September 1984

**COMPEDNIUM OF LOW-COST PACIFIC SALMON
AND STEELHEAD TROUT PRODUCTION FACILITIES
AND PRACTICES IN THE PACIFIC NORTHWEST**

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AND PRACTICES IN THE PACIFIC NORTHWEST

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PREFACE

Over 200 fish culture experts provided information for this document. While too numerous to mention each individual by name, their affiliations are acknowledged in Appendix 1 and 3 or within this report.

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COMPENDIUM OF LOW-COST PACIFIC SALMON AND STEELHEAD TROUT PRODUCTION FACILITIES IN THE PACIFIC NORTHWEST

INTRODUCTION

The proposal for a study to identify low-cost fish production facilities originated with the contributors to the Pacific Northwest Power Planning Council Fish and Wildlife Management Plan. Fish Management Consultants (FMC) modified that approach and prepared a proposal for Bonneville Power Administration (BPA) consideration. Together, we developed a study which has resulted in this Compendium of Low-Cost Salmon and Steelhead Trout Production Facilities for the Columbia River Basin.

The purpose of the study was to research low capital-cost salmon and steelhead trout production facilities and identify those that conform with management goals for the Columbia Basin. The species considered were chinook salmon (Oncorhynchus tshawytscha), coho salmon (O. kisutch), sockeye salmon (O. nerka), and steelhead trout (Salmo gairdneri). The objectives were:

- 4. Produce a compendium of low-capital propagation facilities, including any descriptions and schematics required for clarification.
- B. Identify the unit cost, the available vendors, sources of detailed information, and specific locations where the unit or system can be reviewed.
- C. Identify cost-saving operational techniques and tools.
- D. Illustrate how each low-capital propagation facility reviewed can or cannot be incorporated into the goals of the Columbia River Basin.
- E. Provide a listing of factors for consideration in site selection evaluation.
- F. Using low-capital propagation facilities, provide prototype designs for average physical and **climatological** conditions for twenty facilities, including costs and manpower requirements and skills.

The study was deemed necessary because natural production in the Columbia Basin is critically low in **certain** areas. Large centralized hatcheries have not been managed to address this problem and, in fact, are partly responsible for it.

The first Columbia River salmon hatchery was built by the Washington Fish Propagating Company on the Clackamas River in Oregon's Willamette Valley in 1876 (**Wahle** and Smith, 1979). Nearly 100 salmon and **steelhead** trout hatcheries have since been

Introduction

constructed in the Basin. Most were built during the middle portion of the century, when largescale hydro-electric development occurred, at a time when Fisheries Science was a relatively new field. The fish agencies were confronted with the problems of insufficient skills and inadequate technology to properly assess the effect of dam building on fish. Compensation for losses usually involved the construction of a hatchery to replace the production lost through inundation of natural habitat. But production from these facilities was mainly directed toward massive onstation releases, with little attention given to the effect on natural production. The ultimate result was the production of large numbers of hatchery fish which benefited the sport and commercial fisheries, but which depressed many natural stocks mixed within the fisheries and harvested at the same rate. Management goals set to harvest hatchery stocks, as we now know, could only lead to lowered levels of natural production. This perspective on what has occurred, not only on the Columbia but on other streams of the coastal states, is presented not as criticism, but rather as a reality that simply resulted from a lack of knowledge. The fact that natural production in many streams is below optimum levels necessitates the implementation of management techniques to restore these pastures to production capacity.

Within the Columbia Basin, tribal, state, and federal biologists are making concerted efforts to provide a more balanced management plan. The consensus is that there is a massive potential for natural production that is not utilized (Northwest Power Planning Council, 1982). In order to harness this potential, new and innovative artificial production methods must be implemented to aid natural production. High construction costs, dwindling sources of quality water supplies, and the large number of affected streams require that smaller, more efficient, low-cost facilities be used to help restore the natural stocks. There is considerable information available on low-cost fish production techniques and facilities, but much of this has been developed by individual agencies and hatchery managers, and it has not been widely disseminated within the fisheries community. For the last decade, the salmonid enhancement program in British Columbia has included many small projects directed at problems discussed above (Glover, 1983). Recent publications by Leitritz and Lewis, (1980); Piper et al., (1982); Alaska Department of Fish and Game, (1983); and McNeil and Baily (1975); are good reference materials on hatchery operations, but they do not include all the available types of fish facilities or sufficient cost information.

We believe this document will serve as an important tool in fish culture. It is a comprehensive listing of the facilities, techniques, and equipment used in artificial production in the Pacific Northwest. In most cases, it was necessary to describe both high- and low-cost facilities in order to make comparisons. Further, what is low cost to one agency or manager may not be to others, and it depends to a considerable extent on program objectives, location, and available funds. We believe that sufficient information has been detailed to assist hatchery managers and administrators in making facility choices that will help restore fish runs at the lowest possible cost. If the report serves that purpose, the efforts of the authors, contributors, and the BPX will have been worthwhile.

The compilation of material for the report was initiated by establishing lines of communication with all the fisheries agencies and tribal communities involved with Columbia River salmon and steelhead trout fisheries. A preliminary report outline,

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including chapter contents and a report format, were submitted to each agency and tribal representative for their review and comment. Their responses were incorporated as appropriate, and the final report outline and format was developed by BPA and FMC.

Data were compiled through a literature search, site visitations, and personal communications with knowledgeable hatchery personnel. Over 80 state, federal, and tribal facilities in Oregon, Washington, Idaho, and British Columbia were visited (Appendix 3), and additional information was obtained from Alaska Fish and Game, Alaska Salmon Ranchers, and Norway. Also, approximately 150 hatchery administrators, managers, biologists, and technicians were consulted.

Over 250 vendors of fish culture-related materials and equipment were solicited, and those responses that were applicable are noted in Appendix 2. BPA and FMC agreed that vendor contacts would be limited only to Pacific Northwest firms and those outside this area that are known by the fisheries agencies as frequent suppliers. Neither BPA nor FMC endorses the products distributed by the vendors, and they are noted herein for informational purposes only. Throughout the report the advantages and disadvantages of particular equipment items are noted. These were developed from communications with hatchery managers and from the personal knowledge of FMC members and associates. Comments under disadvantages are not intended to impugn a vendor or his product. Rather, the comments should always be read as intended: "as compared to other options."

Construction cost estimates are based in 1983 dollars for average construction conditions, including a 50 mile remoteness factor for labor and material supply sources. These estimates also include a 25 percent cost surcharge for engineering and construction contingencies. These data were obtained from cost estimating manuals, contacts with manufacturers and suppliers, and from documented price data on recent hatchery construction projects. Equipment costs are also based on 1983 dollars F.O.B. at the factory and were supplied by vendors.

Our discussion of the fish facilities and their component systems, for the most part, is presented in a format that describes the unit, details advantages and disadvantages, and shows costs, vendors, and where the unit can be seen. This format was chosen because it allows ready comparison of units, identification of sources of further information, and possible vendors. This format was modified in instances where comparisons were not possible and it was not used for equipment. Vendors; named as suppliers of a product represent a sample only, and Appendix 2 should be consulted for other suppliers. Where multiple measurements of objects are given in the text, we have used the sequence of width x length x depth (or height).

Although we tried to be objective, we realize that many of the advantages and disadvantages noted may be questioned, since, in many instances, we found differences of opinion on individual units both between and within fisheries agencies. Obviously personal preference exists within agencies, and this has affected facility selection and construction costs.

In the appendices, in addition to the lists of vendors and production facilities visited, we have included a glossary of commonly-used technical terms and abbreviations for the

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various fishery agencies, a representative check-list of tools and equipment frequently used at a fish cultural facility, job descriptions for hatchery personnel required at low-cost facilities, and finally, examples of the methods we used to determine rearing space for prototype stations

CHAPTER 1

WATER QUALITY

Water quality is the single most important factor in selecting a hatchery site. The potential success of a proposed facility usually can be predetermined through a careful analysis of the water supply. Because water quality is so critical to good fish husbandry, we are including a discussion of its more important aspects and their relationship to fish culture. In this chapter, we illustrate acceptable water quality standards in terms of: 1) temperature, 2) dissolved gases, 3) turbidity, 4) toxic materials, and 5) pathogens. Succeeding chapters describe water quality requirements for each life stage and how these requirements are affected by facility design and operational techniques. Water quality needs will be an important consideration in the presentation of prototype facility design illustrated in Chapter 9 of this report. The treatment of hatchery effluent water will also be discussed in the latter Chapter.

Numerous manuals are readily available for more detailed information on fish and water quality, but we recommend a recent one prepared by Piper, et al. (1982).

Most fisheries agencies involved in salmonid aquaculture have adopted the water quality criteria used by the Alaska Department of Fish and Game (Table 1) for evaluating potential fish hatchery water supplies. A water supply that meets or exceeds these standards will provide an excellent environment for the culture of salmonid fishes.

