69
Maximum						10.49	9.89	11.32	10.85			0.00	-0.60

Weekley Oxygen **Requirements (lb/raceway)**

Dote	Oregon		**Oxygen/Treatment**
	First	second	
01-Aug-89	0	0	0
08-Aug-89	0	0	0
15-Aug-89	0	0	0
22-Aug-89	0	0	0
29-Aug-89	0	0	0
05-Sep-89	0	0	0
12-Sep-89	0	0	0
19-Sep-89	0	0	0
26-Sep-89	0	0	0
03-Oct-89	0	0	0
10-Oct-89	0	0	0
17-Oct-89	0	0	0
24-Oct-89	0	0	0
31-Oct-89	0	0	0
07-Nov-89	0	0	0
14-Nov-89	0	0	0
21-Nov-89	0	0	0
28-Nov-89	0	0	0
OS-Dee-89	0	0	D
12-Dec-89	0	0	0
IO-Doe-89	0	0	0
26-Dec-89	0	0	D
02-Jan-90	0	0	0
09-Jan-90	0	0	0
16-Jan-90	0	0	D
23-Jan-90	0	0	D
30-Jan-90	0	0	0
06-Feb-90	0	0	0
13-Feb-90	0	0	0
20-Feb-90	0	0	0
27-Feb-90	0	0	0
06-Mar-90	0	0	0
13-Mar-90	0	0	0
20-Mar-90	0	0	0
27-Mar-90	0	0	0
03-Apr-90	0	0	0
10-Apr-90	0	0	0
17-Apr-90	0	0	0
24-Apr-90	0	D	0
01-**May-90**	0	0	0
08-May-90	0	0	0
15-May-90	0	0	0
Total	0	0	0 lb 0 cubic feet

EVALUATION OF PURE OXYGEN SYSTEMS AT THE UMATILLA HATCHERY

Task 2-Engineering Assessment of Existing Design

Final Report

Prepared by

Fish Factory

Prepared for

Jerry Bauer, Project Manager
U.S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
P.O. Box 3621
Portland, OR 97208-3621

Contract Number DE-AP79-90BP10722

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Executive Summary

An assessment of the oxygen contactors and oxygen supply system for the existing design currently planned for installation at Umatilla Hatchery resulted in findings that would improve efficiency, reliability, or other operations. The existing design was then compared against other potential methods and locations of oxygen delivery, including the Zeigler LHO unit. The overall recommended oxygen injection method reflects considerations of cost, timing, efficiency, and reliability, Because construction is well underway on the Umatilla Hatchery, recommendations will be classified into three groups:

A. Changes Needing Immediate Action

The following recommendations are time-critical and need immediate action for inclusion into the current construction phase.

(1) Addition of 1500 gal LOX tank and vaporizer.

(2) Installation of conduiting between contactors to allow automatic control of gas-to-liquid ratio.

(3) Extension of the spray column further down into the water to increase absorption efficiency.

(4) Maintain two or more raceway backup pumps on-site with the required equipment to allow one person to remove and replace pumps.

(5) Add oxygen supply lines for the degassing columns and to the end of each raceway (needed to allow potential installation of LHO units).

(6) Test the LHO system at the Irrigon Hatchery.

B. Changes That Can Be Implemented After Construction Is Finished

(1) Depending on the results of the testing program at the Irrigon Hatchery, give serious consideration to the installation of the LHO system at the Umatilla Hatchery. Retrofitting the Umatilla Hatchery with the LHO could improve the reliability of the pure oxygen system as well as reduce the annual operating costs of the hatchery.

(2) Install a solenoid-controlled “boost” line to each contact unit to increase the oxygen flow to the upstream units when a pump power failure is detected. This modification is more important if the current spray columns are retained.

C. Changes That Can Be Deferred Until After The System Is Operating

(1) Document the performance of the existing spray columns.

(2) Document the dissolved carbon dioxide concentration in the water supply for the hatchery.

(3) Document the impact of carbon dioxide retention in the degassing columns on pH changes.

(4) Evaluate the impact of feeding on pH changes.

(5) Evaluate conversion of the first column of each Michigan raceway series to a packed column.

(6) Evaluate conversion of the degassing columns to pure oxygen column.

Items 5 and 6 should be considered if the current spray columns are retained.

The current PSA generators do not have enough capacity to meet the design daily oxygen requirement for the Umatilla Hatchery. The addition of a 1500 gal liquid oxygen (LOX) system is recommended.

Serious consideration should be given to retrofitting the Umatilla Hatchery with the LHO unit to improve reliability of the pure oxygen system as well as reduce the annual operating costs of the hatchery. The LHO system can be installed in the existing Michigan raceways with only small additional modifications. Because the LHO system is relatively new, it is recommended to evaluate this unit at the nearby lrrigon Hatchery before proceeding with full-scale retro-fitting of the units in the Umatilla Hatchery.

Once the system is operational, the carbon dioxide concentration of the supply water should be determined and the operational characteristics of the degassing and spray columns evaluated. Problems with pH changes due to metabolic carbon dioxide production could limit the operation of the hatchery. If it is decided not the install the LHO system, modifications B-2, C-5, and C-3 may be needed to increase system reliability.

Introduction

The Northwest Power Planning Council has established a goal of doubling the size of salmon runs in the Columbia River Basin. The achievement of this important goal is largely dependent upon expanding the production of hatchery fish. Pure oxygen has been commonly used to increase the carrying capacity of private sector salmonid hatcheries in the Pacific Northwest (Gowan, 1987; Severson et al., 1987). The use of supplemental oxygen to increase hatchery production is significantly less expensive than the construction of new hatcheries and might save up to $500 million in construction costs.

The Umatilla Fish Hatchery is being constructed (near Irrigon, Oregon) to produce summer steelhead, spring chinook, and fall chinook. Bonneville Power Administration will fund construction, operation, and maintenance of the hatchery and Oregon Department of Fish and Wildlife will operate and manage the facility. Initially, the hatchery was designed to produce 160,000 lb of salmon and steelhead using a 2-pass water reuse system. In 1987, the objectives were modified to allow testing of an oxygen supplementation system which would boost production to 290,000 lb. The use of supplemental oxygen at the Umatilla Hatchery is attractive for three reasons; (1) the increased production would more fully meet smolt requirements for the Umatilla River adult return goals, (2) the cost efficiency of producing smolts at the hatchery would be greatly increased, and (3) it would provide an opportunity to thoroughly test the oxygen system which would have system-wide applications in the Columbia River Basin (Umatilla Master Plan, 1989). The pure oxygen columns at the Umatilla Fish Hatchery are based on a design used by the Michigan Department of Natural Resources (Boersen and Chesney, 1987; Westers et al., 1987).

Because there has been no long-term experience with oxygen supplementation systems in the Columbia River Basin, Bonneville Power Administration contracted with Fish Factory (DE-AP79-90BP10722) to perform an independent review and evaluation of the pure oxygen design for the Umatilla Hatchery. This report documents Task 2 - Engineering Assessment of Existing Design and is based on the oxygen requirements for the hatchery presented in the Task 1 report (Fish Factory, 1990a). The existing design will be compared to alternative oxygen contact systems and recommendations will be made to increase reliability and reduce operating costs.

Project Objectives and Description

Project Objectives

The Umatilla Hatchery is a part of the overall program for the rehabiliation of the salmon and steelhead populations within the Umatilla Basin in Eastern Oregon. The Umatilla Hatchery is not designed for adult holding, acclimation, and spawning. Eggs will be collected at several sites in the Umatilla Basin and incubated at the hatchery. The smolts will be planted back into the basin at a number of sites to "supplement" wild smolts. A significant monitoring and evaluation effort is planned to fully evaluate this technique. The production objectives of the hatchery are:

Parameter	Summer Steelhead (STS)	Spring Chinook (SCH)	Fall Chinook (FCH)
Number	420,000	1,080,000	5,940,000
Size (#/l b)	5	15	60
Weight (lb)	84,000	72,000	99,000

Due to operational constraints and the lack of an adequate number of broodstock, additional fish will be reared at other hatcheries for release into the Umatilla Basin.

Project Description

The hatchery will use two types of outdoor rearing raceways, referred to in this report as the Standard Oregon raceway and the Michigan raceway. The overall layout of the outdoor rearing units is presented in Figure 1. The key characteristics of these two raceways are presented below:

Parameter	Standard Oregon Raceway	Michigan Raceway
Volume (ft^3)	6200	1890
Water Flow (gpm)	1500	940
Baffles	no	yes
Number of Passes	2	3
Supplemental Oxygen	no	yes
Number of banks	5	8
Total Number of Raceways	10	24

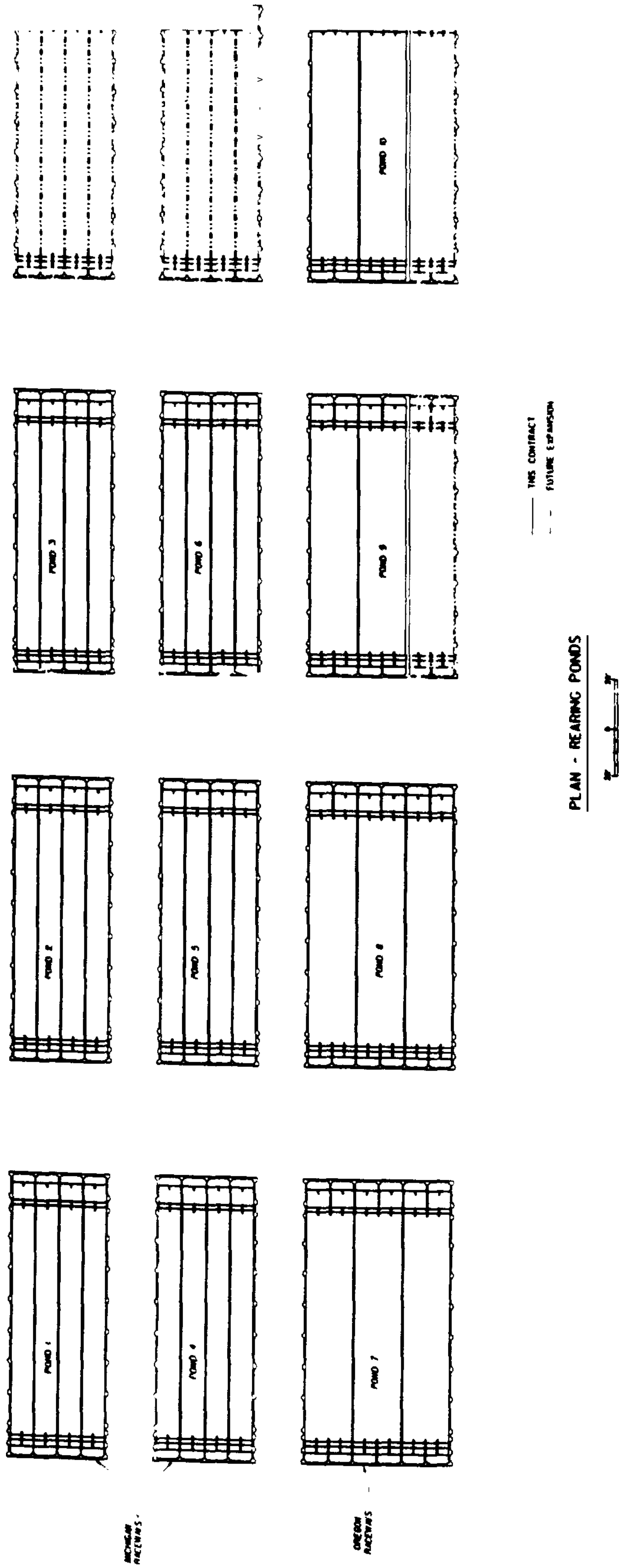


Figure 1 Layout of the outdoor rearing ponds at the Umatilla Hatchery (Umatilla Fish Hatchery Construction Drawing)

The baffles in the Michigan raceways will increase the water velocity near the bottom of the raceway and are designed to make the raceways essentially self-cleaning. Additional information on the project is presented in the following documents:

Umatilla Fish Hatchery- Environmental Assessment

Umatilla Hatchery Master Plan

Umatilla Fish Hatchery - Construction drawings

Detailed citations for these documents are presented in the reference section.

Summary of Task 1

The engineering assessment of the pure oxygen system at the Umatilla Hatchery presented in this report is based on the oxygen requirements documented in Task 1. A brief summary of the results of Task 1 (Fish Factory, 1990a) are presented below. For detailed information on the oxygen requirements for different treatments, the Task 1 report should be consulted.

