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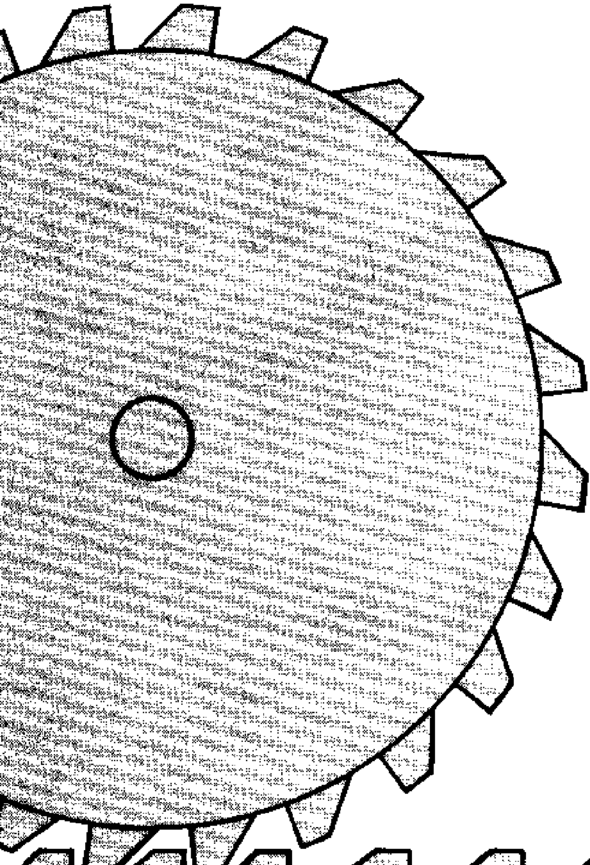

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A Production Cost Analysis of Closed System Culture of Salmonids

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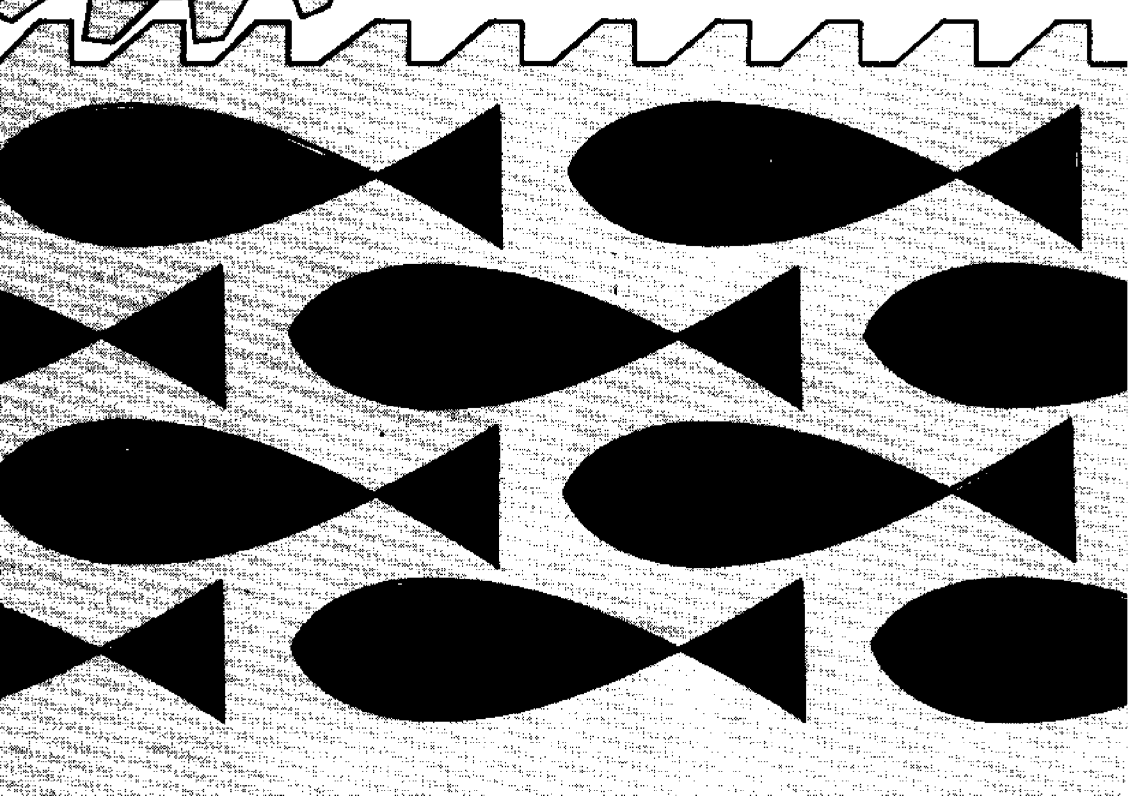