In the absence of technical data, the existence of healthy fish in all life stages would provide empirical evidence of suitable water quality.

PART I. TEMPERATURE

Temperature is very important in the selection of a water source. It can: 1) determine growth and development rates, 2) limit disease problems, 3) maximize operational flexibility, 4) aid the smoltification process, and 5) acclimatize fish to the receiving waters.

Generally, salmonids rear best at temperatures between 46F and 55F. With lower temperatures, development and growth may be too slow to achieve program objectives, while temperatures between 55F and 70F may encourage certain diseases. Based on the results at the Spring Creek NFH, the fall chinook do well at constant temperatures around 50F. Eggs subjected to prolonged periods at temperatures above 55-60F incur higher losses, while adults held at temperatures above 70F may perish.

Water temperature is very important in maximizing facility use. Piper (ibid.) states that "as the water temperature increases, the loading factor decreases 5% for each degree (F)

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Table 1. Alaska Department of Fish and Game water quality standards for salmonid aquaculture. (1)

<u>Water Qualities</u>	<u>Standards</u>
Alkalinity	undetermined
Aluminum	<0.01 mg/liter
Ammonia (un-ionized)	< 0.0125 mg/liter
Arsenic	<0.05 mg/liter
Barium	< 5.0 mg/liter
Cadmium	<0.0005 mg/liter (100 mg/liter alkalinity)
	<0.005 mg/liter (<u>></u> 100 mg/liter alkalinity)
Carbon Dioxide	<1.0 mg/liter
Chloride	< 4.0 mg/liter
Chlorine	<0.003 mg/liter
Chromium	< 0.03 mg/liter
Copper	< 0.006 mg/liter (100 mg/liter alkalinity)
	<0.03 mg/liter (<u>></u> 100 mg/liter alkalinity)
Dissolved Oxygen	>7.0 mg/liter
Fluorine	<0.5 mg/liter
Hydrogen Sulfide	< 0.003 mg/liter
Iron	< 0.1 mg/liter
Lead	< 0.02 mg/liter
Magnesium	< 15 mg/liter
Manganese	<0.01 mg/liter
Mercury	< 0.0002 mg/liter
Nickel	<0.01 mg/liter
Nitrate (NO ₃)	< 1.0 mg/liter
Nitrate (NO ₂)	< 0.1 mg/liter
Nitrogen (N ₂)	< 110 % total gas pressure (< 103 % nitrogen gas)
Petroleum (oil)	<0.001 mg/liter
pH	<6.5 - 8.0
Potassium	<5.0 mg/liter
Salinity	<5.0 parts per thousand
Selenium	<0.01 mg/liter
Silver	<0.003 mg/liter (fresh water)
	<0.0003 mg/liter (salt water)
Zinc	< 0.005 mg/liter
Sodium	< 75.0 mg/liter
Sulfate (SO ₄ ⁻²)	< 50.0 mg/liter
Temperature	<0° - 15° c
Total Dissolved Solids	< 400.0 mg/liter
Total Settleable Solids	<80.0 mg/liter (25 JTU)

Note: Synergistic and antagonistic chemical reactions must be considered when evaluating a water source against these criteria.

(1) Source: Fish Cultural Manual, Alaska Department of Fish and Game, FRED Div., June 1983. p.16.

rise in temperature. Conversely, as the water temperature decreases, the loading factor will increase." If density is not a limiting factor, a 50% increase in the production would be gained by using 50F water instead of 60F water. Thus, potential advantages can be gained by the timely augmenting of warm spring and well-water supplies present in the Columbia River Basin with cooler river water, particularly at the time of release when the poundage being held is at its greatest.

We know that temperatures above 55F retard smoltification in steelhead trout. Recent record returns of steelhead trout to WDG mid-Columbia River stations are attributed mainly to the acclimatization of the juveniles before release into the Columbia River. Studies at the WDF Klickitat Salmon Hatchery demonstrated that coho salmon reared in warm spring water survived much better when acclimatized to the colder river water before release.

For a production program, we recommend a water supply with a range of useable temperatures. For example, a constant 50-55F ground-water supply and a surface source with seasonably fluctuating temperatures of 40-60F.

PART II. DISSOLVED GASES

The two most abundant atmospheric gases are oxygen and nitrogen. In a quality water supply, oxygen should be near saturation, while nitrogen can be at any level less than saturation. High elevation and high temperature reduce the amount of gases water can retain. Table 2 gives dissolved oxygen levels for various temperatures and elevations.

The total dissolved gas pressure of the water supply is important because of a phenomenon known as gas bubble disease. Fish living in water supersaturated with dissolved gases can suffer from the formation of gas bubbles in their body tissues. Susceptibility varies with the species and size. Generally, chinook salmon are more susceptible than coho salmon or steelhead trout, and fry or fingerlings are the most susceptible life stages. It is recommended that the total dissolved gas pressure of the water supply remain below 103% to eliminate problems with gas bubble disease in young salmonids, however we refer you to Chapter 2, Part III B on gas stabilization and more detailed notes on atmospheric gases.

Table 2. Dissolved oxygen in parts per million for fresh water, in equilibrium with air.⁽¹⁾

Water temperature, F		Elevation in feet		
		1,000	2,000	3,000
40	13.0	12.5	12.1	11.6
50	11.3	10.9	10.5	10.1
60	10.0	9.6	9.3	8.9
70	9.0	8.7	8.4	8.0

(1) Condensed From Leitritz, E. and R. Lewis. 1980

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PART IIL WATER HARDNESS

Total water hardness, acidity, and alkalinity may be a concern in the Columbia River Basin. Piper (ibid.) describes a desirable range for pH of 6.5-9.0 and water hardness (CaCO_3 - equivalent concentration) of 120-400 ppm. Total hardness in the upper range, however, may cause problems during the incubation process. This was one of several variables suspected of causing problems in incubating chinook salmon at Ringold Springs Rearing Pond near Pasco, Washington and in coho salmon at Rocky Ford Creek Hatchery, Ephrata, Washington. The total hardness was 380 ppm at Ringold Springs Rearing Pond. More recently, total hardness is suspected to have been the cause of problems with eggs incubated in the groundwater supply at the Priest Rapids Salmon Hatchery just upstream from Ringold Springs.

PART IV. TURBIDITY

Suspended solids, or silt, in a water supply has the potential to smother incubating eggs and alevins in the tender stages when they cannot be moved. Eyed eggs, however, will stay viable without water during short periods while the silty water supply is bypassed. Salmonids rarely suffer from muddy water unless it is for a prolonged period and occurs during the early feeding stages. Gill tissue irritation is a common result of excessive turbidity. Piper (ibid.) states, "In general, turbidities less than 2,000 parts per million are acceptable for fish culture." Chapter 2 will address silt removal from water supplies.

PART V. TOXIC MATERIALS

Particular attention must be given to the potential pollution from toxic materials in the water supply or from the use of materials or equipment that create toxic conditions. Usually, the heavy metals, particularly zinc and copper, are the most common cause of mortality or sub-lethal adverse effects on salmonids. This is not as likely to occur in the highly buffered waters present in many Columbia River Basin water sources. But in poorly buffered water, a galvanized intake screen or a short galvanized or copper pipefitting can provide a concentration of ions that will cause high mortality to salmonids during the incubation stage.

Contamination from toxic materials originates from a variety of sources, such as used containers, uncured concrete, paint, or contaminated feed.

Some Columbia River Basin water sources may be exposed to herbicide or pesticide contamination. These chemicals are commonly utilized in agriculture and find their way into surface or groundwater supplies. At present, there is an identified pesticide contaminating groundwater in a section of the Yakima River valley.

PART VI. PATHOGENS

It is well recognized that diseases may adversely affect the success of salmon and steelhead trout hatcheries. This is most often identified with poor fish culture practices; however, it is not widely known that many disease problems can be prevented by proper selection of a water supply.

Many salmon and steelhead hatcheries in the Columbia Basin have had a history of disease problems related to their water source. Examples are:

<u>Hatchery</u>	<u>Disease</u>
WDF-Klickitat Salmon Hatchery	Sunburn of chinook salmon due to very clear spring water and lack of shade.
WDG, WDF - Ringold Springs Rearing and Steelhead Pond	Parasitic trematodes invading the fish eye due to pond water conditions which favor the snail's intermediate host.
WDF - Priest Rapids Salmon Hatchery	Soft-shell egg disease due to high levels of bacteria in water supply.
USFWS - Leavenworth National Fish Hatchery	IHN virus present in water supply or in adult salmon.
WDF - Rocky Reach Hatchery	Columnaris and furunculosis carried by suckers and other fish in the Columbia River water supply.
Trout Lodge - Rocky Ford Creek	Redmouth disease from carp and trout in the water supply.
USFWS - Spring Creek National Fish Hatchery	Gill disease due to malfunctioning water reuse system (high metabolic load).
WDG, WDF - Wells Salmon and Trout Hatchery	Columnaris and gill disease of adult salmon and steelhead due to temperature and contamination of Columbia River water.