The range of oxygen consumption rates for the different treatments are presented in Table 1:

Table 1 Raceway Oxygen Consumption (mg/L) and Cumulative Oxygen Consumption (mg/L) for each Treatment

Treatment	First Pass	Second Pass	Third Pass	Total System
STSMICH	0.45-3.77	0.45-3.77	0.45-3.77	1.35-11.31
SCHMICH	0.62-2.98	0.62-2.98	0.62-2.98	1.86-8.94
FCHMICH	1.28-3.64	1.28-3.64	1.28-3.64	3.84-10.92
FCHOREG	0.60-1.69	0.60-1.69	----	1.20-3.38
SCHOREG	0.29-1.41	0.29-1.41	----	0.58-2.28

The oxygen requirement depends strongly on the minimum oxygen criteria. Two oxygen criteria based on effluent concentrations from the raceways were tested: (1) saturation (depending on elevation and temperature) and (2) 7 mg/L (a criteria commonly used for flow-through salmon hatcheries). The results of the modelling for the two dissolved oxygen criteria cases are summarized in Table 2:

Table 2 Absorption Efficiencies and Oxygen Requirements

Parameter	Saturation Criteria	7 mg/L Criteria
Absorption Efficiency (%)	44.8	44.6
Daily Design Oxygen Requirement (lb)	2,300	1,700
Weekly Design Oxygen Requirement (lb)	13,600	11,400
Yearly Design Oxygen Requirement (lb)	197,000	86,000

There is probably little biological basis to support the saturation criteria, although it provides higher dissolved oxygen concentrations and therefore its selection may be more prudent during the experimental phase of the Umatilla Hatchery. Depending on the parameter used, the intensity of the Michigan system is 2.9-4.4 times higher than the Standard Oregon system.

Sources of Oxygen

Enriched oxygen may be obtained from three sources: high pressure oxygen gas, liquid oxygen (LOX), and on-site oxygen generators. In many facilities, at least two sources of oxygen are used. The most economic source will depend on power costs, transportation charges, and the mode of operation.

High Pressure Oxygen Gas High pressure oxygen gas (98 - 99 %) can be obtained in cylinders containing 100 - 250 ft^3 at 2550 psi. The cost of this form of oxygen ranges from $8 to $10/100 ft^3 in the United States. A number of cylinders can be connected together using standard manifold assemblies to increase the total capacity. Because of the high pressure and oxidizing properties of compressed pure oxygen, these systems present safety hazards.

The use of large numbers of gas cylinders is expensive and therefore is commonly restricted to small transport systems or as a backup system. High pressure cylinders do not vent gas when on standby.

Liquid Oxygen (LOX) Liquid oxygen (98 - 99 %) is produced on a large-scale basis by distilling liquefied air. Production facilities generally produce in excess of 125,000 lb/day. For a given volume, liquid oxygen contains 860 times as much oxygen as oxygen gas. At one atmosphere pressure, liquid oxygen boils at - 182.96 C. To reduce the amount of oxygen converted to gas, liquid oxygen must be stored in a Dewar's type of insulated container. The maximum gas pressure in these containers is generally in the range of 150 to 200 psi. If the pressure exceeds these values, gas is vented to the atmosphere through a safety valve. Approximately 0.25 % of the liquid will be lost per day, if the tank is off-line. LOX tanks should be sized so that the minimum gas use rate exceeds the off-line vent rate to avoid wastage.

Liquid oxygen containers range from 30 gal to greater than 10,000 gal. The smaller tanks are movable and will be refilled and delivered to the use site. Liquid oxygen for larger tanks will be transported to the use site in a bulk truck then pumped into the storage tank. A liquid oxygen supply system will consist of a storage tank, evaporator, filters, and pressure regulator (Figure 2). Steel pipe and copper tubing are recommended for oxygen lines. Special care must be used in construction and installation of pure oxygen piping and fittings to remove grease and oil which may present a fire hazard when in contact with pure oxygen.

The cost of liquid oxygen may vary from $0.25 to $3.00/100 ft^3 in the United States, depending on the amount purchased and number of pure oxygen plants in the area. Delivery costs vary from $.03 to $0.15/lb per 50 miles. The LOX tank and vaporizer can be purchased or rented. The monthly rental charges for a 1400 gal LOX tank is $325.

Oxygen Generators In the last 5 years, a number of manufacturers have developed pressure swing adsorption (PSA) systems that produce 15 to 400 ft^3 gas/hour. These units require a source of 90 - 150 psi filtered air and generate

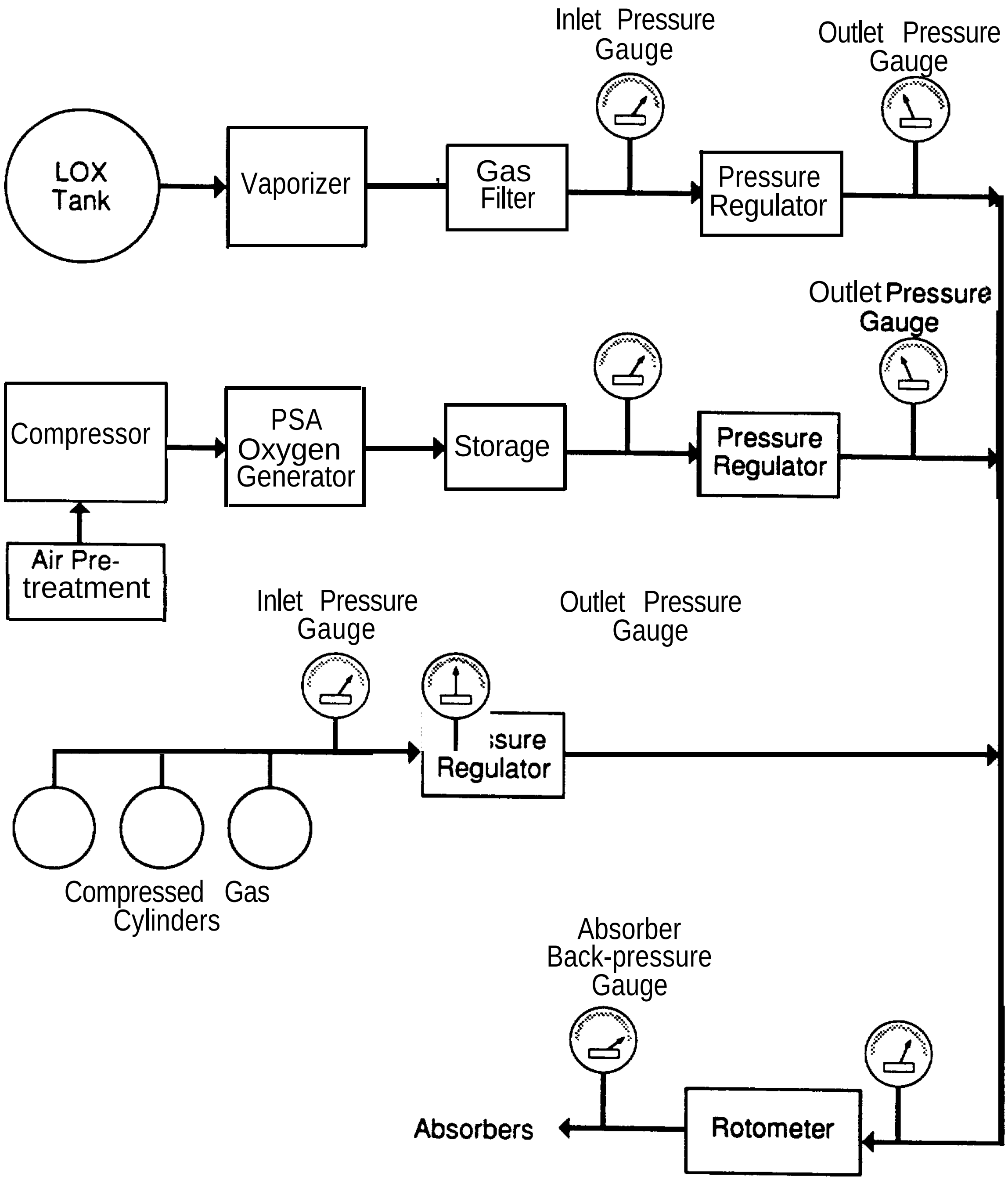


Figure 2 Major components of an oxygen supply system using liquid oxygen and PSA as primary supply systems, and compressed oxygen for emergencies

enriched oxygen gas of 85 to 95 % oxygen. Oxygen generators work on a demand basis, so oxygen is produced only when needed. Although oxygen generators have proven to be very reliable and require little maintenance, they are not as reliable as compressed gas or liquid oxygen systems.

The power requirement of a PSA system for a production-scale facility can range from 5 to 50 hp and will generally require a standby electrical generator. Installation of a PSA system may also require construction of a separate building for the compressor due to heat and noise, but heat from the compressor can be utilized for heating water or space.

Production Oxygen Systems For production systems, more than one source of oxygen is generally required. The selection of the oxygen source(s) will depend on a number of site specific conditions and the biases of the designers and hatchery managers. When compressed gas cylinders are used as a source of emergency oxygen, the discharge pressure on the emergency system regulators is set slightly below the normal supply line pressure so that switch over to the emergency system is automatic (Figure 2). Isolated production facilities may find PSA systems to be more economic due to high LOX transport costs. Sites near LOX production plants may find LOX more attractive due to reduced capital and maintenance costs.

Pure Oxygen Systems

When compared to air, pure oxygen is relatively expensive and only systems with high absorption efficiencies are generally economic. At least 5 types of oxygen absorption equipment have potential for use at the Umatilla Hatchery.

Packed Column A pure oxygen packed column consists of a sealed column packed with high specific-surface area media (Figure 3). Water is distributed uniformly over the upper surface of the media by a perforated plate or spray bar. Pure oxygen packed columns are efficient nitrogen strippers and most production columns are designed to both increase dissolved oxygen and strip out nitrogen (Colt and Bouck, 1984; Hackney and Colt, 1982).

Spray column A spray column is similar to a packed column except it does not contain media. This type of system may be required in reuse systems due to problems with media fouling. In some of the spray columns used in Michigan, the discharge pipe is smaller than the column diameter. This type of design produces a vacuum of 20 - 50 mm Hg (Boersen and Chesney, 1987) resulting in excellent degassing of nitrogen. The columns as designed for the Umatilla Hatchery do not have a reduced discharge diameter.

Submerged Spray Column In locations with limited hydraulic head, it may be necessary to submerge the spray column in the raceway (Figure 4). The absorption efficiency of these columns is in the range of 35-40% (Horton Dennis and Associates, 1990).

LHO The LHO (Low Head Oxygenator) system manufactured by Zeigler Brothers is a multi-compartmented spray column. All of the oxygen gas is introduced into a single compartment and then flows into the remaining compartments in a cross-flow

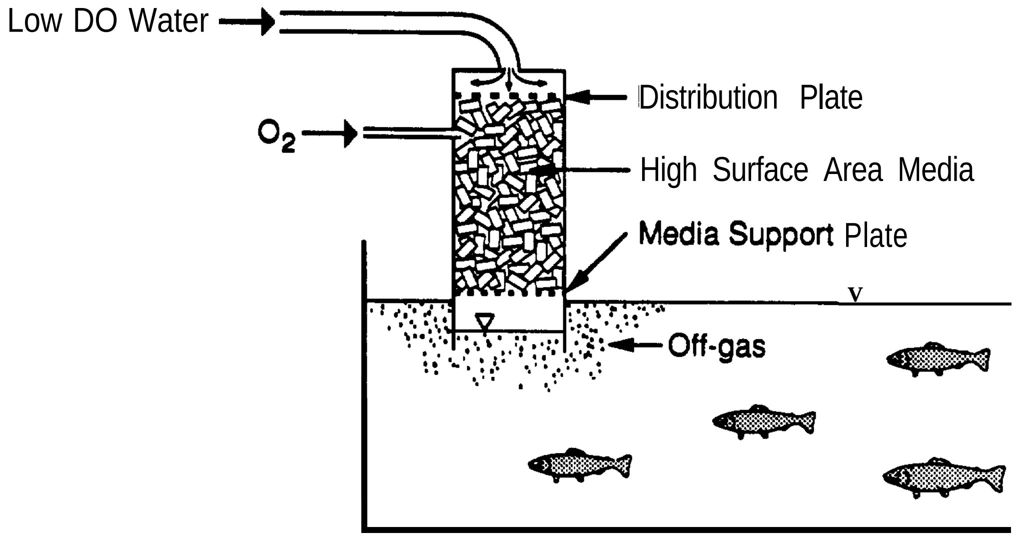


Figure 3 Packed Column

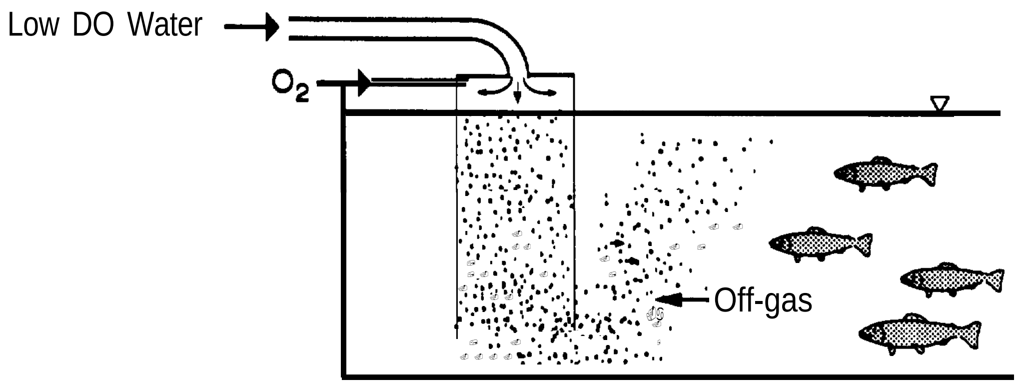


Figure 4 Submerged Spray Column

manner (Figure 5). This cross-flow process approximates an ideal counter-current absorption column and can achieve up to 90% absorption of oxygen gas in 8-12 inches of drop. The compartments may be filled with some type of plastic media, but typically are not.