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Additional copies are available from the Marine Advisory Service, University of Rhode Island, Narragansett Bay Campus, Narragansett, Rhode Island 02882. Copies of *The Technology of Closed System Culture of Salmonids,* Marine Technical Report 30, by T.L. Meade, also are available for $1 each from the Marine Advisory Service. Please make checks payable to the University of Rhode Island.

Kingston 1975

With the growing shortages of resources, particularly land and water, the time to consider the water reuse concept for fin fish aquaculture is here. The technology has been proven, but well recognized is the lack of "hard" cost data associated with constructing and operating an intensive, closed-cycle system. Without such data, determining likely profitability is nearly impossible.

This report presents cost data for a model commercial salmon culturing operation with the capacity to produce about 1 million smolts at a cost of about 10 cents each. An initial investment of about $250,000 includes one year's operating expenses. This model, the authors believe, is the minimum size to be economically feasible. Adaptations, however, should be considered on an individual basis.

Moreover, the state-of-the-art of culturing technology at the time of this study dictated a 40-week production cycle. Individual approaches to making the operation year-round should be considered—from using smolts for input into a larger grow-out facility to becoming involved in a release program.

Systems Design and Operation

The facility selected for this study consists of two culture systems. One is used in hatching the eggs and growing the fingerlings to a size suitable for stocking into the other, where they are grown to smolts. Both the fingerlings and the smolts are held in silos.[1]

The hatching and fingerling development system accommodates 1,088,000 fingerlings at 400 per pound or about 2,719 pounds of total biomass with a stocking density of 2 pounds per cubic foot. Based on 30 percent mortality to the smolt size, 1,242,868 eggs are required. For the smolt system, the maximum capacity is approximately 435,000 smolts at 10 per pound or 43,500 pounds of biomass, based on a stocking density of 4 pounds per cubic foot of tank capacity and 30 pounds per gallon-per-minute flow. The tanks in both systems are paired in stepped series with one tank placed 12 inches higher than the other. This is done to use gravity to help circulate water through the system.[2]

The culture water is treated to remove ammonia.[3] Ammonia oxidation takes place in the main filter where autotrophic bacteria convert ammonia to nitrate (nitrification). Nitrate in turn is removed from the culture water as a gas by the denitrification process.

The nitrification filters are circular with conical bottoms to facilitate solid waste (sludge) removal. Any solid matter entering the filters through the water settles to the bottom and is periodically pumped to the wastewater area for further settling and chemical treatment. As with nitrification, denitrification capacity is based on maximum biomass loading in pounds of fish. Denitrification is accomplished after the eggs have hatched and for as long as the fish are actively feeding through the smolt stage.

Water is circulated through the fingerling and smolt culture systems at constant rates of 325 gallons per minute and 1500 gallons per minute, respectively. For flushing solids from the culture tanks, a vertical velocity is required of 1.3 feet per minute, or 275.4 gallons per minute for the fingerling system and 1100 gallons per minute for the smolt system. Each set of tanks is flushed separately on an alternating basis and is controlled automatically.

Water is maintained at 55°F (± 2°) except during a period of slowed growth during which the water is maintained at 45°F (± 2°). A single 20-ton refrigeration unit with two evaporators serves both systems. It is necessary to heat the culture water during the cold months.

Feeding is accomplished automatically by electrically operated feeders. One is suspended above each tank, and is supplied from bulk storage bins.