At many of the above stations, the disease-caused losses became a limiting factor to successful hatchery operation during some years. As a rule it is far more cost-effective to prevent fish diseases than treat them.

An analysis of hatchery water sources to determine potential disease problems and their control should include the following:

Presence of carriers of bacteria and virus

Are there fish living in the water supply?

Generally, the higher the biomass and the more diverse the species, the greater the chance for disease carriers.

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Presence of parasite hosts

Are there invertebrates, birds or animals present which are known to be hosts for parasites?

Invertebrates such as snails and **copepods** frequently are hosts for parasites which infect fish. Gulls and piscivorous mammals also commonly shed infective parasitic forms into water supplies.

Toxic algae blooms

Does the water supply have a history of toxic algae?

This problem frequently occurs in warm-water fish or pond culture, and will cause rapid mortalities.

Reconditioning of water

Does the hatchery propose to recycle or recondition the water?

Often malfunctioning reconditioning systems will result in diseases being rapidly spread throughout the hatchery.

Clarity of water

Is the water extremely clear or turbid?

Clear water may allow sunburn, while excessively turbid water exacerbates gill irritation.

Quality variations

Has the water source been sampled a number of times under various conditions?

Sometimes a water source which is normally adequate will periodically become unacceptable; gas supersaturation is a common example.

Disinfection

How feasible is it to disinfect the water supply?

Spring sources may be quite easily disinfected, while with river or lake sources this is often not feasible.

Organic material concentration

What is the level of organic contaminants?

Many mildly pathogenic fungi and bacteria attack fish reared in water with elevated levels of organic contaminants.

Bioassay test

Has a group of healthy fish been reared in the water supply as a test?

Live fish will often provide the best means to test a proposed water supply if problems are suspected.

Minimizing stress

Will juvenile or adult fish need to be transported long distances or require excessive handling in order to operate the hatchery?

Stress is often the primary cause of disease. It is far better for adult fish to migrate to the hatchery, rather than be trapped and transported.

Water Quality

Human health

Is the site located upstream of a human domestic water diversion?

Some fish diseases and some chemicals utilized in the hatchery may be harmful to humans. The hatchery should be located so as not to compromise human safety.

Water control for disease treatment and sanitation

Can the water flow be shut off for disease treatment?

Many hatchery ponds cannot be drained to enable effective disease treatment.

Seldom will a water source be totally adequate for all fish disease prevention criteria. However, each potential supply source should be evaluated for disease prevention along with other necessary criteria. If the water source is suitable for most needs, the deficiencies should be evaluated to determine if they can be minimized through engineering or management approaches. The most cost-effective and pathologically sound water supply will prove to be the best investment for a successful hatchery program.

CHAPTER 2

WATER COLLECTION, DELIVERY, AND QUALITY IMPROVEMENTS

This Chapter describes the facilities and equipment utilized in providing water for fish cultural needs, and discusses various ways to treat the water supply to meet the quality criteria set forth in Chapter 1. For a typical fish hatchery, the water system is one of the major costs and can approach 50% of the total project. Facilities and equipment for water collection, conditioning, delivery, control, and drain systems detailed have been successfully utilized in Northwest salmon and steelhead trout fish cultural operations. Permits are commonly required for these construction activities (see Chapter 10).

PART I. WATER COLLECTION SYSTEMS

This Section discusses the various facilities and equipment in use to collect surface runoff, spring, and ground waters for fish cultural needs. Surface waters are considered as streams and lakes generally supplied from rain, or run-off from melting snow or glaciers. Spring waters are those surfacing from below ground, and ground waters are those collected from wells or from excavations that produce a continual flow.

A. SURFACE WATERS

The collection of surface waters requires a reliable system to protect hatchery fish from loss of water. Most Northwest streams have large fluctuations in flows, with the resulting bank erosion, turbidity, gravel deposition, and large amounts of floating debris. Cold winters can also cause stream icing conditions on the water surface as well as the stream bottom. Therefore, to insure a continuous water supply, a complex intake may be required according to the size and goals of the facility, and the adversity of the stream conditions. Unfortunately, maintenance-free intakes have not been developed to handle all stream flow conditions, so operators must be equipped to maintain water flows to the hatchery at all times. Adverse weather conditions usually maximize water supply problems. Lake water surface intakes also have a number of the above noted undesirable characteristics, but generally are not of the same magnitude because the larger body of water dampens the intensities of flows, sediments, and debris.

Various water intake facilities and methods are explained and analysed below.

1. Stream and Lake Bank Intakes This intake is a concrete box structure located on the bank of a stream or lake at a level that permits free entry of water for either pumping or gravity flow diversion into a pipeline or open ditch, but it should not be built in an area of back eddy. Low-cost facilities generally provide for double screening of the incoming water; first through a trash rack with large openings, and then through a small-mesh screen system. The two screens prevent large trash,

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leaves, debris, sediments, wild fish, etc. from entering the diversion and should be parallel to the flow of the stream to assist in keeping them clean. The structure should also have the capability for the installation of stop logs to shut down the water system for maintenance and cleaning. The actual intake in the concrete box can have vertical or inclined screens depending upon the needs of the system.

On streams where low-flow conditions do not afford sufficient depth for the required water diversion, small dams may be required to raise stream water elevations. These small dams may be a permanent concrete sill, a semi-permanent rock-filled dam, a temporary stream gravel dam, or a temporary rack with wood facing spanning the stream width. Regardless of which type of system is used to raise the water level, there should be provision for lowering the water to allow the forebay to be cleaned.

Advantages:

- Highly reliable for diverting water under varying stream flow and lake water conditions
- 0 Structure can be overtopped without serious damages or danger to the water supply
- 0 Simple construction
- 0 Small water diversions can utilize small pre-cast concrete intake boxes

Disadvantages:

- Structure creates higher upstream water levels and may require flood and flowage easements in sensitive areas
- Requires daily inspection and the maintenance requirement can be hourly during adverse weather and water conditions
- Sand, silt, and muddy water pass through the diversion causing operation problems in incubation and rearing
- 0 Requires periodic **cleanout** of sediments from inside the intake as well as the waterway leading to the intake
- If a water diversion dam is required, upstream fish passage for native fish may be needed
- Screens are subject to freezing with reduction of water to fish facilities

Cost:

Capital costs can vary from \$1,000 for a 3-4 cfs capacity concrete pre-cast water diversion box, as installed at the Red River Salmon Rearing Pond with a bulldozed temporary gravel check dam, to \$100,000 for 60-75 cfs capacity concrete intakes for the Bonneville Fish Hatchery and Quinault National Fish Hatchery with concrete dams and fishways. Life expectancy is 50 years for all three structures.

Chapter 2

Information Sources:

Idaho Fish and Game Red River Salmon Rearing pond and Pahsimeroi Steelhead Collection Facility
Oregon Fish and Wildlife Bonneville Fish Hatchery
U.S. Fish and Wildlife Service Quinault NFH and Winthrop NFH, Washington

2. **Instream Diversion Dam with Screen Intake Structure** This type of intake requires a concrete dam with an overflow section capable of passing 100-year floods. On all or a portion of the overflow section's downstream side, inclined plane screens are installed to pass water into a diversion flume, pipeline, or open ditch. Inclined plane screens are sloped with the water flow providing self-cleaning of the screen surfaces (Fig. 1). The screen slopes vary with each installation depending on the designer's criteria. At the Tulalip Tribal Hatchery in Washington, Tulalip Creek screens were installed on a 1 on 1 slope, while Hatchery Creek screens at the Quinault National Fish Hatchery, Washington, were installed on a 1 on 3 slope. Both installations have excellent self-cleaning performances and easily divert all of the normal stream flows.

Figure 1. Inclined plane screen at the Gnat Creek Fish Hatchery (OFW). Note leaves washed down by the water.