Direct Iniection of Oxygen into Supply Pipeline In hatcheries with a long supply pipeline (>500 ft), it may be possible to directly inject pure oxygen into the supply line. The absorption efficiency can approach 100%, depending on the length of the line and the maximum line pressure. Absorption efficiencies are probably limited to 80-90% to prevent problems with gas bubble trauma (gas bubble disease). Detailed performance data and design information is largely lacking for this method.

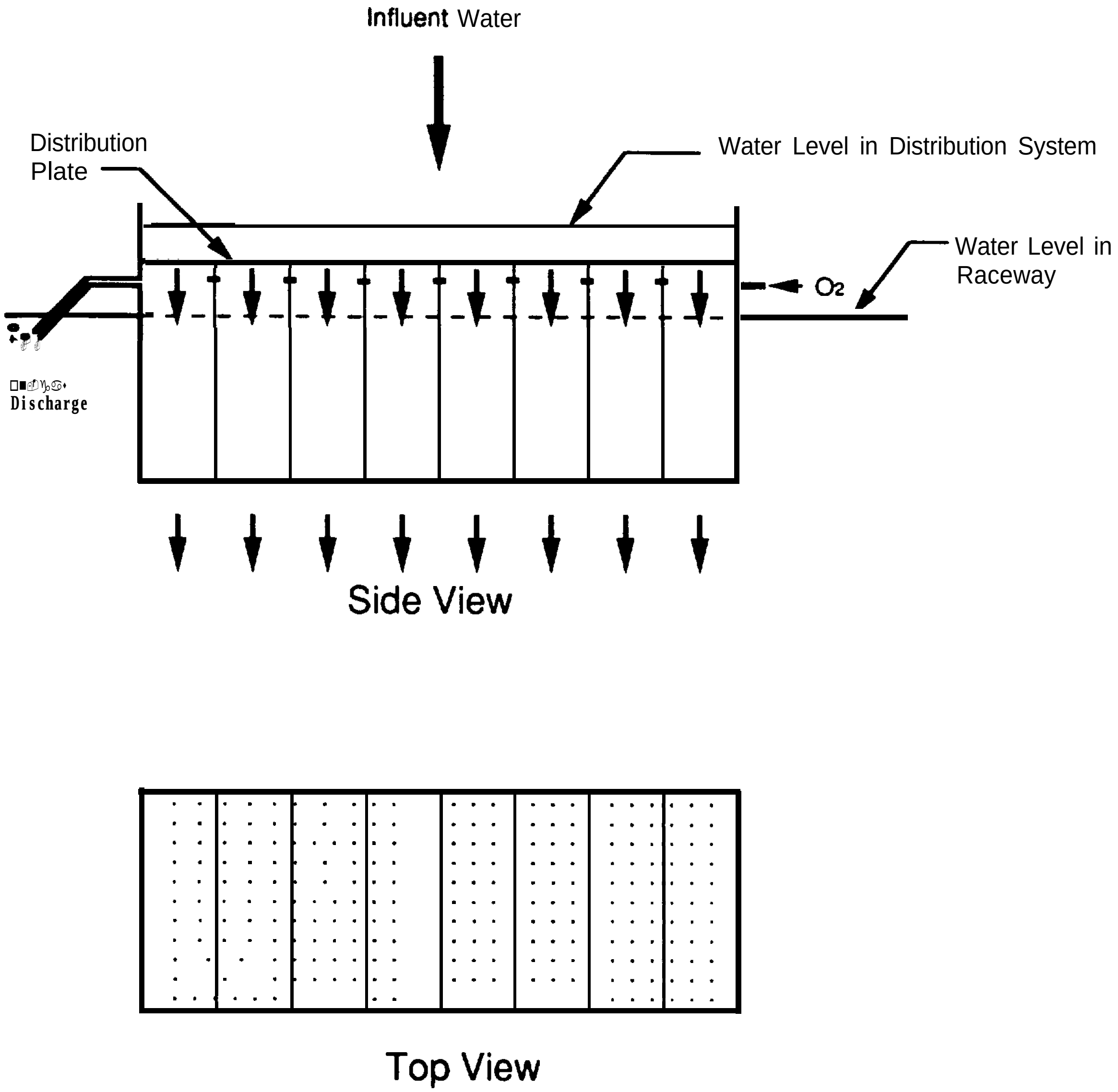
Configuration

Pure oxygen systems may be configured in several different ways. One common configuration is the full-flow configuration, where all of the process water passes through the oxygen absorber system, either single-pass with no reuse (Figure 6a) or with reuse (Figure 6b). Another variation of the full-flow configuration is the series/parallel configuration (Figure 6c). A second type of system is called the side-stream configuration (Figure 6d) where only a portion of the flow is passed through the absorber unit system then is distributed back into the rearing units generally at several locations.

Pull-flow The full-flow configuration has been used when existing hatcheries are retro-fitted with packed column (Westers et al., 1987) or jet aerators (Colt and Westers, 1982). This configuration is ideal for sites with enough head to operate the oxygen system without external power input. The maximum carrying capacity of this configuration is limited by available dissolved oxygen (DO_{in} - DO_{out}), which in turn is limited by either loss of oxygen due to bubble formation or gas supersaturation considerations.

Side-stream The side-stream configuration is much more flexible than the full-flow configuration as the oxygen rich process water can be mixed in at several points to reduce problems with gas supersaturation or bubble formation. Generally, a pressurized packed column is used to produce dissolved oxygen concentrations in the range of 100 - 150 mg/l. Oxygen loss due to bubble formation when the water is distributed back into the rearing units can be a problem and requires use of pipe transitions that gently and rapidly mix the two waters. In production systems, the cost of distribution piping for this type of system may be significant. It is also possible to increase the oxygen capacity of an individual rearing unit by construction of additional oxygen absorption units, something that can not be done with the full-flow configuration.

From disease transmission considerations, the most desirable configurations are the single-pass system (Figure 6a), followed by the reuse systems (Figure 6b,d), and then the series/parallel system (Figure 6c). To reduce disease transmission between rearing units by birds or other predators, a “bird” enclosure may be required for all configurations.



Not to Scale

Figure 5 LHO system

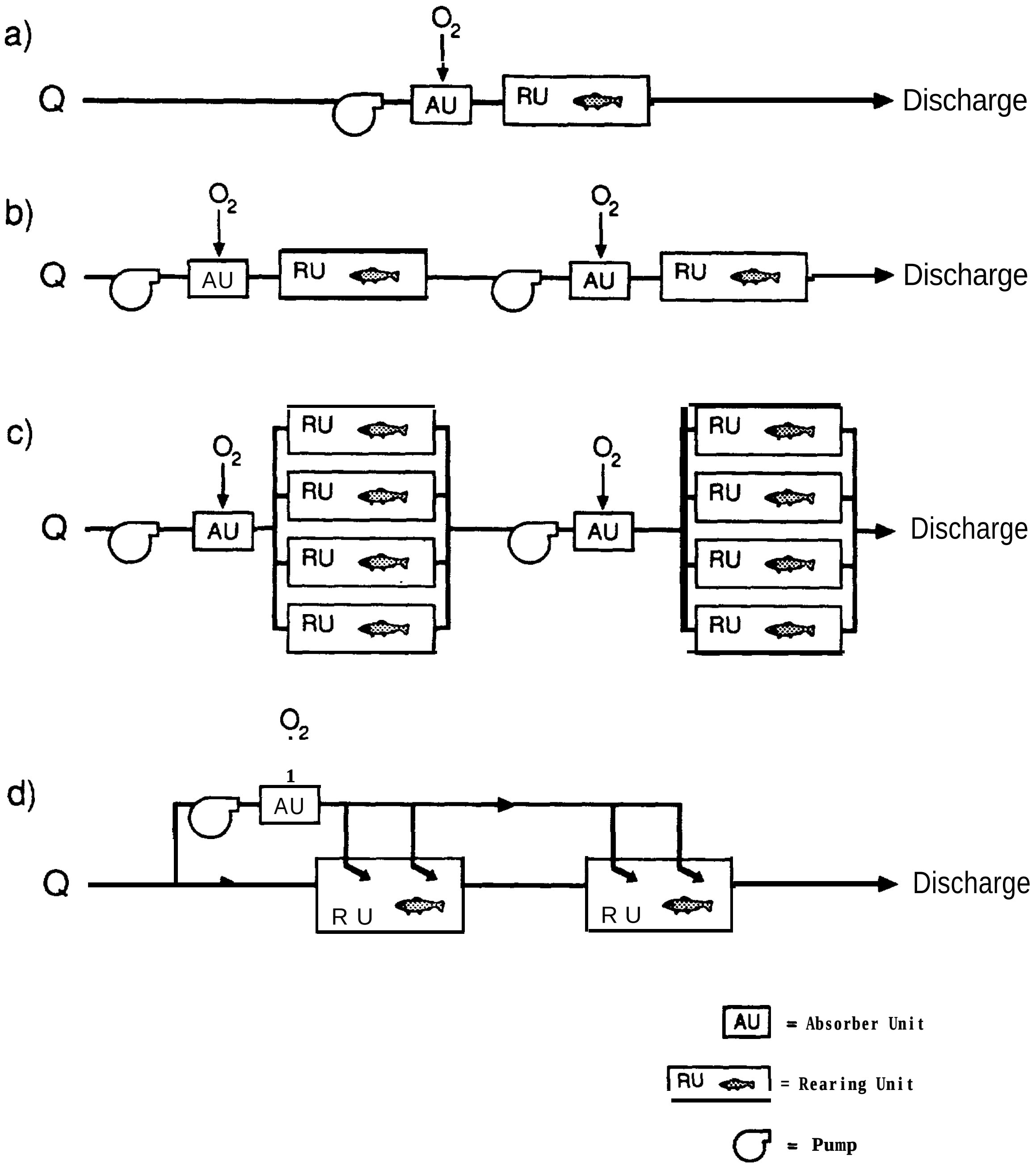


Figure 6 Configuration of pure oxygen systems. (a) Single-pass, full-flow configuration; (b) full-flow configuration with reuse; (c) full-flow, series/parallel configuration with reuse; and (d) side-stream configuration

Process Control Options

The oxygen demand of a production system has a significant diel and seasonal variation. In addition, the oxygen demand from a single raceway or raceway series can change due to the transfer or harvest of fish. The ability to adjust oxygen concentrations to meet temporal or spatial changes in oxygen demand can have a significant impact on the over-all economics of pure oxygen use.

Diel Control The simplest control strategy for diel changes in oxygen demand is to design for the maximum oxygen demand (Figure 7a). This may result in low utilization and absorption efficiencies. Step control (Figure 7b) uses one system to provide base capacity and a second system to provide peak capacity. A more complex control system could increase the ADO (change in DO through the absorber unit) to track the change in oxygen demand (Figure 7c).