To minimize the risk of high mortality due to ammonia toxicity resulting from a loss of electrical power, both systems include backup water circulating pumps driven by air-cooled, butane-converted engines which are installed for manual or automatic operation. During emergency operation, all tanks in each system are provided equal water flows. In addition, oxygen flows are increased and feeding is discontinued. If an electric power loss is experienced during a period in which refrigeration of the culture water is necessary, more of the cooler ground water is circulated through the systems to help maintain optimal temperatures. Incoming water is pumped to a water storage tank. There is also an emergency system for supplying water to the storage tank. The same types of pump and engine are used as those installed in the smolt system for emergency operation. All water going into the culture systems is sterilized to prevent the introduction of harmful bacteria or fungi. Also, the pH, ammonia, nitrate, and nitrite concentrations are checked regularly and kept below certain established harmful levels.

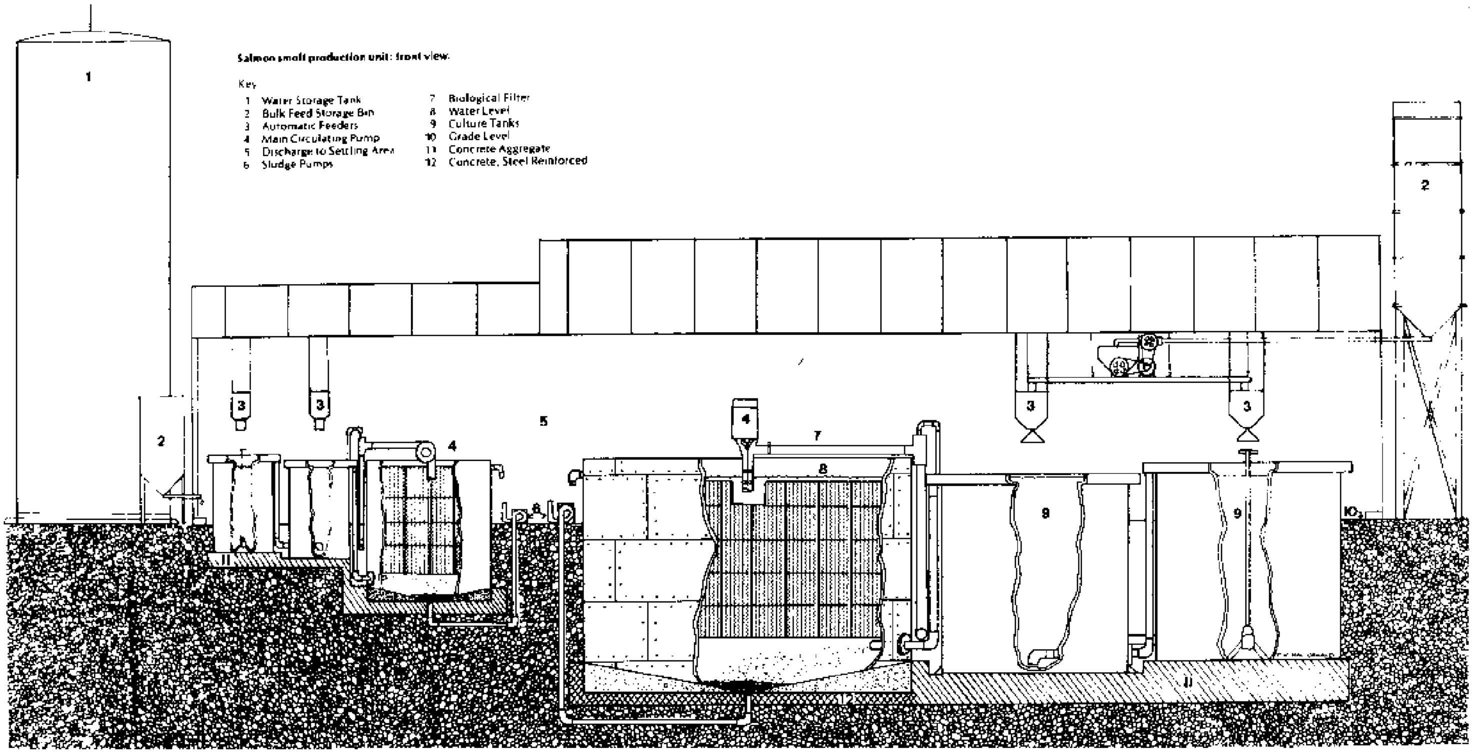
Both culture systems are set in the ground on concrete slabs for two important reasons: (1.) less expensive, thin-walled tanks are used, and (2.) such thin-walled construction allows the relatively constant year-round soil temperature to aid in maintaining system temperatures. In addition, the entire facility is housed.