Advantages:

- Highly reliable for diverting water under varying stream flow conditions
- Structure can be overtopped without serious damages or danger to the water supply
- Self-cleaning capability

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Disadvantages:

- Requires daily inspection and the maintenance requirement can be hourly during adverse weather and water conditions
- Sand, silt, and muddy water pass through the diversion causing operation problems in incubating and rearing
- Requires periodic **cleanout** of sediments from inside the diversion flume
- Depending on location, may require passage facilities for native fish
- Structure creates higher upstream water levels and may require flood and/or **flowage** easements in sensitive areas
- Screens are subject to freeze-up with reduction of water to fish facilities, Temporary screen removal, portable heaters or heat lamps on the screens, or the introduction of warm well water on the screen surface are solutions to the freeze-up problem
- Inclined plane screening systems lose about 2 feet of available head between the dam and the diversion flume

Cost:

The capital cost of the 8-foot high West Fork Tulalip Creek diversion dam at the Tulalip Tribal Hatchery, Washington, with screened intakes was \$119,000, and the system diverts 14.5 cfs. The capital construction cost of the 5-foot high Hatchery Creek diversion dam at the Quinault NFH, Washington, with screen intakes was \$40,000, and diverts 12 cfs. Costs for this type of structure vary greatly depending on dam height and the stream width. Life expectancy of these structures is 50 years,

Information Sources:

Tulalip Tribal Salmon Hatchery, Washington
U.S. Fish and Wildlife Service Quinault NFH, Washington

3. **Instream Rock Filter Intakes** Considerable funds and manpower have been invested in improving water quality by filtering stream water through rock and gravel (Fig. 2). Most have developed problems, however, and few are presently in use. Filtration methods have included the use of perforated pipe or well screens carefully buried in trenches and backfilled with washed, graded gravel. Intakes centered in rock-filled wire **gabion** baskets, and intakes located along stream banks behind rock filter walls have also been tried. In operation, filters tend to soon become plugged. Backwash systems using water or compressed air have been installed but were unsuccessful in cleaning the systems. An additional problem has been the difficulty in preventing the passage of fish through the filters from the water supply systems. The rock filtering processes remain available but we do not recommend them. Information sources are the OFW **Elkhorn** Fish Hatchery and WDF Humptulips Salmon Hatchery.

4. **Miscellaneous Submerged Screen Intakes** The low-cost submerged screen intakes described below are from the Canada Department of Fisheries and Oceans, (1980). These type of intakes should be considered for secure water areas of lakes

Chapter 2

and spring-fed ponds where damage potentials are minimal. Note that these intakes all have approximately 10 ft² of screen area to screen 1 cfs of water. Intakes are required to be accessible for cleaning at regular intervals. All intakes are easy to build and can be constructed and installed for under \$1,000 each. Life expectancy is 10 years for the wood and 25 years for the metal intake parts. We also refer you to Swan et al., (1980) for the various types of surface intake screens used on pump stations located in the Columbia River watershed upstream of **Pasco**, Washington. A direct quote from the Canadian publication follows:

“Multiple well screens connected to a submerged pipeline on a lake bottom have been used to screen water for a municipal supply. The screens are normally positioned approximately 3 metres from the bottom of the lake to prevent silt and debris from entering the water system.

Figure 2. Rock-filled **gabions** ready for use at the Clatsop County Rearing Pond, Oregon.

A floating water intake can be fabricated utilizing two simple pontoons with a section of well screen supported between them. A flexible polyethylene pipeline can be connected from one end of the well screen to the shore. This type of intake can be used in either lakes or rivers, and is often ideal for supplying water to a fish egg incubation facility or temporary supply for rearing ponds.

A temporary intake may be constructed by connecting a flexible pipe to a well screen, which is raised above the bottom by simple support legs welded to each end of the screen (Fig. 3). This type of assembly may be installed

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in pools of streams, impoundments behind beaver dams, small lakes, or in other stable, clean water sources.

A screened intake can be made from a drum or welded rectangular frame covered with woven wire mesh (Fig. 4). This intake can be used in a stream or lake, supported below the water surface from floats.”

Information Sources:

Canada Department of Fisheries and Oceans
B.C. Ministry of Environment, Vancouver, B.C.
Washington Department of Fisheries, Grays River Hatchery

Figure 3. “Horizontal-vertical screening facility located in a diversion channel off the main stream. Water flows through the horizontal and vertical sections of the screen and is available for use in the irrigation channel or other water use facility downstream. Fish and debris are guided to the bypass culvert which discharges back to the main stream. (Adapted from P. A. Slaney, 1977)” Courtesy of Canada Department of Fisheries and Oceans and British Columbia Ministry of Environment, Vancouver, B.C.

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Figure 4. "Intake screens for pumps with capacities less than 2050 litres per second (i.e., one cubic foot per second, 450 U.S. or 375 IMP. gal. per minute). Adapted from Department of Fisheries of Canada (DWG No. 4-3-4 1965)" Courtesy of Canada Department of Fisheries and Oceans and British Columbia Ministry of Environment, Vancouver, B.C.

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B. SPRING WATERS

Spring water collection is much easier than surface waters because of constant water flows and the general absence of sediment, debris, and ice. Spring water is commonly collected through an intake constructed within a cut-off wall dam that serves as an impoundment. These impoundments are sometimes covered to protect water quality. Open impoundments can have problems of algae and vegetation growth, wild fish, snail infestations, contamination from animals, and a temperature loss in severe climates. Fenced enclosures are also used to prevent animals and people from entering and degrading spring water areas.

The cut-off wall dams usually are installed 2 to 3 feet below ground level and extend 2 to 3 feet above ground levels. The wall can be constructed of concrete, sheet steel piling, Wakefield wood piling, or a combination of the above materials. The water intake is through an opening in the dam with a vertical or upstream sloping screen in the upstream face of the dam. Inclined plane screens sloping downstream from the dam can also be installed, as for the proposed Nisqually Tribal Salmon Hatchery near Olympia, Washington (Fig. 5). A roof cover over the spring impoundment is either metal or wood construction supported on concrete footings. Operations require daily inspections to clean screens as necessary.

Cost:

A 35-foot long spring intake structure with cut-off wall dam costs about \$6,000, and has a 50-year life expectancy. The same structure with the Nisqually-type inclined plane screen intake costs \$8,000, and also has a 50-year life expectancy. Concrete or concrete block footings with a metal roof over the spring will cost \$16/ft², and have a 25-year life expectancy. A wooden roof will cost \$12/ft², and have a 10-year life expectancy. For a low-cost cover, floating wood frames covered with 4 mil black plastic sheeting would cost approximately \$0.20/ft² plus labor.

Information Sources:

U.S. Fish and Wildlife Service Spring Creek NFH and Carson NFH, Washington
Idaho Fish Game Niagara Springs Steelhead Hatchery
Washington Department Fisheries Klickitat Salmon Hatchery
Washington Department of Game Ringold Steelhead Hatchery and Goldendale Fish Hatchery

C. WELL WATERS

Well water is generally excellent for hatchery operations and is usually disease-free, clear, clean, and at a constant temperature. This water is useful for incubation or tempering surface waters for rearing and adult holding. It is advisable, however, to determine the chemical qualities of the water before any great expenditure is made (set Chapter 1, Table 1).

Figure 5. Typical spring water intake structure. Courtesy of the Nisqually Indian Tribe.

Water Collection, Delivery, and Quality Improvements

Wells are usually developed with cable tool, mud rotary, or air rotary drilling rigs. Rainey wells are not applicable to this report because of the high development cost. Shallow, large diameter cistern-type wells can be dug by hand. Pump bowl **diameters** increase as pumping capacity increases, therefore, well diameters are sized for the pump and the estimated quantity of water available for pumping. An increase in well diameter will not produce appreciably more water. Pumps for wells are chosen from test pumping data, where well water quantity versus ground water level **drawdown** depth from ground surface to the pumping water level are physically measured.

Frequently, well pumps have been oversized because of the desire to pump all available water indicated by test pump data. Test pump data are obtained from 24 to 40 hours of test pumping, while the permanent production pumps run continuously for several months as required by operations. The production water levels associated with pumping usually stabilize at greater depths with less water available for pumping. Our recommendation is to choose pumps sized for 80% of the test pumping water quantities. When well pumps are oversized, well water levels can fall below pump suction and cause surging. Surging causes air to be pumped together with water, and leads to pump bowl cavitation and an overdraft on the water aquifer that brings sediment into the casing. The overdraft can also cause pump bowl wear and eventual well failure.

Well pumps should be selected with overall efficiencies of energy input to water output of not less than 75%. Northwest production well pumps are normally powered by electric motors. Deep well turbine pumps are generally used for high capacity production wells. Recently, high quality submersible pumps with attached submersible electric motors have been developed. This submersible equipment provides improved security against vandalism, the ability to safely locate wells in flood zones that can be inundated with seasonal high water, and eliminates the need to lubricate pump shaft bearings located between the pump and motor.

Deep well vertical turbine pumps are available with pump shaft lubrication by either oil or water. Water lubrication is recommended to keep oils out of the fish culture operations.

cost:

- a. Well drilling and furnishing and installing well casing pipe costs about \$6.50 per inch of well diameter per foot of well depth.
- b. Well test pumping of less than 50 gpm with cable tool **bailor** costs about \$40 per hour. A variable speed pump with pumping capacities to 200 gpm costs about \$60 per hour. A variable speed pump with pumping capacities of 200 gpm to 1,000 gpm costs about \$100 per hour.
- c. Electric powered permanent production pumps cost \$500 per HP for pumps rated over 40 HP, and about \$1,000 per HP for pumps rated under 10 HP.
- d. A **12-inch** diameter well that is 300 feet deep and equipped with a 50 HP pump capable of pumping 700 gpm, costs about \$50,000. This cost does not include bringing electrical service to the well site, but does include pump panel switches, starters, heaters, and other controls.