Increasing the degree of control over the absorber process will also increase the capital costs for process control equipment and maintenance, and may reduce the over-all reliability of the operation. A simple control system with a lower utilization and absorption efficiency may be more desirable than a complex system with better operational characteristics.

In production systems, the amount of oxygen transfer can be adjusted by changing the water flow (i.e., turning on another pump) or changing the pure oxygen flow rate (G/L ratio). The degree of control will depend on the total number of units on a tank or raceway series and the control characteristics of the individual systems. The step control system is the simplest and most common type of control system. Proportional controls are probably only economic on a side-stream configuration due to the high cost of proportional valves or variable speed motors. The use of either the step change or proportional change will generally require on-line monitoring of dissolved oxygen and computer control.

Total required oxygen capacity may be minimized by staggering the feeding times within each raceway series to reduce the peak oxygen demand following feeding (Figure 7d). This may also have the additional benefit of eliminating the need for continuous DO monitoring and on-line control.

Seasonal Control The control of oxygen transfer for seasonal changes in oxygen demand can probably be made by manual control of pumps and oxygen flow rate on a weekly basis.

Production Units In series raceways or circular tanks with reuse, both the operating characteristics (G/L ratio and system pressure) and the number of units in operation can be used to adjust the amount of available dissolved oxygen. In a centralized side-stream system, it may be possible to adjust the available dissolved oxygen by adjusting the individual side-stream flows.

In production systems, the biomass within individual rearing units may vary by a factor of 5 or more. It will be necessary to design the oxygen absorber unit to supply the maximum value to each rearing unit. It also may be necessary to operate all the rearing units at the maximum rate if the operational staff is unable to adjust G/L ratios

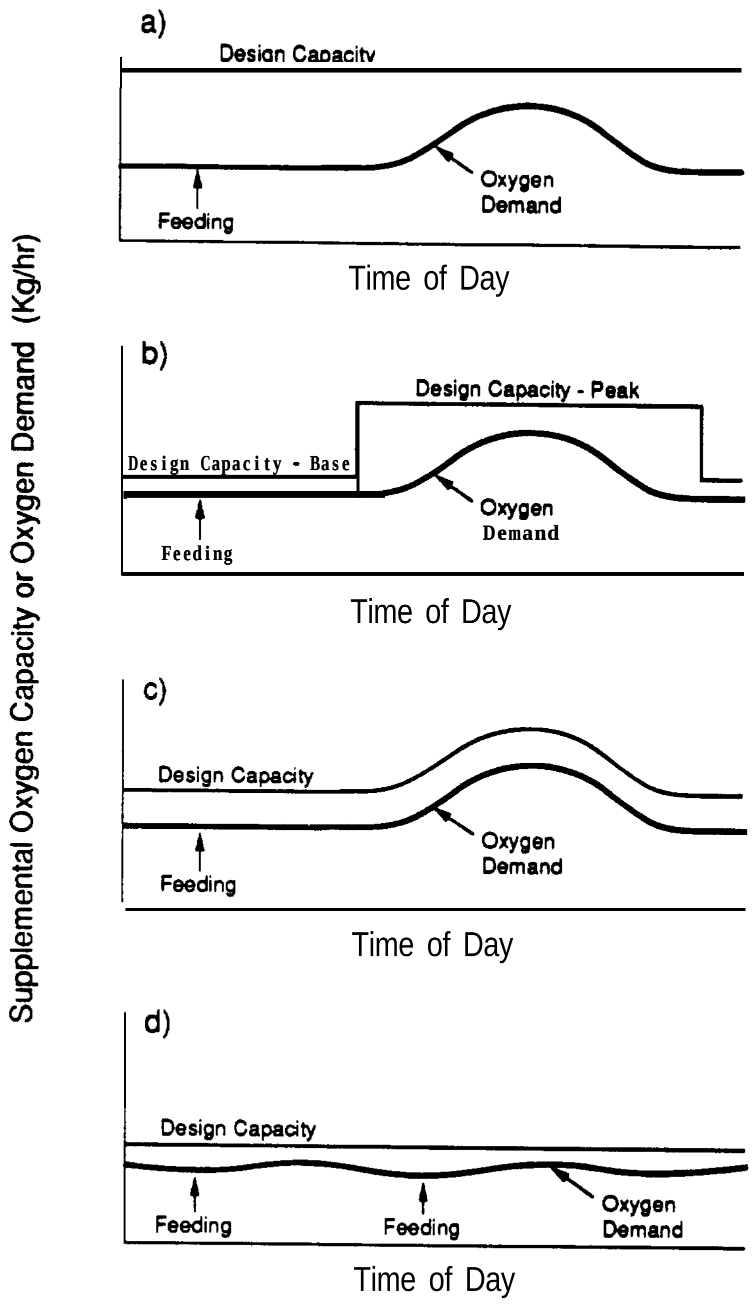


Figure 7 Control strategies. (a) Design for peak demand; (b) step control; (c) proportional control; (d) reduced peak demand

(or other control parameters) on a frequent basis or ensure even distribution of animals within rearing units. This may increase the total oxygen supply capacity by 2 - 3 times over the computed supplemental oxygen requirement for the whole system but greatly reduce operational problems. In this mode, the series/parallel configuration (Figure 6c) may be more desirable than the other configurations (Figure 6a,b,d) as high levels of dissolved oxygen from the lighter loaded rearing units is mixed into the process water, resulting in higher overall dissolved oxygen concentrations to the following absorber units.

Continuous Monitorina and Control

Optimization of pure oxygen requires accurate and continuous information on dissolved gas concentrations in the rearing units (Kuhlmann, 1983). In addition, the feeding schedule and amount can be linked to the dissolved gas concentrations. While computer controlled monitoring systems are highly reliable, the same can not be said for dissolved oxygen probes. Some of the recently introduced models are much more reliable, but all require maintenance on a regular basis.

Ideally, a separate oxygen monitoring probe should be installed in each rearing unit. An alternative is to use a single DO probe at a central site and switch between the different process waters (Kinghorn, 1982). This last option may have reduced capital costs, but requires extensive piping and regular line cleaning to prevent significant oxygen consumption in the piping by bacteria.

While continuous monitoring of DO concentrations may allow optimization of oxygen absorption, it may be prudent to not use on-line control for baseline oxygen requirements, but restrict its use for the variable oxygen requirement. In this manner, failure of the DO probe, DO meter, or control systems will not result in total system failure and total mortality.

Reliability Considerations

Although pure oxygen systems can significantly increase production, major to complete mortality may occur if they fail. Some of the most common failures are presented in Table 3. While good design practices and operating procedures can reduce the incidence of failure, a well-designed alarm system is also needed. At a minimum this would include the following alarms:

Loss of electrical power to site

Loss of water pressure or flow

Differential pressure in oxygen feeder lines

Dissolved oxygen meter in rearing units

These alarms should be connected to a central control panel with audible and visual signals or automatic phone dialers. In many production facilities using pure oxygen, on-site personnel will be required 24 hours a day.

Table 3 Common Types of Failures and Solutions For Pure Oxygen Systems

On-site Generators

Loss of power. Requires standby motor-generator unit plus emergency source of oxygen.

Failure of motor or compressor. Requires backup motor/compressor unit.

Failure of controller or solenoid valves resulting in air rather than enriched oxygen being supplied. May result in oxygen depletion or gas bubble trauma. On-line dissolved oxygen meter can detect this type of failure.

Liquid Oxygen

Impossible to deliver bulk oxygen due to floods, mudslides, or heavy snow. Requires emergency source of oxygen.

Piping

Failure due to rupture, backhoe, or human activity. Differential pressure meters can detect this type of failure. Special care required during construction and fabrication to removal grease and oil.

Regulator

Clogging due to inadequate cleaning or scale formation in pipes. Control panel should allow by-passing of regulator.

Water Supply

Failure of motor/pump or water supply. Requires backup motors/pumps and/or motor generator unit. Pressure or flow alarms can detect this type of failure.

Oxygen Absorber

Poor adjustment of operating water level, oxygen flow, or pressure may result in very low absorption efficiencies. On-line dissolved oxygen meters can detect this type of failure.

Water Quality Criteria in Pure Oxygen Systems

Increasing the intensity of a hatchery results in an increase in the concentration of metabolic wastes such as ammonia, carbon dioxide, suspended solids (fecal solids + uneaten feed), and organic compounds. Therefore, water quality criteria for high intensity culture systems needs to encompass the joint effect of all these water quality parameters simultaneously. Because high levels of one parameter may reduce or increase the toxicity of the other parameters, water quality criteria for high intensity systems may be quite different from those for typical rearing systems. While there may be some uncertainty or questions about the appropriate criteria for a given culture situation or condition, this has little effect on the overall relationships presented in this report. The criteria used in this study is stated at the end of each of the following subtopic reviews.

Oxygen (Minimum)

Based on recent research, the criterion for dissolved oxygen are in the range of 6-7 mg/liter for coldwater fish and 4-5 mg/liter for warmwater fish (Colt et al., In Press). A significantly higher criterion is required for the incubation of salmonid eggs, especially above 10 C (Rombough, 1986). Some of the beneficial effects of high dissolved oxygen concentrations under hatchery conditions may be due to simultaneous stripping of chronic levels of gas supersaturation (Westers et al., 1987).

Oxygen (Maximum)

Based on oxygen toxicity considerations, Colt et al. (In Press) suggested a maximum oxygen partial pressure of 300 mm Hg. Under pond conditions, maximum oxygen levels may be limited by high dissolved gas pressures resulting from photosynthesis and heating (Krom et al., 1989).

Dissolved Oxygen Criterion	(low)	6.5 mg/liter
	(high)	300 mm Hg

Carbon Dioxide (Maximum)

High concentrations of carbon dioxide (hypercapnia) may cause formation of calcareous deposits in the kidneys (nephrocalcinosis). The kidney deposits are composed mainly of calcium phosphate, apatite, and brushite. The prevalence and severity depends primarily on the carbon dioxide concentration and, to a lesser degree, the mineral composition of the diet (Smart et al., 1979). The growth and feed conversion ratios of rainbow trout reared at 12 and 24 mg/liter of carbon dioxide were similar over a 275 day exposure. Fish reared at 55 mg/liter of carbon dioxide showed reduced growth and higher feed conversion ratios, but it was only after about 330 days at this exposure that growth was seriously impaired (Smart et al., 1979).

For salmon and trout, SECL (1983) recommends that the carbon dioxide concentrations should be maintained below 20 mg/liter. This criterion is not strongly based on experimental data and may be conservative especially if the DO is high.

Allowable carbon dioxide levels in the culture of warmwater species is largely lacking, but carbon dioxide concentrations in intensive systems routinely exceed 40-50 mg/liter in pure oxygen systems (Anthonie Schuur, Aquacultural Management Services, personal communication). Rapid changes in carbon dioxide concentrations should be avoided due to the potential impact on blood pH (Colt et al., In Press).

The potential impact of carbon dioxide on pH and ammonia toxicity at the gill surfaces (Lloyd and Herbert, 1960) have not been considered as there is still major uncertainty in this area (Erickson, 1985; Szumski et al., 1982). All criteria are based on concentrations or pressures in the bulk water.

Dissolved Carbon Dioxide Criterion	20 mg/liter

Ammonia (Maximum)

Criterion for ammonia is based on the un-ionized form (NH_3) and should be expressed in terms of nitrogen. The un-ionized ammonia criterion varies from 10-21 μg/liter NH_3-N (Alabaster and Lloyd, 1982; SECL, 1983; USEPA, 1976; Westers and Pratt, 1977). Recent work indicates that gill hyperplasia, a reported characteristic of ammonia toxicity, is probably not caused by unionized ammonia (Meade, 1985) and a reasonable safe concentration for production trout systems could be as high as 40 μg/liter.

Some of the differences between laboratory and production experiments may be related to inappropriate analytical procedures used in the measurement of pH. It is common to measure pH in the laboratory at room temperature. Because of changes in activity coefficients and equilibrium constants, the pH of a water sample will change with temperature (ASTM, 1989). The measurement of pH at a temperature different than the test temperature can produce a small numerical change but highly significant error in pH that can result in major errors in the computation of un-ionized ammonia at the test temperature. The loss of carbon dioxide from the water sample may result in large pH errors, especially under production conditions.