The wooden-frame building has aluminum siding and an aluminum roof. The entire facility, including the building, storage tanks, two wastewater settling ponds, roads and walks, occupies less than one acre.

Production Processes

To begin the production cycle of 270 days the arriving eggs are distributed equally on eight hatching screens, one for each fingerling tank. After the eggs have hatched (day 15), the water temperature is raised to accelerate growth. (All time estimates are approximate.) Once the fry go on feed, they are fed all they will consume. When the fingerlings have grown to the appropriate size and the maximum biomass loading of 2719 pounds is reached (day 75), one-half are transferred to the smolt system. The remainder are held at 45°F (± 2°) to slow their growth as much as possible without harming them. The fingerlings in the smolt system are fed at a rate which produces the maximum rate of growth and diminishes over time, beginning at about 3.5 percent of body weight per day and decreasing to less than 2 percent per day.

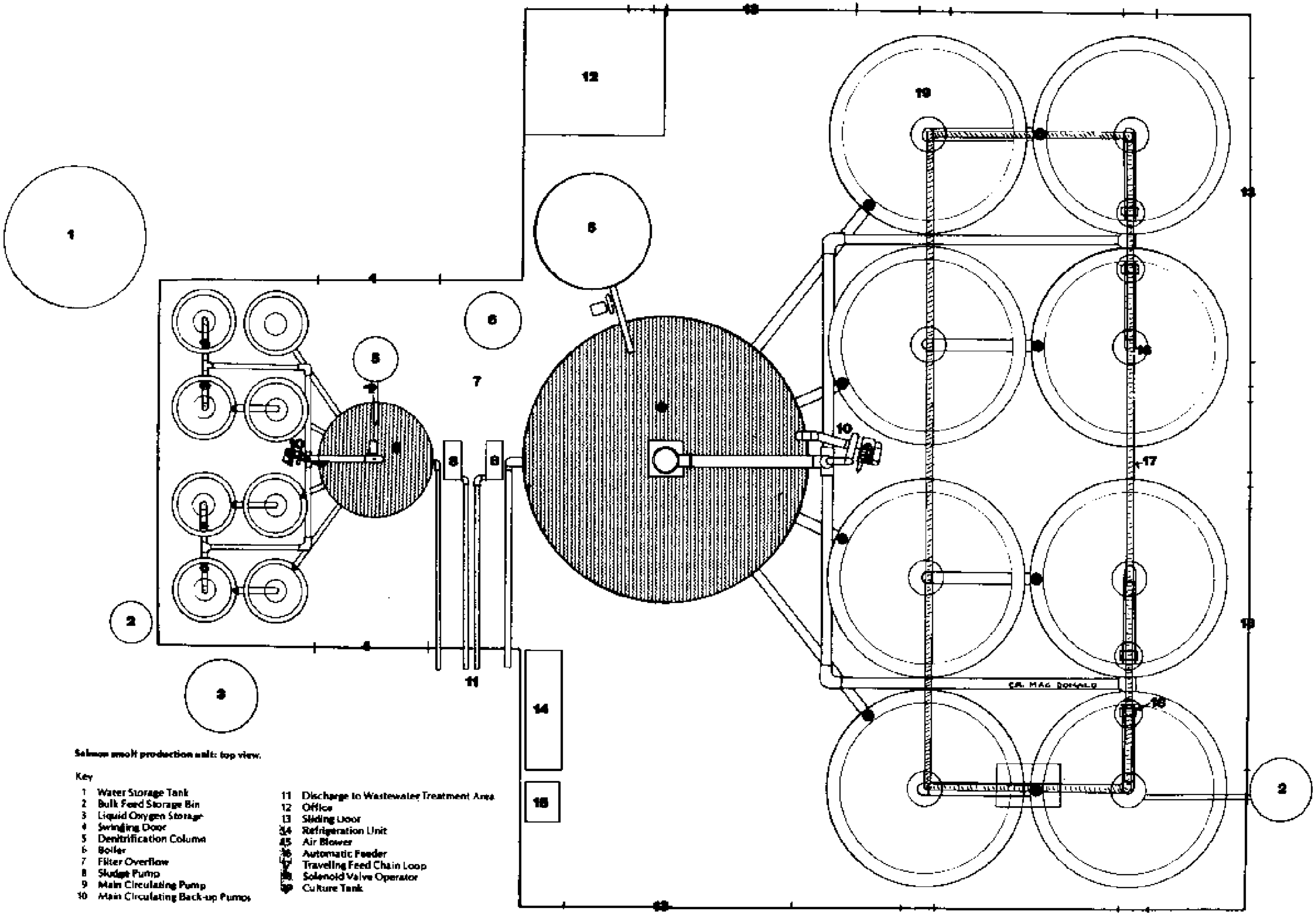
At a predetermined time before the first harvest of smolts (day 154), the temperature in the fingerling system is raised to 55°F (± 2°), and the feeding rate is increased to accelerate growth. The timing is such as to enable the maximum biomass loading to be reached at about harvest time for the smolts. Once the first batch of smolts are harvested (day 210), the system is restocked with the remaining fingerlings, and the process is repeated. By the time the next shipment of eggs has hatched and the fingerlings are ready for transfer, the second harvest of smolts is completed (day 270) in time for another production run.