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- e. Life expectancy of the well is 25 years. To maintain pump efficiencies, the pump should be overhauled every 10 years.
- f. Well production pumping costs at \$0.04 per kilowatt-hour of electricity are shown under “Pumps” in the next section (II A), Table 1. Electrical demand charges of an additional \$5 to \$25 per month, depending on pump motor horsepower, are not included.

Information Sources:

U.S. Fish and Wildlife Service Leavenworth NFH, Washington, and Kooskia NFH, Idaho
Oregon Fish and Wildlife Gnat Creek and Bonneville Fish hatcheries
Washington Department of Fisheries Priest Rapids Salmon Hatchery
Washington Department of Game and Department of Fisheries Wells Salmon and Trout Hatchery

D. INFILTRATION SYSTEMS

Infiltration systems are used in developing ground water supplies in areas where a high ground water table is present and large water quantities are stored. This type of condition exists in floodplains where gravel deposits allow upstream water to continuously supply and permeate these deposits. Infiltration water is useful for fish culture because the water is not only clear and debris free, but most importantly, the water temperatures usually lag stream temperatures by about six weeks. Therefore, one can expect 2 to 4F warmer water in winter and 2 to 4F cooler infiltrated water in summer, compared with adjacent stream water temperatures during these critical water temperature periods.

This water is easily developed by excavating to depths below the water table. These excavations can be open trenches, channels, or backfilled trenches with perforated pipe drintile with gravity flow to a pump site or a channel. Infiltrated ground water, as with all ground water supplies, may contain supersaturated nitrogen. This supersaturated condition may be continuous or seasonal, particularly when this water is warmer than the surface waters (see Chapter 1).

An early application of using infiltrated water was **Satsop Springs (WDF)** near **Elma, Washington**. A number of installations in British Columbia utilize infiltrated waters for spawning, incubation, and rearing channels (Fig. 6). These channels are 1/2 to 1 mile long and 20 to 50 feet wide, with 12 to 18 inches of gravel substrate. The DFO indicated that construction costs were about \$140,000 per mile of channel. However, construction is simple and many were built very economically using volunteer labor and equipment. Spawning and incubating gravels should be mechanically cleaned at two- to four-year intervals for optimizing the system.

The USFWS Winthrop National Fish Hatchery has developed 6 cfs of infiltrated water from about 200 feet of trenching at a cost of **\$40/lin** ft of backfilled trench with perforated pipe, and \$10,000 for the pump sump and pumping system. Life expectancy is 25 years.

Figure 6. An incubation and rearing channel developed in British Columbia which uses an infiltration water system **(DFO)**.

At many large dams, good quantities of infiltrated water are available from their downstream toe drains and can be collected for fish culture uses. Toe drain waters from the U.S. Corps of Engineers' Chief Joseph Dam have been studied and recommended as **useable** for the prime water supply source for a fish hatchery (Koch and **Cochran**, 1977). Chelan County **PUD's** Rocky Reach Dam toe drain water presently supplies 4 cfs of quality water to **WDF's** Rocky Reach Hatchery. **Both** of the dams are on the Columbia River upstream of Wenatchee, Washington.

Information Sources:

Worth Creek-Harrison River Side Channel, British Columbia
Little **Mountain-Chehalis** River, Chehalis Indian Reserve Side Channel, British Columbia
North Vancouver Outdoor School Mini Hatchery, British Columbia
Rod and Gun Club-Puntledge River Side Channel, British Columbia
U.S. Fish and Wildlife Service Winthrop NFH, Washington
Washington Department of Fisheries Rocky Reach Hatchery

PART II WATER DELIVERY SYSTEMS

These systems involve the use of pumps, siphons, and gravity for water delivery through channels and/or pipelines from collection sources to the fish culture facilities, and then drain back to the receiving waters.

A. PUMPS

Pumps are mechanical devices for raising water to higher elevations or to higher pressures when the flow is constricted by a closed pipe system. Pumps require a rotating power source, usually an electric motor for fixed rpm, or a fueled engine for independent and variable speed operation. Following are several types of pumps:

1. Piston Pump A piston is moved back and forth in a cylinder with water passing through a valve as in an old style domestic pump or in boiler feed pumps.
2. Gear Pump Two gears in mesh turning in a close-tolerance case take liquid in on open teeth and squeeze liquid out as teeth close in mesh.
3. Rubber Vane Pump A rubber vane impeller in an eccentric case takes liquid in as vanes open and discharges as vanes close past eccentric.
4. Axial Flow Propeller Pump **This** pump, used in fisheries work, has a propeller type impeller rotating in a close-tolerance enclosure connected to the vertical discharge pipe up to a delivery elbow. Above the elbow is the electric motor driving the propeller by a long shaft supported in the center of the vertical delivery pipe. This type of pump is designed for low-heads of 10 to 20 feet with large flow capacity. A **12-inch** pump with **15-foot** head will deliver 2,000 gpm at 72% efficiency with a 15 HP motor. The axial flow propeller pump is less expensive than **centrifugals** and is less efficient.
5. Centrifugal Pump Centrifugal type pumps come in a variety of classifications but all have a rotating impeller enclosed in a close-tolerance case. Centrifugal force from rotation of the impeller forces water to the outside of the case where it is discharged. As the water leaves the case, a vacuum causes new liquid to enter at the center of the impeller. Centrifugal pump types include self-priming, ditch, open impeller, closed impeller, multiple stage, high pressure, centrifugal driven, jet, and submersible. Modern development of seals, motors, and wiring has allowed the submersible centrifugal pump to become widely used for fisheries water supplies from wells, river intakes, and infiltration water sources.
6. Air Lift Pump These pumps are sometimes used in lakes for bottom to surface circulation. A solid **wall** or perforated pipe is suspended vertically from the surface to the lower lake levels. Air is introduced in the pipe, creating a flow of water to the surface as the air rises. Again, caution should be applied in the introduction of air to prevent supersaturation. Avoid dispensing air in the lower elevations of deep water.

Water Collection, Delivery, and Quality Improvements

Fish hatchery water pumps are either propeller or **centrifugal** types that have the following characteristics:

Propeller

1. Low head to 20-foot lift
2. High capacity to 20,000 gpm
3. Efficiencies in low 70% ranges
4. Ability to pump sand and silt without excessive propeller damages
5. Costs less than centrifugal pumps
6. Available for trailer mounting if portability is required

Centrifugal

1. Low to high head lifts
2. **Low** to high capacity water deliveries
3. Efficiencies in high 70% ranges
4. Sand and silt in water damages impellers
5. More costly than propeller pumps
6. Pump shafts longer than 20 feet require **prelubrication** (not applicable to submersibles)

Advantages:

- Initial capital construction outlay less costly than gravity flow pipelines with remotely located river intakes
- **Multiple** pumps can be sized and used for varying water quantities
- Pumping intake locations are usually much closer to the hatchery and can be more easily observed for security and maintenance
- Auxiliary power unit can be located in close proximity to the power control centers for power distribution

Disadvantages:

- Power cost and pump repairs are continuing costs of the system not found in a gravity system
- Standby generator for minimum pumping flow, or reservoir storage is required for use during power outages
- Heavy equipment needed to remove and replace pumps
- Platform and pump installation subject to flood and debris damages
- Flow diversion can be required during low flow periods

Cost:

Costs are dependent on pump platform support installation, pump capacity, pump lift, pump motor horsepower, and equipment quality. Electrical pumping costs are a major operational expenditure. Table 1 illustrates production pumping costs at different heads, assuming **\$0.04/kilowatt-hour** for electricity. Equipment failure could be devastating to fish life, therefore, high quality, highly efficient pumping equipment is recommended for the water delivery systems. Life expectancy of pumps is 25 years with pump overhaul at ten-year intervals.

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Table 1. Monthly production pumping costs at various **lifts**.⁽¹⁾

<u>Production</u>	<u>50' Lift</u>	<u>100' Lift</u>	<u>150' Lift</u>	<u>200' Lift</u>
50 gpm	\$18.14	\$36.00	\$54.43	\$72.29
100	36.00	72.29	108.29	144.58
150	72.29	144.58	216.86	289.15
200	108.29	216.86	325.44	434.62

(1) Based on \$0.04 per kilowatt-hour. Does not include kilowatt demand charges; usually **\$1.00/mo/kilowatt**.