Un-ionized Ammonia Criterion	12.5 μg/liter NH_3-N

pH (Maximum and Minimum)

Criterion for pH may depend on species, life stage, and ionic composition of the water. For incubation and early fry rearing, SECL (1983) recommended that the pH be maintained between 6.5 - 8.5. Because oxygen will only be used for fry and fingerlings, a slightly wider criteria will be used:

pH Criterion	(low)	6.0
	(high)	9.0

Preliminary results at Williamette Fish Hatchery have indicated reduced feeding in the third raceway of a three-pass Michigan system using pure oxygen (Joe Sheahan, Williamette Hatchery, personal communication). Due to the low alkalinities (20-30 mg/L) of the hatchery water, the metabolic carbon dioxide drops the pH of the water by approximately 1 pH unit 3-4 hours after the start of feeding. Even though the pH was equal to 7.00, an acceptable value, the diel change in pH appears to have a significant impact on the fish. It is unknown if these effects are due to the actual change in carbon dioxide concentration or the resulting pH change. An alternative criteria based on a maximum pH change of -0.50 pH unit change will also be used in this report:

Alternative pH Criteria	(low)	-0.50

The alternate criteria is not based on an absolute pH criteria, but limits the daily pH drop resulting from metabolic carbon dioxide production to no more than 0.50 pH units. This criteria is based on the observations at the Williamette Hatchery.

Modeling of Production Capacity Limitations at Umatilla Hatchery

The modeling approach used in this report is based on water quality criteria for critical parameters, metabolic characteristics of fish under production conditions, and basic carbonate chemistry. The specific details of the model are presented in Appendix A.

Water Quality at Umatilla Hatchery

Since the wells for the Umatilla Hatchery are not in service at this time, water samples were obtained from the Irrigon Hatchery on October 10, 1990. Five sites were sampled:

Well water	
Influent to Raceway # 29	(first series)
Effluent from Raceway # 29	(first series)
Influent to Raceway # 30	(second series)
Effluent from Raceway #30	(second series)

The water samples were analyzed by the contractor within 48 hours of sampling. The pH of the water was measured before and after long aeration. Upon aeration, the pH of the waters significantly increased (Figure 8) and indicates that the water is supersaturated with dissolved carbon. Based on the pH before and after aeration, the concentration of carbon dioxide in the water samples ranged from 2.55 - 4.06 mg/L. The mean alkalinity of the samples was 92 mg/L @ $CaCO_3$.

Aeration in the central columns and spray distribution system between the raceways removed a significant amount of carbon dioxide. The increase in carbon dioxide due to fish metabolism was 0.98 and 0.77 mg/L in the first and second series of raceways, respectively (Figure 9). The decrease in pH due to fish metabolism was -0.13 and -0.10 units in the first and second series of raceways, respectively.

Available Dissolved Oxvaen in a Pure Oxygen System

When the influent DO is increased above the atmospheric equilibrium concentration by the use of pure oxygen, the maximum influent DOs are limited to approximately 20.1 mg/L at 13 C because of oxygen toxicity considerations in a raceway system (Figure 10). Higher influent oxygen concentrations can be used in circular tanks due to the mixing characteristics (Colt and Watten, 1988).

The maximum influent DO concentration must also consider total gas pressure and problems with gas bubble trauma (gas bubble disease). The influent total gas

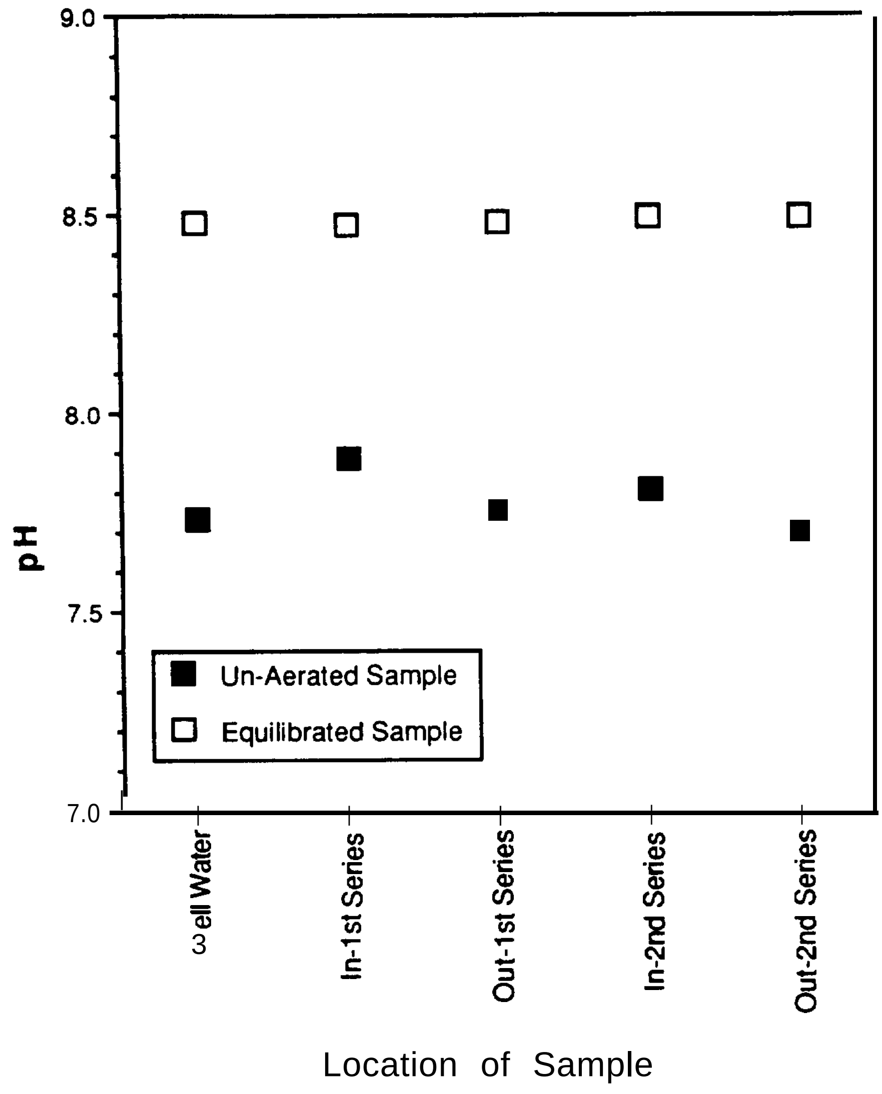


Figure 8 pH of Irrigon hatchery water before and after aeration as a function of location

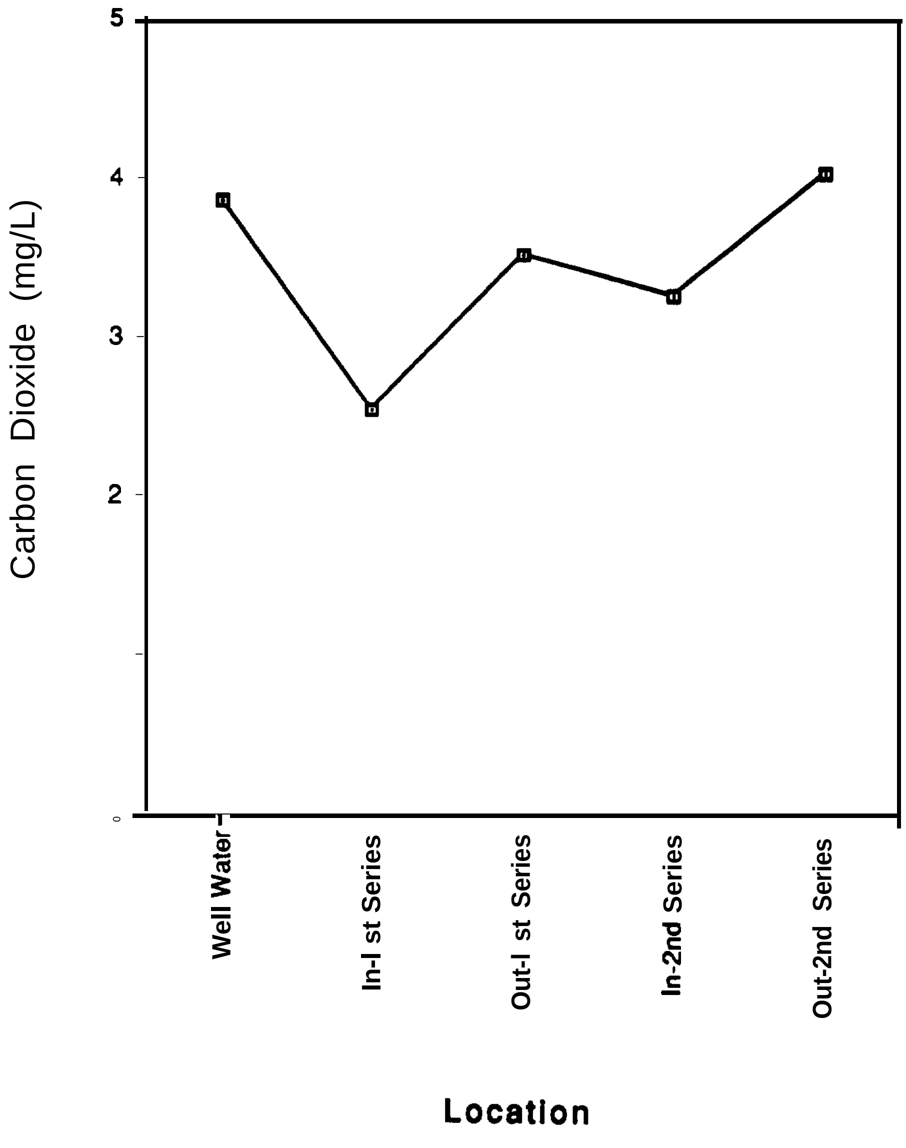


Figure 9 Carbon dioxide concentration in Irrigon Hatchery as a function o l ocation

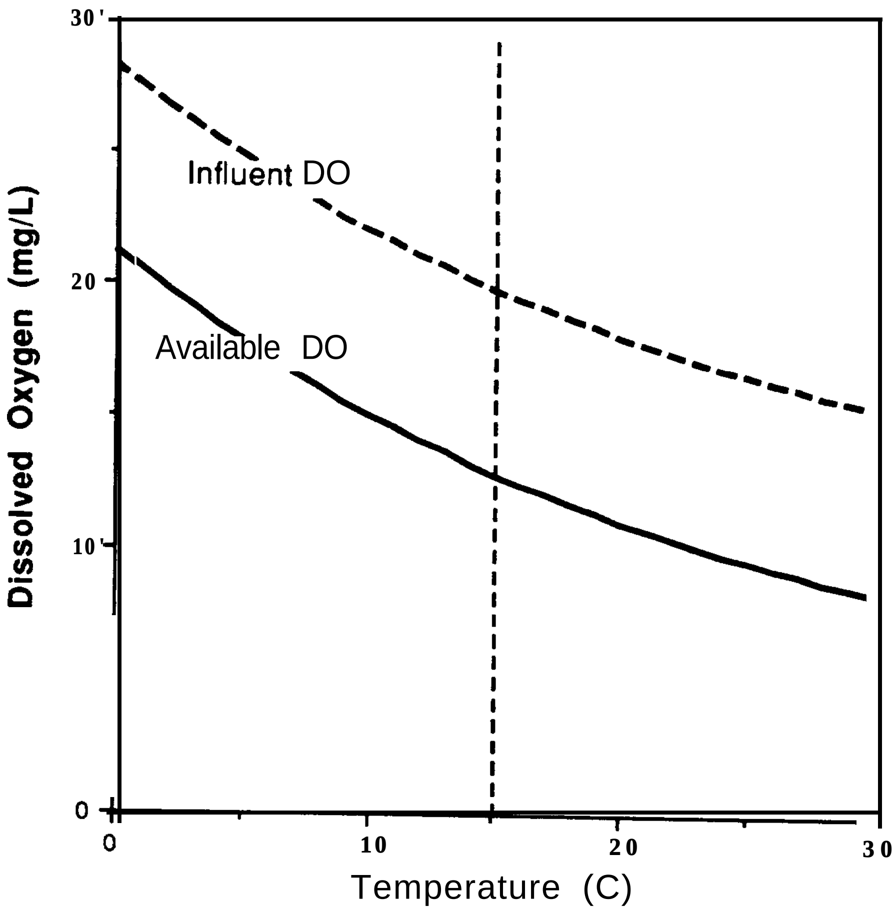


Figure 10 Maximum available DO (mg/L) based on a maximum oxygen partial pressure = 300 mm Hg

pressure will depend strongly on the nitrogen + argon in the source water and the transfer characteristics of the pure oxygen system (Colt and Watten, 1988).

pH

The metabolism of oxygen produces carbon dioxide and results in a reduction in the pH of the culture water. The decrease in pH depends both on the initial influent carbon dioxide in the water and the amount of carbon dioxide added by the fishes metabolism (Figure 11). For the aerated water in Figure 11, it is assumed that the influent carbon dioxide is equal to 2.6 mg/L. This concentration is similar to the influent concentration of carbon dioxide to the raceways at the Irrigon Hatchery. The influent carbon dioxide concentration for the equilibrated sample is equal to the local saturation concentration.