Salmon smolt production unit: front view.

Key

1 Water Storage Tank
2 Bulk Feed Storage Bin
3 Automatic Feeders
4 Main Circulating Pump
5 Discharge to Settling Area
6 Sludge Pumps
7 Biological Filter
8 Water Level
9 Culture Tanks
10 Grade Level
11 Concrete Aggregate
12 Concrete, Steel Reinforced



Salmon smolt production unit: top view.

Key

1 Water Storage Tank
2 Bulk Feed Storage Bin
3 Liquid Oxygen Storage
4 Swinging Door
5 Denitrification Column
6 Boiler
7 Filter Overflow
8 Sludge Pump
9 Main Circulating Pump
10 Main Circulating Back-up Pumps
11 Discharge to Wastewater Treatment Area
12 Office
13 Sliding Door
14 Refrigeration Unit
15 Air Blower
16 Automatic Feeder
17 Traveling Feed Chain Loop
18 Solenoid Valve Operator
19 Culture Tank

Costs

Cost of Producing Salmon Smolts. The costs summarized in table 1 are those which can be expected in producing about 1 million Chinook salmon smolts from the egg. These costs are based on input markets for southern New England in 1974. Costs of components will vary considerably with circumstances. However, items and assumptions are listed in detail for ease in updating cost estimates according to changing circumstances, including application to other suitable salmonids and warm-water species.

Investment: Land. The cost of uncleared commercial land in southern New England ranges from $1,000 to $3,000 per acre depending on the specific location and topography. The figure represents the cost of relatively level land, the type best suited for such a facility. The sum of $7,000 is alloted for clearing and site preparation and for installing a well, bringing the total cost to $10,000.

Investment: Building. The building is designed to provide the most efficient facilities for the given production capacity with the minimum capital outlay and maximum simplicity. Aluminum siding and roofing are durable and almost maintenance-free, thereby minimizing yearly maintenance and repair costs. Cost projections are in table 2.

Investment: Culture Systems. Included are all the components and associated piping and fittings for the fingerling, smolt and support systems. Polyester resin tanks and polyvinyl chloride piping were chosen because of their suitability for use in salt and brackish water environments which are normal for salmon. A wide range of materials is available for use in such systems; however, the species chosen for culture is a major factor in determining which are best suited. In producing certain species, the capital investment can be lowered by selecting other less costly, but suitable, materials, such as steel or aluminum. However, it is not possible to operate under salt- or brackish-water conditions without costly preparation. Cost projections for the culture systems as described are summarized in table 3.