Information Sources:

U.S. Fish and Wildlife Service Dworshak NFH, Idaho and Warm Springs NFH, Oregon
Washington Department of Fisheries Lewis River, Upper Kalama, Lower Kalama,
Cowlitz, and **Washougal** Salmon hatcheries

Pump suppliers are found in the phone directory yellow pages, such as Byron
Jackson, **Paco**, Pearless, Johnson, and H.D. Fowler Pump companies

B. GRAVITY

Columbia River fish hatcheries commonly utilize buried gravity flow pipelines for fish cultural water supplies. These installations are considered the most reliable, risk free, and the preferred method for a fish hatchery water delivery system. On station, the water supply is further distributed and drained through combinations of buried pipelines, exposed pipelines, pipe manifolds, supply and drain troughs, water supply head and drain boxes, stop logs, gate valves, butterfly valves, and slide gates. Water supply troughs and head boxes are also the preferred method over manifold pipe systems for supplying water to stacks of vertical incubators, as individual water adjustments are more easily made without affecting flows in any of the other units using the same water supply.

1. Pipelines The importance of a reliable, uninterrupted water supply demands that high quality pipelines be installed, and that the lines be installed so that air will not be trapped, causing loss of flow or gas supersaturation. A quality pipeline is constructed of durable material, possesses good water flow characteristics, is watertight with no joint leakage, and is not difficult to install.

Pipelines 12 inches in diameter, or larger, with good performance records are made of reinforced concrete; ductile iron; concrete cylinder; welded steel; cement asbestos; aluminized-coated, welded-seam, corrugated steel; and wood staves. PVC plastic, black steel and ductile iron pipes for small diameter lines under 12 inches also have good performance records.

Water Collection, Delivery, and Quality Improvements

Advantages:

- 0 Most reliable system for water delivery
- 0 **Minimal** maintenance required as related to other facilities
- Minimal water transportation losses
- Minimal exposure to accidental chemical spill or contamination
- Pipelines, when buried, are secure and have minimal problems with floods
- Non-ferrous materials (listed above) avoid **decompositon** from electrolysis
- Wood stave pipe leaks are easily repaired while under pressure

Disadvantages:

- Buried pipeline leakage difficult to detect and to locate
- Wood stave pipe requires line to be maintained filled with water to prevent shrinking in cross section and leaking
- Welded steel, corrugated metal, black steel, and PVC plastic pipes cannot be installed around curves or bends without special sections
- Entrained air can supersaturate water

cost:

Costs are itemized (Table 2) for furnishing and installing the various buried pipelines, including special sections, air valves on high points, blow-off valves on low points of pipeline alignment, and a large blow-off valve on the terminal end of the line.

Table 2. Approximate costs of buried pipelines.⁽¹⁾

<u>Pipelines 12-inch diameter and larger</u>		<u>Pipelines under 12-inch diameter</u>	
Reinforced concrete	\$5.00	PVC	\$3.00
Ductile iron	5.00	Ductile iron	3.00
Concrete cylinder	5.00	Black steel	3.00
Welded steel	5.00		
Wood stave	4.30		
Corrugated steel	2.50		
Cement asbestos	5.00		

(1) The above costs are per inch of pipe diameter per linear foot of pipe. Therefore, a **12-inch** diameter reinforced concrete pipe will cost 12 x \$5.00 or \$60.00 per linear foot. All pipelines have **50-year** life expectancies.

Information Sources:

Reinforced concrete pipe - Concrete Products of Moses Lake, Moses Lake, h.4
Ductile iron pipe - Pacific States Cast Iron Pipe Co., Portland, OR
Concrete cylinder pipe - Ameron Pipe Division NW, Portland, OK
Welded steel pipe - **Beal** Pipe and Tank Corp., Portland, OR

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Wood stave pipe - National Tank and Pipe Co., Clackamas, OR
Corrugated steel pipe - Waterworks Supply Co., Portland, OR
PVC pipe - Hinds Supply Co., Portland, OR
Black steel pipe - Hinds Supply Co., Portland, OR

2. Open Channels Open channels may be unlined, or lined with concrete or culvert pipes cut into half-flumes to minimize water loss in areas of pervious soil materials. Culvert pipe flumes are also used in steep terrain where ditch maintenance would be difficult or impossible. Ditches are constructed to various sizes and shapes depending on the water capacity requirement and ditch gradient. For normal ground conditions, 3 feet of water depth in a ditch with a 3-foot bottom width, and 1 1/2 to 1 bank slopes, will deliver about 60 cfs when excavated to a 0.03% ditch grade. Steeper ditch grades will cause erosion of an unlined ditch and must be avoided.

Advantages:

- Highly reliable for water delivery
- Provides significant storage capacity for water interruptions
- Low cost
- Easy to construct

Disadvantages:

- High maintenance cost, with need for ditch cleaning every other year
- High potential for water transportation losses. This could be critical during low flow periods
- High exposure to accidental spill or contamination
- Uniform ditch gradient requires following ground contours and may necessitate long ditch lengths
- Inverted siphon crossings may be required for passing under roadways and streams
- Corrugated flume sections may be required in difficult terrain
- Ditching in wetswampy areas requires specialized equipment
- **May** be problems in freezing weather

Cost:

An unlined open channel ditch costs about **\$4/linear** foot.

A ditch lined with 2 inches of concrete costs about **\$22/linear** foot.

Information Sources:

Idaho Fish and Game Pahsimeroi Steelhead Collection Facility and Chinook Salmon Facility

U.S. Fish and Wildlife Service Winthrop NFH, Washington

Washington Department of Game **Ringold** Springs Steelhead Pond

Washington Department of Fisheries **Ringold** Springs Rearing Pond

c. SIPHON

This section will examine two types of siphons. A true siphon and an inverted siphon. **Both** systems have fish cultural applications; however, we caution their use because of their questionable reliability (see Disadvantages). A third type, the intermittent siphon, does not appear to have fisheries uses, and is used in automatically flushing public toilets where continuous water flows are not required or desired.

The true siphon is a device for transferring water through a water-tight pipeline from a higher elevation water source to a lower elevation discharge point over an obstruction that is at a higher elevation than the water source.

Because internal pipe pressures and external atmospheric air pressures try to equalize, water will flow through the pipe system if air obstructions are cleared. A siphon will also cease to function if the obstruction is higher than 34 feet above the water source. To make the siphon operate, a vacuum pump with a dome is needed at the high point in the pipeline to remove **all** air from the line. Air removal is periodically required to insure that the suction side of the siphon remains below atmospheric pressure. As air collects at the pipeline's high point, the air rises into the dome and is removed from the system by the vacuum pump. If only a small pocket of air is allowed in the dome, under vacuum conditions this air will expand into larger bubbles and can reduce pipeline flow. If the bubble is not removed, additional air brought in with the water flow will expand the bubble until pipe flow shuts down.

Inverted siphons are used for irrigation projects, and are also applicable for fish hatchery open channel delivery systems, where road or stream crossings are necessary. The open channel diverts the water into an inverted siphon pipeline that crosses under the roadway or stream, and returns the water to the channel on the opposite side at the same water surface elevation, less pipeline entrance, exit, and friction losses.

True Siphon Advantages:

- Water can be lifted over obstructions higher than intake water surface elevations without pumping
- Site specific conditions may locate pipeline alignments and/or excavations for cost effectiveness over gravity flow pipeline alignments
- Vacuum pump can be located at the hatchery or other convenient location with a small air-tight line to the siphon's high point dome. This line can be laid in the same ditch utilized by the siphon pipeline

True Siphon Disadvantages:

- A siphon system is not as reliable as a gravity flow system and requires maintenance, surveillance for air problems, and an alarm system for water shut down
- A vacuum system at the high point is required to activate pipe siphon flow
- Initial siphoning startup and restarts are slow
- Supplemental water supply is required for back up

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- Both ends of the siphon must be water sealed, or shut-off with a tight valve on the delivery end, for siphoning startup
- During long power outages an auxiliary power source, or manually operated mechanism, is needed to operate the priming system
- A 33- to 34-foot high loop in the vacuum line is needed to eliminate water entering the vacuum line and pump because vacuum pumps do not operate when water flooded

Inverted Siphon Advantages:

- Highly reliable
- Low maintenance
- Easily installed
- Low cost

Inverted Siphon Disadvantages:

- Requires periodic silt flushing through a cleanout-blowoff system to maintain flow capacities

cost:

True siphon special equipment costs will vary from \$1,000 to \$10,000, depending on vacuum pump size, pump location, and cost for bringing in electrical power. One-third horsepower vacuum pumps can be purchased for about \$200, while larger 3 HP pumps cost about \$1,300 each. Life expectancy for the pump is 10 years, and 50 years for the other special equipment.

Inverted siphon pipeline costs per foot can be found in the preceding section, "Pipelines". Pipeline life expectancy is 50 years.