For alkalinity = 92 mg/L and temperature = 13 C, pH will not be limiting if a minimum pH criteria of 6.50 is used. The metabolism of 20 mg/L of oxygen will drop the pH from 8.49 to 6.93 and from 7.96 to 6.89 for the equilibrated and aerated samples, respectively. If the alternative pH criteria of -0.50 pH units is used, only 4.2 and 1.8 mg/L of oxygen can be used for the aerated and equilibrated samples, respectively.

Carbon Dioxide

The amount of oxygen that can be metabolized before the carbon dioxide concentration equals the water quality criterion for carbon dioxide is equal to 13-14 and 16-17 mg/L for the aerated and equilibrated samples, respectively (Figure 12).

Un-ionized Ammonia

If all the metabolically produced carbon dioxide is retained in the water, it is impossible to exceed the un-ionized ammonia criteria for either the aerated or equilibrated samples (Figure 13). If all the metabolically produced carbon dioxide is removed from the water, only l-2 mg/L of oxygen can be metabolized before the un-ionized ammonia concentration of 12.5 µg/L is exceeded.

Overall Production Capacity

Carbon dioxide removal in pure oxygen aeration systems is minimal (Watten et al., In Press) due to the low gas-to-liquid ratios used in these systems. The maximum cumulative oxygen consumption (COC) in mg/L that can be metabolized before each parameter becomes limiting is equal to:

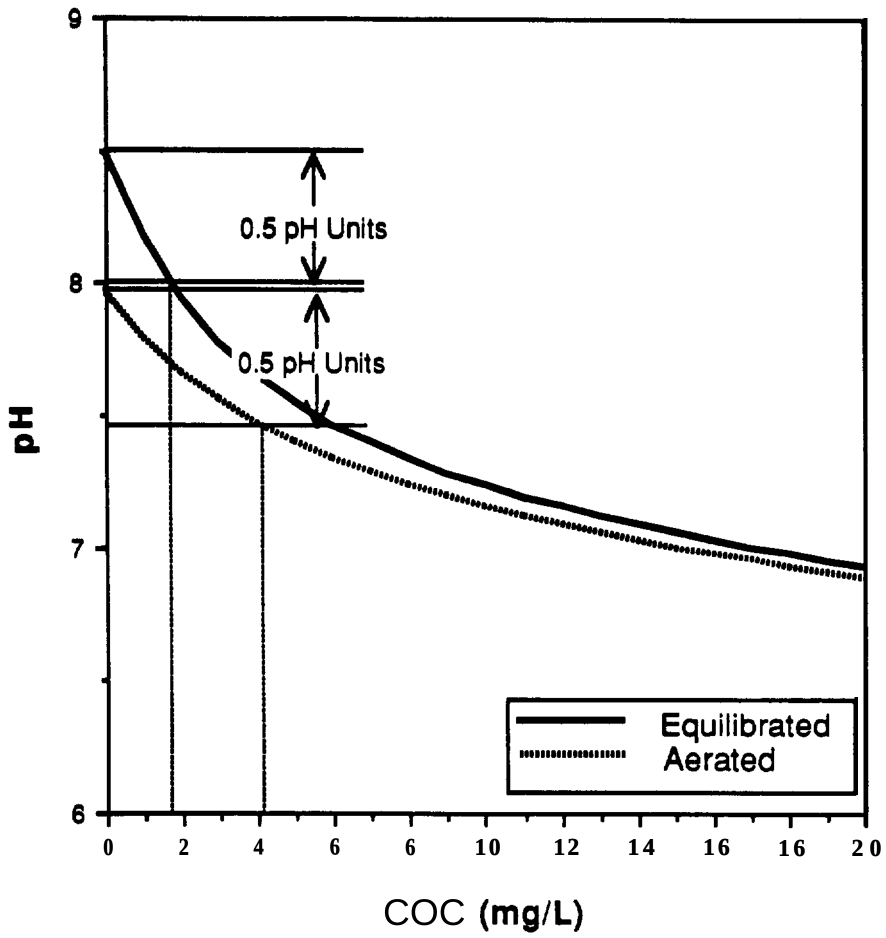


Figure 11 pH as a function of cumulative oxygen consumption. The carbon dioxide concentration of the aerated and equilibrated samples are 2.6 mg/L and saturation. (Assumes no loss of excreted carbon dioxide from the water, alkalinity = 92 mg/L, and water teinperature = 13 C)

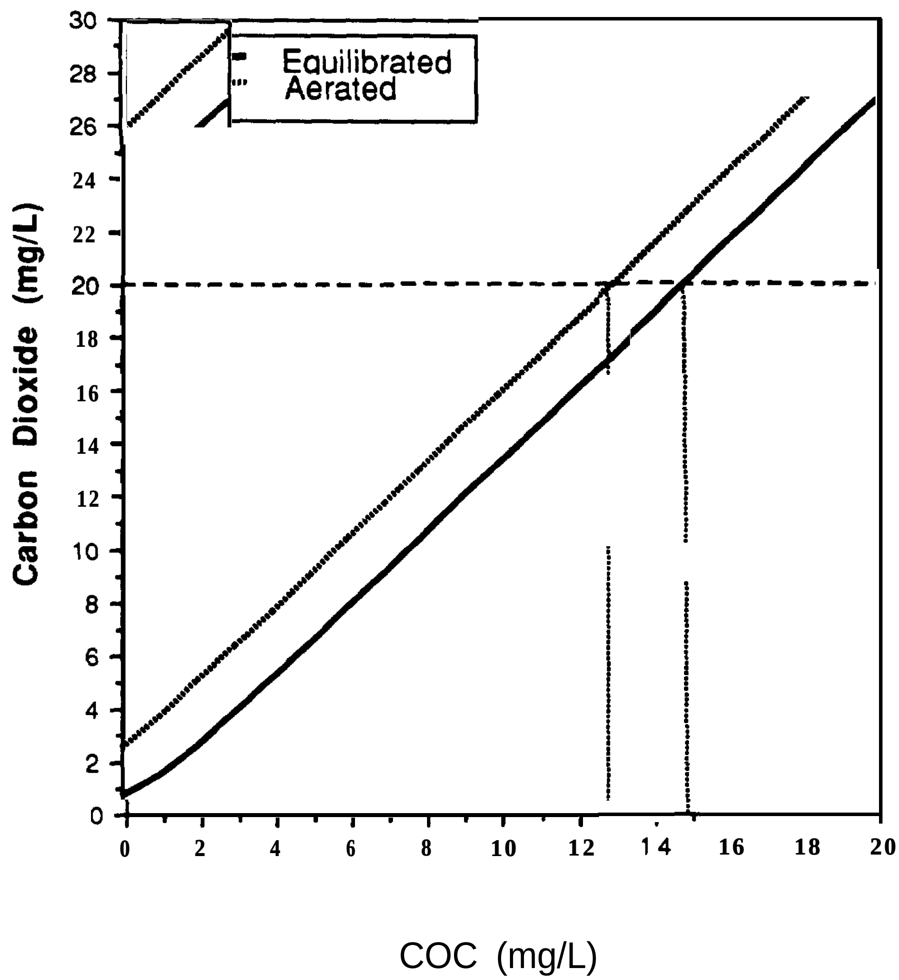


Figure 12 Carbon dioxide concentration as a function of cumulative oxygen consumption. The carbon dioxide concentration of the aerated **and** equilibrated samples are 2.6 mg/L and saturation. (Assumes no loss of excreted carbon dioxide from the water, alkalinity = 92 mg/L, and water temperature = **13 C)**

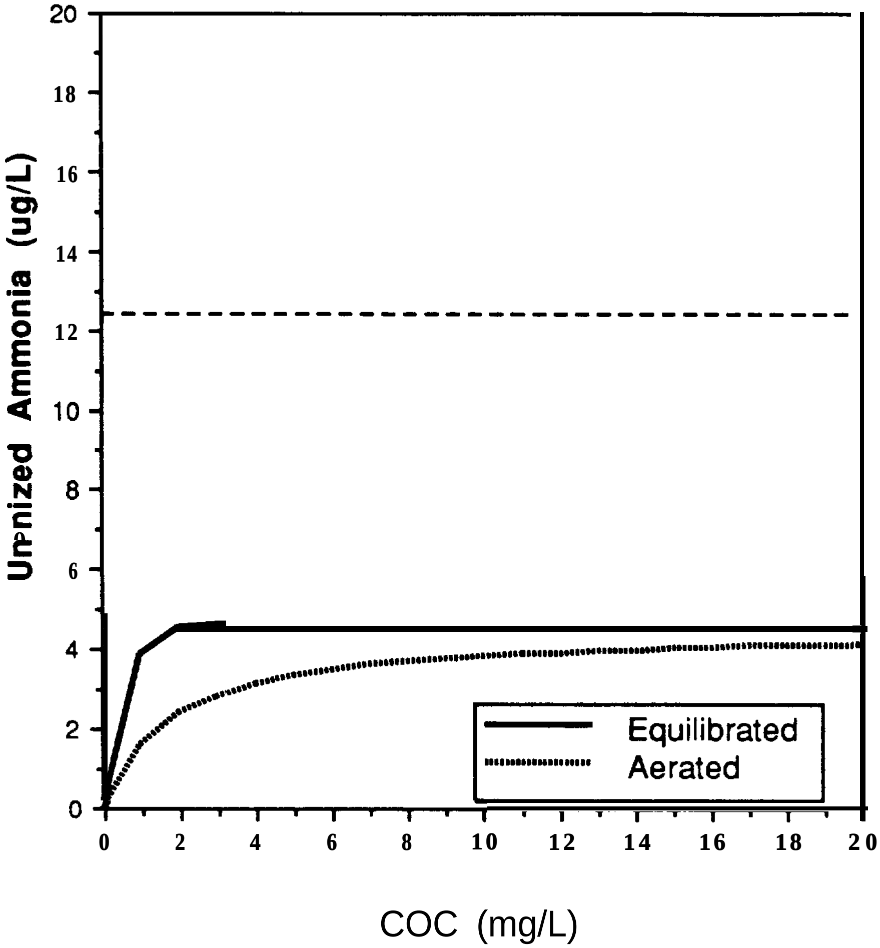


Figure 13 Total ammonia nitrogen and un-ionized ammonia nitrogen concentration as a function of cumulative oxygen consumption. The dashed horizontal line is the maximum unionized ammonia criteria of 12.5 μg/liter NH_3-N. The carbon dioxide concentration of the aerated and equilibrated samples are 2.6 mg/L and saturation. (Assumes no loss of excreted carbon dioxide from the water, alkalinity = 92 mg/L, and water temperature = 13 C)

Parameter	Equilibrated	Aerated
Dissolved Oxygen		
oxygen toxicity[1]	13.7	13.7
gas bubble trauma	variable	variable
pH		
pH (6.00)	>20	>20
pH (-0.50 pH Units)	1-2	4-5
Carbon Dioxide		
carbon dioxide	16-17	13-14
Un-ionized Ammonia		
un-ionized ammonia	>20	>20

1 For a single raceway type unit; does not apply to circular tanks.

The maximum COC in the 3-pass Michigan systems planned for the Umatilla Hatchery range from 9-11 mg/L (Fish Factory, 1990a). Based on the alternate pH criteria of a -0.50 change, the current system will have problems with meeting this alternate criteria. Maximum carbon dioxide production occurs 3-4 hours after feeding and this peak may be up to 1.44 times the mean value. To reduce problems with low pHs, it may be necessary to stagger the feeding times in the different raceways of a given series to reduce peak carbon dioxide concentrations in the second and third raceways.

Because of the sensitivity of this analysis on influent carbon dioxide and pH, these tests should be repeated when the production wells at Umatilla are completed. If the same amount of carbon dioxide is present in the well water, the nitrogen stripping columns must be operated to only remove 34% of the influent carbon dioxide. Control of the gas-to-liquid ratio to the column can be used to modify the carbon dioxide removal characteristics. The removal of too much carbon dioxide in the nitrogen stripping column may result in problems in meeting the pH criteria.