Depreciation and Repairs. The annual depreciation charge and the maintenance repair bills are $10,216.92 and $615.00, respectively. These figures are derived as indicated in table 4.

Property Tax. The property tax used in this budget is $35 per $1,000 of assessed valuation with the assessed valuation at 80 percent of average market value. Average market value was assumed to be 50 percent of initial cost. While tax and assessment rates vary from area to area, the level chosen is fairly representative of the region under present conditions in southern New England. Under these conditions, the annual tax is $1,065.

Insurance. The annual cost of fire insurance is $2,000, based on the specifications presented earlier. Liability insurance for the proposed plant is $2,374.63. This figure includes only Workmen's Compensation ($1.03 per $100 payroll) at $1,874.63 and "premises and operation" at $500. Insurance, such as product liability or forms associated with marketing, have not been included.

Labor Force. Wages, salaries, and fringe benefits are included in table 5 and are for a full-time manager at $13,000 per year; one full-time, semi-skilled laborer at

$120 per week for 40 weeks or $4,800; and one part-time, unskilled laborer at $36 per week for 40 weeks. Total salaries and wages are $16,240. Fringe benefits amount to $1,264.92. Only the labor cost for 40 weeks (one production period) is projected.

Eggs. At present, eggs cost $.01 each and 1,242,868 are needed per cycle at a cost of $12,428.68.

U/V Sterilization. U/V lights cost $7 each and have a useful "life" of 7000 hours (or a 40-week production cycle) with a replacement cost of $42.

Truck and Hydraulic Hoist. A three-quarter-ton truck with a hydraulic hoist mounted in the rear is needed for handling fish. The basic truck cost is $3,744, and the hoist, $300. Operation cost is approximately $500 per year.

Electricity. Power requirements for each electrical component were computed. These are presented in table 6.

Laboratory Supplies. Monitoring water quality requires the use of laboratory glassware at a cost of $75 and certain chemicals at a cost of $125.

Fuel Oil. Fuel oil cost is based on a use rate of nine gallons per hour for 1831 hours at a cost of $4,946.

Butane Gas. In order to ensure the readiness of the air-cooled engines, they are operated periodically at a total cost of $20.

Feed. Standard commercial diets are used in the form of crumbles and pellets. Feed costs are based on a conversion rate of 1.5 to 1 (1.5 pounds of feed to 1 pound of weight gain). With feed costing an average of $.14 per pound, the production of 87,000 pounds of smolts results in a total feed cost of $18,271.47.

Projecting feed use rates is extremely difficult. For the purpose of this study use rates are used to project feed consumption. One is used for the fingerling stage, and another for the smolt stage. In actuality, consumption rates decrease with age and/or size so the rates represent averages, which seem to result in a fairly realistic projection of total feed used during one production period (40 weeks).

Opportunity Cost of Capital. The cost analysis thus far has included no mention of the opportunity cost of capital. Yet, whether one is using equity capital or borrowed funds, these funds have an opportunity cost which reflects the return available from alternative investments. Table 7 illustrates the effect of interest rates on production costs. Rather than distinguishing between equity and borrowed capital, the same interest rate is applied to both in table 7.

As indicated in table 7, production costs range from $.92 per pound when no allowance is made for the opportunity cost of capital, to $1.07 per pound when this opportunity cost is set at 15 percent per year.