Information Sources:

Air-Oil Products Corporation of Portland, OR is supplier for Gast vacuum pumps
U.S. Fish and Wildlife Service Quinault NFH, Washington
Washington Department of Fisheries Willapa, Hood Canal, and Dungeness Salmon hatcheries

PART III. WATER QUALITY IMPROVEMENTS

The importance of a quality water supply for fish culture is noted in Chapter I. In many **cases** it is virtually impossible to find a water source that meets all the desired requirements, and some water supplies require special treatment to **prevent the entrance** of undesirable elements into the hatchery. Techniques are available to improve water quality. Methods and facilities to remove debris, settleable solids, wild fish, undesirable biological organisms, and to optimize dissolved gas levels and water temperatures are discussed in this chapter.

Water Collection, Delivery, and Quality Improvements

A. DEBRIS REMOVAL

Common debris found in surface water that requires removal is silt, sand, leaves, sticks, ice and heavy **bedload**. These materials may cause physical harm to the fish or plug the water supply system; causing a disastrous loss of fish and considerable expense to effect repairs to the supply system. Water intake systems are designed to prevent the entrance of debris and **bedload** into the system, but finer materials, including settleable solids and colloidal materials, generally must be dealt with at some point beyond the intake. The discussion that follows considers the types of facilities required to remove debris before the water enters the hatchery incubators or ponds.

1. Coarse and Fine Screens Trash racks are usually located on the outer edge of the intake facility. They are generally constructed of wooden 2 x 4's equally spaced, 3/8- x 2-inch equally spaced metal bars, or large-mesh wire screens. These racks prevent the larger debris and heavy **bedload** material from entering the water intake facility.

The material used for the interior screens may be heavy-duty hardware cloth, either steel or stainless steel; perforated or slotted plates, either aluminum or stainless steel; or closely spaced aluminum or steel rods. These can be used at the intake directly behind the coarse screens or trash rack, or in the water system at a more convenient downstream location. They remove the finer materials from the water and prevent the entrance of wild fish into the hatchery.

The regulatory agencies have fish screening requirements to protect wild fish from entering water intakes, and the general approach velocity and screen mesh size by size of fish are noted in Table 3.

Table 3. Recommended maximum approach velocity and minimum screen mesh size for salmonids on intake systems in the Columbia River. (Source: Swan, 1980).

<u>Fish type</u>	<u>Approach velocity</u>	<u>Screen mesh size</u>
Salmonid fry	0.5 feet/sec	0.14 inches
Salmonid fingerlings	1.0	0.25

Some fisheries agencies have used a heavy-duty wedge wire grating in select locations for a combination trash deflector and fine screen system. Grating bars are V-shaped with the 3/16-inch wide top face to the outside. The V bars are spaced with a 0.1 18-inch clear opening at the top face and are supported on 1/2-inch diameter bars on 4-inch centers, which are supported by 1/2 x 1-1/2-inch bars on 9-inch centers. This grating has a good performance record but the cost per square foot is high.

Advantages:

- See above description discussion

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Disadvantages:

- Requires regular cleaning or brushing
- Units are usually remote from main facility
- Requires almost continuous attention during storms, floods, and freezing conditions
- Fine sands and silts pass through these screens

Information Sources:

Washington Department of Fisheries Grays River Salmon Hatchery for the wedge wire grating intake

Tulalip Tribal Salmon Hatchery, WA for the wedge wire grating intake

Most all Northwest salmon and steelhead hatcheries for trash rack and fine screened intakes

Pacific Wire Works, Inc.

Cost:

Hardware cloth screens cost about **\$14/ft²**; life expectancy is ten years.

Wood 2 x 4 trash racks cost about **\$8/ft²**; life expectancy is ten years.

Metal flat bar trash racks cost about **\$45/ft²**; life expectancy is 50 years.

Wedge wire grating (stainless steel) costs about **\$53/ft²**; life expectancy is 50 years.

2. Inclined Plane Screen The inclined plane screen for screening hatchery water supplies can either function as a fine screen or a combined coarse and fine screen. This screen has been previously noted in this Chapter (Part I, A-2, Instream Diversion Dam with Screen Intake Structure), and is popular because of excellent performance including (almost) self-cleaning of the screen surfaces by the water action (Figs. 1 and 5).

This unit is installed in a box structure sloping downstream in the direction of the water flow. Screened water falls through the screen and the debris and wild fish fall off the screen's lower end and are returned to the stream. The water chamber under the screen connects to the water supply system. The screen is framed with structural steel members, and the screening material can be hardware cloth, perforated plate, or wedge wire grating media. The type of material used will depend on the size of the stream, severity of flooding, amount of water used, etc.

Advantages:

- Low maintenance
- Highly effective
- Partially self-cleaning with excess water
- Can be designed for an adjustable slope angle with the horizontal
- The screen can be cleaned by back flushing if designed with this capability
- Wild fish pass downstream

Water Collection, Delivery, and Quality Improvements

Disadvantages:

- Passes silt and sand
- Requires regular observation and debris removal if necessary
- Can freeze if water supply is low during extremely cold weather

Cost:

Following cost estimates are only for the structural steel-framed screens:
Hardware cloth screens cost about **\$24/ft²**; life expectancy is 15 years.
Perforated plate screens cost about **\$28/ft²**; life expectancy is 15 years.
Wedge wire grating costs about **\$53/ft²**; life expectancy is 50 years.

Information Sources:

U.S. Fish and Wildlife Service Eagle Creek NFH, Oregon, and Kooskia NFH, Idaho
Washington Department of Fisheries George Adams and Grays River Salmon hatcheries

3. Rotary Drum Fine Screen Rotary drum screens are most commonly used at irrigation diversions to prevent wild fish from entering the diversion canals. They can also be used on fish pond outlets to retain fish or to screen hatchery water supplies. Hatchery water supplies generally take the screened water from inside the drum while the debris is carried over the top and washed off the downstream side of the drum by the water flow. A trash rack in front of this facility may be required. These screens, including advantages, disadvantages, costs, and vendors are described in detail in Chapter 5.

4. Water Settling Basins Water settling basins settle out stream **bedloads** of gravels, sand, and heavy silt from hatchery raw water supplies. The lighter fine silts, clays, and colloidal materials in suspension are extremely difficult to remove without specialized equipment, including sand or artificial media filters. **Bedload** settling occurs where water velocities lessen, and is observed in **forebays** of dams, intakes, pipelines, head boxes, and all types of incubation and rearing pond systems. Hatchery designs should provide for lessening of **bedload** impacts in the incoming hatchery water supplies and also provide for a means of removing these accumulations.

Sizing of settling basins depends on the specific gravities of the settleable solids and the percentage reduction desired. However, 1- to 2-minute retention time with a properly designed basin will provide substantial solids reduction. In the cases where settling basin lagoons are specifically built to settle out solid materials to provide better water quality to hatching and rearing facilities, water is usually introduced into the basin bottom as slowly as possible to minimize turbulence. The water is taken out at the rim, or far end near the surface, to obtain maximum settling. Access for mechanized equipment should be provided to periodically remove the settleable solids.

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In situations where pond space is available, hatchery operators should consider utilizing a portion of unused rearing or holding ponds for water settling to improve water quality (prior to incubation uses, **etc**).

Advantages:

- Easily constructed
- Low maintenance
- Provides effective settleable solid removal
- Collects settleable materials at one location for disposal
- Basins can provide some water storage for use during emergencies

Disadvantages:

- Settling basins require regular cleaning and sediment disposal; alternative is to increase basin depth for operation storage to extend cleaning interval time periods
- By-pass system required for cleaning, maintenance, and cold weather freeze-up
- Cover may be necessary to eliminate wind blown contaminants

Cost:

See Chapter 5 for comparable **ft³** costs for various large rearing ponds. Life expectancies are also similar to those noted for each large pond.

Information Sources:

U.S. Fish and Wildlife Service Little White NFH, Washington, Eagle Creek NFH, **Oregon**, and Kooskia NFH, Idaho
Oregon Fish and Wildlife Big Creek Fish Hatchery
Washington Department of Fisheries Skykomish Salmon Hatchery

5. Other Debris Removal Methods Several debris removal methods that we consider too **costly** for low-cost facilities or as ineffective, are noted below. Sources of **information** are provided for those who might want to explore these possibilities.

Micro-filters (Fig. 7) and sand filters are used to remove colloidal materials from water. The former can be observed at the WDF Naselle Salmon Hatchery or by contacting North Star. Unit cost is about \$90,000 for a system that will handle 1 cfs of water. The sand filter is used at the Dworshak National Fish Hatchery, Idaho, and supplied by Becker Industries, Clatskanie, OR.

Belt screens are widely used in industrial water intake systems and can be used for hatchery intakes or to retain fish in a pond, as used by WDF. Pacific Wire Works, Portland, Oregon or WDF can be contacted for further information.