Little quanitative information is available on the degree of carbon dioxide retention in production systems. Detailed documentation on the retention of carbon dioxide in production raceways is needed to further refine production capacity limits.

Efficiency of Existing System

The computation of the oxygen projections are presented in the Task 1 Report (Fish Factory, 1990a). The actual amount of oxygen that must be supplied to the oxygen contactor depends on the amount required by the fish and the absorption . efficiency of the oxygen contact system. The following relationship between AE (absorption efficiency) and ADO (change in DO in the oxygen contactor) was assumed:

$$AE(\%) \quad = \quad 60 - (6)(\Delta DO)$$

This is based on work on similar (but not identical) units at the Williamette Hatchery (Fish Factory, 1990b). There is little published data on the performance of the columns that are planned for use at the Umatilla Hatchery. A significant result of the relationship between AE and ADO is that the absorption efficiency strongly decreases as more oxygen is added:

The overall absorption efficiencies for the two dissolved oxygen criteria cases are comparable:

Parameter	Saturation Criteria	7 mg/L Criteria
Absorption Efficiency (%)	44.8	44.6
Yearly Design Oxygen Requirement (lb)	197,000	86,000

Yearly design oxygen requirements were based on the computed oxygen requirements and a safety factor of 1.25. This safety factor accounts for over-adjustment of the flowrates to the individual raceways and other losses.

The yearly cost of oxygen for the two criteria are presented in Table 4 as a function of absorption efficiency and unit oxygen costs:

Table 4 Yearly oxygen Costs as a function of absorption efficiency and unit oxygen costs

AE(%)	Saturation Criteria				7 mg/L Criteria			
	lb/year	$0.40/ft^3	$0.50/ft^3	$0.60/ft^3	lb/year	$0.40/ft^3	$0.50/ft^3	$0.60/ft^3
existing	197,053	$9,490	$11,863	$14,235	85,563	$4,121	$5,151	$6,181
50	176,520	$8,501	$10,627	$12,752	76,355	$3,677	$4,597	$5,516
60	147,100	$7,084	$8,855	$10,627	63,629	$3,064	$3,830	$4,597
70	126,086	$6072	$7,590	$9,108	54,539	$2,627	$3,283	$3,940
80	110325	$5313	$6,642	$7,970	47,722	$2,298	$2,873	$3,447
90	98,067	$4723	$5,904	$7,084	42,419	$2,043	$2,554	$3,064
100	88,260	$4251	$5,313	$6,376	38,178	$1,839	$2,298	$2,758

Reliability of Existing System

The increased density and loading in the pure oxygen treatments at the Umatilla Hatchery will make the reliability of the components and overall pure oxygen system critically important for the success of the hatchery. The reliability of the oxygen supply system, pumps, contactors, and related equipment are considered.

Monitoring and Control of Dissolved Oxygen

The current design does not include a dissolved oxygen monitoring or control system. The oxygen supply flow to each contactor will be manually adjusted on a daily or weekly interval based on measured dissolved oxygen concentrations in the effluent from the raceways. A portable DO probe would be used to measure the dissolved oxygen.

The oxygen demand computations in this report are based on a peaking factor of 1.44 to account for the increase in oxygen demand following feeding. If the oxygen flow could be dynamically adjusted over the daily cycle, the oxygen demand could be reduced by approximately 20-25%. A number of options could be used to dynamically control the oxygen flowrate such as:

(1) Active sensing of DO in each raceway and adjustment of oxygen flow to individual columns using a proportional controller and valve.

(2) Active sensing of DO in representative raceways and control of pressure in the main distribution line using a proportional controller and valve.

(3) Step control of oxygen flowrate using an off-on solenoid valve and a time switch to provide an increased oxygen flowrate. This type of system could consist of a manually controlled base flowrate, plus two of more solenoid-controlled lines with different flow-controlling orifices.

Given that oxygen costs are not dominate in this application, installation of an oxygen control system to reduce costs is not warranted. There may be other reliability considerations that require active control of oxygen flows to specific contactors. This application will be discussed under the section on Raceway Supply Pump Failure.

Pure Oxygen Supply

The current oxygen supply design depends solely on only 2 compressors and 3 PSA oxygen generators. While the small PSA oxygen generators have developed into a reliable unit, they are not as reliable as a LOX supply, which has only a few moving parts.

The design daily oxygen requirements (Fish Factory, 1990a) for the two effluent criteria cases and PSA oxygen generator capacity are presented below:

Parameter	Saturation Criteria	7 mg/L Criteria
Design Daily O_2 Requirement	2,300 lb/d	1,700 lb/d
Design Daily O_2 Requirement	27,700 ft^3/d	20,500 ft^3/d
Design Daily O_2 Requirement	1,154 cfh	853 cfh
PSA Capacity (3 units on line)	1,000 cfh	1,000 cfh
PSA Capacity (2 units on line)	600 cfh	600 cfh

The current PSA system can not supply the design daily oxygen requirement for the saturation criteria case even with all three generators on-line. The failure of a 400 cfh PSA unit during the peak demand period (design daily oxygen requirement) could result in dissolved oxygen concentrations in the last raceway as low as 3-4 mg/L. Mortality could occur if the PSA failure occurred during the period of maximum daily oxygen demand (3-4 hours after feeding). Additional oxygen generators or a LOX system will be needed to supply the required oxygen. A LOX system is probably the most economical way to increase the oxygen supply. Approximately 111 high pressure oxygen cylinders (250 cf) would be needed to the supply the design daily oxygen requirement (2,300 lb). A 1,500 gallon LOX tank would be needed to supply the design weekly oxygen requirement. A one week supply should allow enough time to repair the compressors or PSA generators. If a reduced degree of reliability can be tolerated, a number of small portable LOX tanks could be used to provide additional oxygen.

Line Power

In the event of the loss of line power, standby power generators are included in the hatchery. This system will be able to power the main hatchery pumps, air compressors for the PSA systems, and raceway pumps. The reliable operation of standby power generators and switch gear is critical to success of the pure oxygen system at the Umatilla Hatchery.

Hatchery Well and Supply Pump Failure

The loss of water to the Michigan and Oregon raceways will result in major mortality of fish even if the raceway pumps and oxygen contactors continue to operate. Backup pumps have been installed in the collector well and the Irrigon Hatchery water supply can be used as a backup for the incubation water supply to the Umatilla Hatchery.

Raceway Supply Pump Failure

The failure of a raceway pump will inactivate the oxygen contact unit for that raceway. Water will continue to flow through the raceways and this is controlled by the main supply pumps and the over-flow weirs. Using the saturation criteria, it is unlikely that the loss of a single raceway pump will result in mortality of fish. For example, for the Summer Steelhead, the minimum effluent DO is 9.67 mg/L and the ADO through the raceway is 3.77 mg/L. The loss of a single raceway pump would reduce the effluent DO in the next raceway to 5.90 mg/L. While DOs below 6-7 are undesirable and potentially stressful, they will not result in mortality. The oxygen requirement models presented in Task 1 are based on peak oxygen demand and therefore represent the highest oxygen demand over the whole day. The oxygen demand during much of the day will be significantly less than this peak value. If the system is operated on the 7 mg/L DO criteria, mortality may occur due to raceway pump failure.

To increase the. reliability of the oxygen supply to the individual raceways, the following should be considered:

(1) Maintain two or more backup pumps on-site with the required equipment to allow one person to remove and replace pumps.

(2) Install a solenoid-controlled “boost” line to each contact unit to increase the oxygen flow to the upstream units when a pump failure is detected in any pumps in a series of raceways. This would require installation of more conduiting for signal and control lines, a second oxygen line to each contact unit, and the associated control and signal equipment.

(3) Install oxygen contact system that can operate with the available head between the raceways.

While difficult to quantify, the reliability of a system with 24 pumps and 48 columns may not be acceptable for the important goals of restoring the salmon runs in the Umatilla Basin. Recent experience with similar pumps at the Williamette Hatchery has shown that reoccurring problems with electrical connections and controllers may occur. This may be due to problems in the installation, wiring, and start-up of the pumps and controllers rather than due to the intrinsic design of the pump itself. While these problems may not occur as frequently as at the Williamette Hatchery, the fish at the Umatilla Hatchery will be placed at serious risk when a raceway pump fails. Serious consideration should be given to modification of the basic design of the pure oxygen system for the Umatilla Hatchery to increase reliability.

Alternative Systems

Type and Location of Alternative Systems

Because of reliability concerns with the existing pumped spray column design, alternative contact systems should be considered. A number of different systems and locations can be used.

Pure Oxygen Column (Degassing Columns) The influent degassing columns (located above the headtank structure) designed to remove nitrogen and add oxygen could be converted to pure oxygen columns with minimal changes. It is theoretically possible (but not recommended) to add enough oxygen at this location to carry the 3-pass Michigan system. It would not be possible to add enough oxygen to carry a 4-pass Michigan system because of potential oxygen toxicity problems. While it may be possible to achieve an absorption efficiency of 60-70%, the effluent DO would be controlled by the raceways with the maximum oxygen demand. The conversion of the stripping columns into pure oxygen columns may limit their use in removing carbon dioxide. It may be useful to experiment with this approach and it is recommended that an oxygen supply line be extended to the degassing columns area.

Direct Iniection into Supply Line Due to the lack of significant head and distance between the stripping column and the raceways, this approach is probably not feasible at the Umatilla Hatchery.

Conversion of a Sorav Column to a Packed Column (first Series) Packed columns typically have absorption efficiencies larger than spray columns. Packed columns can not be used in a reuse system because of fouling and clogging. The first column of each raceway series could be converted to a packed column, increasing the absorption efficiency from approximately 45 to 60%.

Modification of Existing Sorav Columns The discharge diameter from the existing columns is the same diameter as the column. Therefore, the pressure within the column will be close to local atmospheric and the water level within the column will be controlled by the water level in the raceway. Because most of the gas transfer is occurring in the water column within the column, the transfer characteristics of this column may be improved by extending the column further down into the water column. A six inch clearance between the bottom of the column and raceway is needed to prevent excessive backup pressure on the column. This modification of the column is recommended and, if changed before fabrication, will be very inexpensive.

Low Head Oxygenator (LHO) The Low Head Oxygenator system (LHO) manufactured by Zeigler can be installed in the existing Michigan raceways. This system could operate without the use of the raceway pumps. It is estimated that the capital cost of installing the LHO system is $65,000. This includes $60,000 for the actual LHO (24 units) and $5,000 for additional piping, fittings, and valves. The capital cost of the LHO units is based on the purchase of 24 units at one time. If the order is divided into more than one order, the total price will be higher than $60,000. It has been assumed that the LHO systems would be installed by the hatchery staff and therefore no labor costs have been included. Installation of these units should be relatively simple and straight-forward.

The annual operating cost for the LHO system is estimated to be $7,100 compared to $27,100 for the existing pumped column system (Table 5):

Table 5 Annual Operating Costs for the Pumped and LHO Systems

Component	Pumped System	LHO System
Pumping	$10,481	----
TDH = 8 ft Q= 1000 gpm E=60% $0.07/Kwh		
O & M	$4,800	$1,200
Oxygen Costs	$11,859 (44.8% AE)	$5,904 (90% AE)
$0.50/100 cf Saturation Criteria		
Total Annual Costs	$27,100	$7,100

This annual operating cost does not include equivalent uniform annual cost of the capital items or the present worth of the annualized items. The absorption efficiency of the LHO system is significantly larger than the existing spray columns, although this has little impact on the economics of the two systems. The real advantage of the LHO is that it eliminates the need for the 24 pumps, motor controllers, conduits, wiring and reduces the size of the mechanical space and standby generator unit. The elimination of these items could have greatly reduced the costs of the Umatilla Hatchery and increased its overall reliability if incorporated during the design phase. At this time, these items have been purchased and should be considered as sunk costs.

The only additional modifications to the existing Umatilla design would be the installation of tees and valves on the existing oxygen supply line, installation of feeder lines to the individual LHO units, and connection of the oxygen supply hose to feeder lines. The LHO units can be mounted with brackets on the stoplogs and are easily removable. If necessary, a rigid support bracket can be installed between the bottom of the unit and raceway surface to support the bottom of the unit.