Table 1. Projected annual operating cost

Depreciation	$10,165.29
Property tax	1,065.00
Fire and liability insurance	4,374.63
Maintenance and repairs	615.00
Salaries, wages, and fringe benefits	17,504.92
Eggs	12,428.68
U/V lights	42.00
Truck	500.00
Electricity	2,863.13
Laboratory supplies	200.00
Fuel oil	4,946.00
Butane gas	20.00
Feed	18,271.47
Oxygen	5,000.00
Methanol	2,250.00
Total cost	$80,246.12
Cost per pound	$ 0.92

Table 2. Projected cost of building and landscaping

Foundations	$13,204.00
Excavation	484.00
Gravel and fill	663.00
Roads and walks	2,000.00
Structure	21,504.00
Plumbing	5,900.00
Electric wiring (500-amp service)	4,600.00
230 VAC 60-cycle	
115 VAC 60-cycle	
Insulation ($.28/ft.^{2})	2,333.00
Total	$50,688.00

Table 3. Projected cost of materials and equipment

Tanks	$ 53,753.84
Piping and fittings	3,901.80
Pumps (with motors)	4,863.25
Valves (with electric operators)	5,598.98
Laboratory equipment	1,470.00
Refrigeration unit (with two evaporators)	8,000.00
U/V sterilizer	1,250.00
Water heater	4,500.00
Fish handling screens	1,520.00
Feeder systems	1,825.00
Truck (with hydraulic hoist)	4,044.00
PVC modules	22,848.00
Total	$113,574.87

Table 3a. Breakdown of costs: materials and equipment

	Quantity	Cost
Tanks		
12' dia. × 12' ht. of .250 polyester resin with collector ring ($3,398.74)	8	$27,189.98
20' dia. × 17' ht. of .250 steel bolted, lined	1	8,308.08
10' dia. × [illegible]7' ht. of .250 polyester resin	1	3,681.96
10'6" dia. × 31' ht. steel, lined	1	5,000.00
6' dia. × 6' ht. of .250 polyester resin with collector ring ($847.75)	8	6,782.01
8' dia. × 10' ht. of .250 polyester resin with collector ring	1	1,810.00
4' dia. × 12' ht. of .250 polyester resin with collector ring	1	981.81
Sub-total		$53,753.84
Pipe and Fittings		
8" dia. sch. 40 PVC pipe ($4.26/ft.)	270	1,150.20
2" dia. #70022 Genova pipe ($.36/ft.)	175	63.00
2" tail piece PVC ($2.00)	8	16.00
8" sch. 80 PVC elbow (54.45)	18	980.10
8" sch. 80 PVC tee ($78.32)	3	234.96
8" sch. 80 PVC flange ($32.12)	26	835.12
8" × 4" bushing	1	52.50
4" #70041 Genova ($1.11/ft.)	108	119.88
4" #72840 Genova elbow ($1.58)	19	30.02
4" #71140 Genova tee ($2.73)	3	8.19
4" sch. 80 PVC flange S.W. ($9.85)	28	275.80
4" × 2" bushing	1	1.09
4" black T/C steel pipe ($2.52)	50	126.00
4" black T/C steel elbow	1	8.94
Sub-total		$ 3,901.80
Pumps		
8" × 48" propeller with 3 hp. electric motor	1	2,900.00
4" × 4" centrifugal with 5 hp. electric motor	1	300.00
4" × 4" centrifugal with 8 hp. gas-converted air-cooled engine	2	658.00
2" × 2" centrifugal with 3 hp. gas-converted air-cooled engine	1	155.25
2" × 2" centrifugal with 1 hp. electric motor ($125)	4	500.00
4" × 5" centrifugal with 8 hp. electric motor	1	350.00
Sub-total		$ 4,863.25
Valves		
8" A.S.A.H.I. butterfly with electric operator ($956.25)	4	3,825.00
4" A.S.A.H.I. butterfly with electric operator ($412.50)	4	1,650.00
2" Braham (gate) ($12.33)	6	73.98
4" black I.C. steel (gate)	1	50.00
Sub-total		$ 5,598.98

Laboratory Equipment		
Specific ion meter	1	435.00
Probes		
Ammonia	1	295.00
Nitrite	1	195.00
Nitrate	1	195.00
Oxygen meter	1	350.00
Sub-total		$ 1,470.00
Other		
Refrigeration unit, 20-ton with 2 evaporators	1	8,000.00
U/V sterilizer, capacity 5000 GPH	1	1,250.00
Water heater, capacity raise temp. 5000 GPH 20°F	1	4,500.00
Fish handling screens	16	1,520.00
Feeder system	1	1,825.00
Truck	1	3,744.00
Hydraulic hoist	1	300.00
PVC modules	408	22,848.00
Sub-total		$43,987.00
Grand Total		$113,574.87

Table 4. Projected investment, depreciation and repairs

Item	Value	Years of Depreciation	Annual Depreciation	Annual Maintenance & Repair
Land (includes site preparation)	$10,000.00			
Building (includes tank foundations)	50,688.00	20	$2,534.40	$200.00
Equipment				
Tanks	53,753.84	20	2,687.69	
Piping and fittings	3,901.80	20	195.09	
Pumps with motors	4,863.25	5	972.65	10.00
Valves with electric operators	5,598.98	10	559.89	5.00
Laboratory equipment	1,470.00	5	294.00	50.00
Refrigeration unit	8,000.00	20	400.00	100.00
U/V sterilizer	1,250.00	20	62.50	
Water heater	4,500.00	20	225.00	50.00
Fish handling screens	1,520.00	10	152.00	
Feeder systems	1,825.00	10	182.50	100.00
Truck with hydraulic hoist	4,044.00	5	808.80	100.00
PVC modules	22,848.00	20	1,142.40	
Totals	$174,262.87		$10,216.92	$615.00

Table 5. Projected salaries, wages, and fringe benefits, one 40-week production period

Salaries and Wages	
1 full-time manager ($250/week)	$10,000.00
1 full-time semi-skilled laborer, 1600 hours ($3/hr.)	4,800.00
1 part-time unskilled laborer, 640 hours ($2.25/hr.)	1,440.00
Fringe Benefits	
Unemployment Compensation	
State = .027 × first $4,200 for each employee	265.68
Federal = .005 × first $4,200 for each employee	49.20
FICA = .0585 × first $13,200 for each employee	950.04
Total	$17,504.92

Table 6. Projected electricity requirement: .746 KWH/HP; Rate = $.04/KWH

Item	HP	KWH	Days	Hours/Day	Total Hours	Total KW	Cost
Pump	5.0	3.730	210	24.0	5040.0	18799.20	$ 751.96
Pump	1.0	.746	195	24.0	4680.0	3491.28	139.65
Pump	3.0	2.238	195	24.0	4680.0	10473.84	418.95
Pump	8.0	5.968	195	8.02	1563.9	9333.35	373.33
			75	4.0	300.0	1790.4	71.61
Pump	1.0	.746	195	4.0	780.0	581.88	23.27
Pump	1.0	.746	210	4.0	840.0	626.64	25.06
Refriger-ation unit	20.0	14.920	90	12.0	1080.0	16113.60	644.54
Feeder	.5	.373	270	4.0	1080.0	402.84	16.11
Pump	1.0	.746	195	24.0	4680.0	3491.28	139.65
Lighting		1.000	270	24.0	6480.0	6480.0	259.00
Total							$2,863.13

Table 7. Effect of various interest rates on production

Interest Rate	Interest Cost* on Capital	Production Cost Total	Dollars per Pound
0	0	80246	0.92
5	4357	84602	0.97
7	6099	86345	0.99
10	8713	88959	1.02
15	13070	93316	1.07

* Calculated by multiplying average value by indicated interest rate. Average value is assumed to be one-half of the total value of $174,262 in table 4, or $87,131.

Conclusions

The importance of selecting a facility that is well suited to the geographic location, climate and the species to be produced cannot be overemphasized. For purposes of comparison, producing the same species in a more traditional open raceway system can take twice as long and cost more than twice as much. This is due primarily to an inability to establish and maintain environmental control.

Maintaining total environmental control has been shown to be prohibitively expensive in some cases. However, careful consideration of certain biological and economic constraints during species selection, site location, and systems design can turn an otherwise too costly undertaking into a profitable venture. Other economic considerations of importance which should be studied include the development of new markets and the expansion of existing ones. Other important areas for further research are (1.) the development and maintenance of brood stock, (2.) feed production and supply, (3.) improvements in water treatment techniques, and (4.) improvement in techniques for retarding fingerling growth so that more flexibility can be built into production schedules, thereby increasing profit potential.

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