Detailed information on the installation of the LHO system in Raceways l-3 is presented in Figure 14 and Table 6. Similar layouts could be used on the other raceway series. This design is based on raceway water depth of 2.25 feet at the front of the raceway, water depth of 2.75 feet at the end of the raceway, 3 inches of water on the distribution plate, 0.28 feet of head loss between raceways, and a resulting 1.47 feet of available fall for the LHO system. The units would be mounted in the front of Raceway 1, rear of Raceway 1, and the rear of Raceway 2. The installation of the LHO in the front of Raceway 1 would reduce the useable raceway volume. With 1.47 feet of available fall for the LHO, the freeboard on the front of Raceway 1 is only 0.28 feet compared to 2.00 feet for the other locations. it may be necessary to reduce the available head to increase the freeboard at this location.

Recommended Alternative System

Serious consideration should be given to retrofitting the Umatilla Hatchery with the LHO system. This would improve the reliability of the pure oxygen system as well as reduce the annual operating costs of the hatchery. It is important to point out that the installation of the LHO system would not prevent the use of the existing pumped system.

Because the design of Umatilla Hatchery has been completed and construction is well underway, it may be prudent to test the LHO system at the near-by Irrigon Hatchery prior to full-scale modification at the Umatilla Hatchery. This would allow testing of the LHO system under production conditions similar to the Umatilla Hatchery.

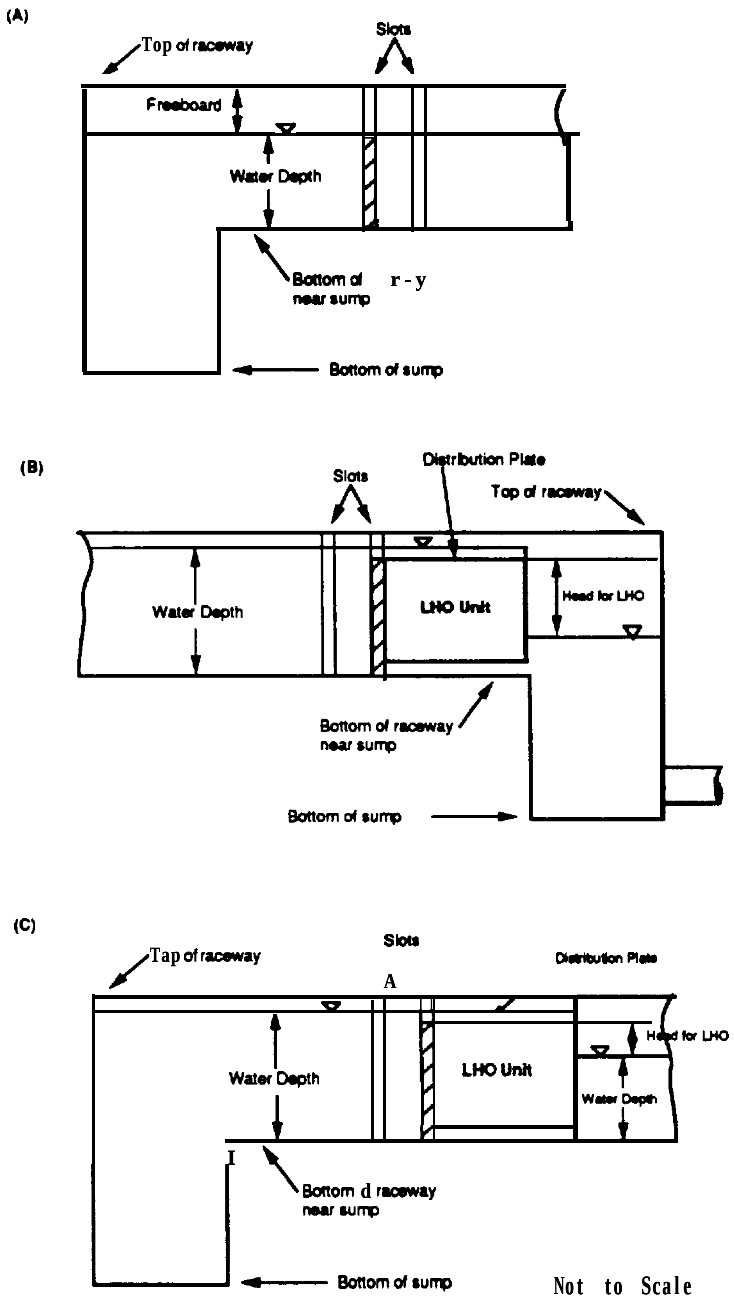


Figure 14 Sketch of Low Head Oxygenator (LHO) installation in existing raceways (a) Side view of the front of ponds 2 & 3, (b) Side view of the rear of ponds 1 & 2, and (c) Side view of the front of pond 1

Table 6 Elevations and dimensions for the installation of the LHO system in the existing raceways

Location I Pond	Elevation Above 200 feet Datum					Raceway Water Depth (ft.)	Freeboard (ft.)	Depth of Water on Distribution Plate (ft.)	Available Head for LHO (ft.)
	Bottom of Sump	Bottom of Raceways near Sump	Distribution Plate	Water Elevation at Sump	Top of Pond				
Front / 1	73.50	77.75	—	81.72	82.00	2.25	0.28		—
Front / 1 after LHO	—	77.72	81.47	80.00	82.00	2.28	2.00	0.25	1.47
Rear / 1	74.50	77.25	—	80.00	82.00	2.75	2.00	—	—
Rear / 1 after LHO	74.50	—	79.75	78.28	82.00	—	—	0.25	1.47
Front / 2	71.50	75.75	—	78.00	80.00	2.25	2.00		—
Rear / 2	72.50	75.25		78.00	80.00	2.75	2.00		—
Rear / 2 after LHO	72.50	—	77.75	76.28	80.00	—	—	0.25	1.47
Front / 3	69.50	73.75	—	76.00	78.00	2.25	2.00	—	—
Rear / 3	70.50	73.25	—	76.00	78.00	2.75	2.00	—	—

Conclusions and Recommendations

An assessment of the oxygen contactors and oxygen supply system (henceforth called "existing design") currently planned for installation at Umatilla Hatchery resulted in findings that would improve efficiency, reliability, or other operations. The existing design was then compared against other potential methods and locations of oxygen delivery, including the Zeigler LHO unit. The evaluations made in this project have tried to identify design adjustments that might be less expensive to perform now, as construction proceeds, to increase efficiency and reduce O&M complexity and related costs. The overall recommended oxygen injection method reflects considerations of cost, timing, efficiency, and reliability.

Because construction is well underway on the Umatilla Hatchery, recommendations will be classified into three groups: (1) changes needing immediate action, (2) changes that can be implemented after construction is finished, and (3) changes that can be deferred until after the system is operating.

A. Changes Needing Immediate Action

The following recommendations are time-critical and need immediate action for inclusion into the current construction phase.

(1) Addition of 1500 gal LOX tank and vaporizers.

(2) installation of conduiting between contactors to allow automatic control of gas-to-liquid ratio.

(3) Extension of the spray column further down into the water to increase absorption efficiency.

(4) Maintain two or more raceway backup pumps on-site with the required equipment to allow one person to remove and replace pumps.

(5) Add oxygen supply lines for the degassing columns and to the end of each raceway (needed to allow potential installation of LHO units).

(6) Test the LHO system at the lrrigon Hatchery.

B. Changes That Can Be Implemented After Construction Is Finished

(1) Depending on the results of the testing program at the lrrigon Hatchery, give serious consideration to the installation of the LHO system at the Umatilla Hatchery. Retrofitting the Umatilla Hatchery with the LHO could improve the reliability of the pure oxygen system as well as reduce the annual operating costs of the hatchery.

(2) Install a solenoid-controlled "boost" line to each contact unit to increase the oxygen flow to the upstream units when a pump power failure is

detected. This modification is more important if the current spray columns are retained.

C. Changes That Can Be Deferred Until After The System Is Operating

(1) Document the performance of the existing spray columns.

(2) Document the dissolved carbon dioxide concentration in the water supply for the hatchery.

(3) Document the impact of carbon dioxide retention in the degassing columns on pH changes.

(4) Evaluate the impact of feeding on pH changes.

(5) Evaluate conversion of the first column of each Michigan raceway series to a packed column.

(6) Evaluate conversion of the degassing columns to pure oxygen column.

Items 5 and 6 should be considered if the current spray columns are retained.

Acknowledgments

We would like to thank Joe Sheahan, Drew Schaeffer, Mike Stratton, and Wade Bergerson for help and assistance during this study.

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Appendix A - Modeling of the Impact of Carbon Dixode

The modeling approach used in this work is based on water quality criteria for critical parameters, metabolic characteristics of fish under production conditions, and basic carbonate chemistry. The specific details of the modeling are discussed below:

Equilibrium pH

pHs of the **influent** water are discussed in terms of their equilibrium pH (pH_e) with atmospheric carbon dioxide. For a given pH_e, the corresponding alkalinity (Alk_e) and total carbonate concentration (C_{Te}) can be computed directly from the definition of alkalinity (Stumm and Morgan, 1981):

$$[Alk_e] = \frac{C^*}{\alpha_1}(\alpha_1 + 2\alpha_2) + [OH-] - [H+] \qquad (1)$$

$$C_{Te} = \frac{C^*}{\alpha_1} \qquad (2)$$

Where:

$[Alk_e]$ = Alkalinity (eq/liter) corresponding with pH_e

C^* = Equilibrium concentration of carbon dioxide (mol/liter)

C_{Te} = Total carbonate concentration (mol/liter) corresponding with pH_e

α_1 = Mole fraction of bicarbonate ion (HCO_3^-) (dimensionless)

α_2 = Mole fraction of carbonate ion (CO_3^{-2}) (dimensionless)

[OH-] = Concentration of OH- (mol/liter)

[H+] = Concentration of H+ (mol/liter)

Non-ideal corrections to Equations 1 and 2 were based on the Davies equation (Stumm and Morgan, 1981). Ionic strength was computed from electrical conductance (Clesceri et al., 1989):

$$\mu = (1.6 \times 10^{-5})(EC) \qquad (3)$$

where

μ = Ionic strength (mol/liter)

EC = Electrical conductance (µS/cm)

All computations are based on an EC of 200 µS/cm, 13 C, and an elevation of 270 feet.

pH after Carbon Dioxide Addition

The final pH after addition of carbon dioxide was computed from a trial and error solution of the following equation (Stumm and Morgan 1981):

$$[Alk'] = C_{T'}(\alpha_1 + 2\alpha_2) + [OH^-] - [H^+] + (\alpha_{NH3})(TAN) \quad (4)$$

Where;

[Alk'] = Final alkalinity after carbon dioxide addition, $Alk_e + \alpha_{NH3}TAN$ (eq/liter)

$C_{T'}$ = Final CT after carbon dioxide addition, $C_{Te} + \Delta CO_2$ (mol/liter)

ΔCO_2 = Amount of excreted carbon dioxide (mol/liter)

α_{NH3} = Mole fraction of un-ionized ammonia (dimensionless)

TAN = Total ammonia nitrogen (mol/liter)

All values of alkalinity and total carbonate concentration (C-r) are reported in meq/liter or mmol/liter, respectively and alkalinity may be converted to practical units by:

$$\text{Alkalinity as } CaCO_3 = \text{Alkalinity (meq/liter)} \times 50.0 \quad (5)$$

The source of the equilibrium constants and physical constants used in this article are listed in Table A-l.

Production of Metabolic Bv-Products

The consumption of oxygen and production of metabolic by-products is proportional to feed consumption (Haskell, 1955; Willoughby, 1968). The production values used in this work are presented in Table A-2.

Table A-l Equilibrium Constants

Parameter	Equation	Reference
pK_1	First dissociation of $H_2CO_3^*$	Plummer and Busenberg, 1982
pK_2	Second dissociation of $H_2CO_3^*$	Plummer and Busenberg, 1982
pK_w	Equilibrium constant for water	Loewenthal and Marais, 1978
pK_a	Equilibrium constant for ammonia	Emerson et al., 1975
C^* for 02	Saturation concentration	Benson and Krause, 1980
C^* for co2	Saturation concentration .	Weiss, 1974
P_{wv}	Water vapor pressure	Green and Canitt, 1967
BP	Barometric Pressure	Colt, 1984 (Equation 12)
X	Mole fraction of CO2 in atmosphere (≈0.000350 in 1990)	Machta, 1983

Table A-2 Metabolic functions based on feed consumption

Parameter	Production (kg/kg feed)		References
	Range	Value Used	
Oxygen	-0.20 to -0.28	-0.25	Hogendoorn, 1983 Willoughby, 1968
Carbon Dioxide	0.26 to 0.39	0.34	Kutty 1968
Total Ammonia Nitrogen	0.026 to 0.032	0.030	Westers & Pratt, 1977