Figure 7. A North Star micro-filter at the Puyallup Salmon Hatchery (WDF).

Gabion screens are rectangular wire mesh baskets (Fig. 2), which, when filled with stones, can be used to stabilize stream banks, develop instream pools, and screen water. Gabions are easily assembled, but are labor intensive, and are not recommended for screening of water supplies because of plugging, passing of wild fish, and the difficulties in backflush cleaning. Terra Aqua Conservation Co., Reno, NV is a supplier of the gabion wire.

B. GAS STABILIZATION

Gas stabilization systems in fish culture water supplies are used to equalize the dissolved gases in water with those in the atmosphere for the purpose of preventing gas bubble disease and to achieve maximum rearing capacity. Water near saturation with dissolved oxygen (DO) is essential for fish life. A deficiency of DO can reduce the rearing capacity of a water supply, or extreme cases of depressed DO levels can cause acute mortality. Nitrogen, on the other hand, can cause mortality by gas bubble disease when in a supersaturated state. Fish rearing problems are caused by too little DO or too much dissolved nitrogen. Oxygen is readily absorbed into surface water by any action which causes turbulence across the air-water interface, such as falling in a cascade, or by wind agitation. Therefore, a water supply from a stream with a steep gradient is usually at or near DO saturation and no treatment is necessary.

However, ground waters, defined as waters from springs or wells, sometimes are very low in DO, and usually supersaturated with dissolved nitrogen. These conditions are caused by both chemical and biological processes. DO in ground waters tends to combine chemically

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with other elements found in the ground, and bacterial growth may also utilize quantities of oxygen. Because both a readily available oxygen supply and agitation are not present in ground water sources, DO levels remain depressed. Dissolved nitrogen is relatively inert, both chemically and biologically, and levels of this gas remain high. Because cold water retains more gas than warm water, the geothermal warming of ground waters will usually cause nitrogen supersaturation.

Gas supersaturation can also occur in a number of other ways. In a fish hatchery system, supersaturation commonly occurs with the introduction of air into the water supply by the Venturi action of leaky pipes and/or pumps. As noted above, cold water retains more gas than warm water so the warming of a water supply causes supersaturation. For example, a steam plant discharging heated condensate water, and geothermal or seasonal warming in reservoirs leads to supersaturation. Therefore, it is important to recognize that supersaturated gas problems in water supplies can be continuous, seasonal, or of an instantaneous nature.

Much experimental work has been done to determine the cause and effects of gas bubble disease in salmonids. The formation of gas bubbles in fish tissue is most closely correlated with the total dissolved gas pressure of the water. Therefore, it is necessary to monitor both oxygen and nitrogen dissolved gas levels to determine the probability of gas bubble disease occurrence. Nitrogen gas generally constitutes about 80% of the total dissolved gas pressure of water, and because of its quantity and relatively inert nature, it is the principal cause of gas bubble disease. Table 4 provides recommended operational limits with hatchery water supplies of varying dissolved gas saturations.

We therefore recommend that waters be stabilized prior to use in a fish hatchery if the DO is less than 90% saturation, or if the dissolved nitrogen is greater than 102% saturation. The gas stabilization equipment selected will have, as its principal function, the interface of air and water with maximum surface area, commensurate with cost, and is used to equalize the dissolved gas pressures in the liquid with those in the atmosphere. Adding air or oxygen to water is often referred to as aeration. Removing nitrogen from water is referred to as degassing or sometimes called deaeration. Both require that the gas phase and the water phase be contacted to permit interphase diffusion to occur. The gas and water can be conveniently contacted with gas dispersed as bubbles. The gas-liquid can be mechanically agitated, as with an impeller, or as in the simplest design, agitation can be accomplished by the gas itself.

Early day hatchery water aeration schemes were simple and required no mechanical assistance, but frequently they could not approach DO saturation. To improve performance, energy must be expended. The energy input (horsepower/DO increment) is linear until about 90% saturation. Further DO increases require increasing aeration power input, and 100% saturation is practically impossible to attain under hatchery operating conditions. For example, Bouck, G.R., (personal communication) indicated that one unit of electrical energy may provide 90% DO saturation and fifteen units of electrical energy would be required to approach 100% DO saturation. Or water falling through a 4-foot high packed column may provide for 90% DO saturation, but an extremely high packed column is required to approach 100% DO saturation.

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Table 4. Dissolved gas limitations for hatchery water supplies.

<u>Dissolved oxygen level</u>	<u>Operations impact</u>
Greater than 90% saturation	Incubation and rearing at maximum loading densities
70% to 90% saturation	Rearing at 30 % reduced loading densities
Less than 70% saturation	Not recommended; fish health impaired by prolonged exposure
Less than 30% saturation	Total fish mortality
<u>Dissolved nitrogen level</u> ⁽¹⁾	
Less than 102 % saturation ⁽²⁾	Incubation and rearing at maximum loading densities ⁽²⁾
Greater than 102% saturation	Fish fatalities can occur; more critical for small fish
Greater than 107% saturation	Total mortality of small fish; gas bubble disease occurs in larger fish

(1) Assuming that dissolved oxygen is at saturation level

(2) It is the opinion of Bouck (personal communication), that supersaturation should not be allowed during incubation as serious damage can occur with Atlantic salmon and brown trout.

Gas stabilization units in use at Pacific Coast hatcheries agitate water in a number of ways to accomplish water contact with the atmosphere to increase DO or reduce dissolved nitrogen gas levels in their water supplies. All of these units require the use of energy to accomplish the water to air contact. The Packed Column Aerator is becoming popular for hatchery operations and appears to be the most cost effective system in use today. The gas stabilization systems now in use are described below.

1. Tower/Media or Packed Column A packed column is a cylindrical tower or pipe constructed of fiberglass, PVC, aluminum, or other rigid, durable material and filled with bio-rings or other bio-medias (Figs. 8 and 9). Tower dimensions are variable, but usually range from 4 to 12 feet high and approximately 8 to 48 inches in diameter. Bouck et al., (1981) reported that 1-inch rings were most efficient, but rings commonly used are approximately 1.5 inches in diameter or larger. An aeration fan can be incorporated to force air into the tower bottom in order to increase water capacity through the system. Water must be free falling with no media submergence. As water is added to the top of the tower it gravitates down through the plastic media. Loading should not exceed 1 liter/min/cm² of tower

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cross section (250 gpm/ft²). Gas stabilization is accomplished by the rumbling water exposed to air. DO is increased and nitrogen is decreased in the same unit. Gases approach their air equilibrium value.

Fish Management Consultants highly recommends pack column system as the very best aerator for fish culture operations. Owsley, (1979) said, "The packed column cannot guarantee nitrogen gas levels of 100 % saturation, but to date the column is the most economical and efficient degasser available to the fish culturist."

Advantages:

- 0 Easily installed on new or existing operations
- 0 Economical to construct
- 0 Highly effective in stabilizing gas levels in water supplies
- 0 Very low operating and maintenance cost
- 0 No moving parts except for the optional air compressor
- 0 The minimal head required can be as little as 3 feet

Disadvantages:

- ° Requires 3 to 15 feet of water head depending on water to be treated
- ° Falling water exposed to the atmosphere will lose or gain temperature units depending on air temperatures. Units that are covered or housed during extreme weather conditions or at all times will minimize water temperature gain or loss to less than 1F
- ° Does not necessarily provide adequate protection if overloaded with water, or if extremely sensitive organisms are involved

Cost:

A 12- x 4-foot Tower/Fan Aerator, capacity 700 gpm, costs about \$6,250/unit.

Figure 8. A packed column gas stabilization system consisting of a single cylindrical tower of aluminum pipe and filled with bio-rings. Dworshak NFH, Idaho (USFWS).

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A 5- x 1-foot Packed Column **filled** about 4.5 feet high with 1.5-inch bio-rings, capacity 100 to 150 gpm, costs about \$200/unit. The above units have a 50-year life expectancy.

Information Sources:

U.S. Fish and Wildlife Service Dworshak NFH, Idaho, and Eagle Creek NFH, Oregon
Washington Departments of Game and Fisheries Lyons Ferry Fish Hatchery
Tulalip Tribal Salmon Hatchery, Washington
Bio-ring plastic media and water distribution plates suppliers: Glitsch, Inc., Norton Co., or Koch Engineering Co.
Fiberglass Tower Shell suppliers: Justin Enterprises, Inc., Chemical Proof Corp., or Ershigs Inc.

Figure 9. Multi-units of cylindrical towers constructed of aluminum pipe and filled with bio-rings.

2. Aspirator An aspirator is defined as an apparatus using suction for moving a fluid or gas. The aspirator aerator utilizes water under pressure moving past a pipe open to the atmosphere, all inside a chamber, to create a vacuum in the air pipe. The vacuum draws in atmospheric air for mixing with the water and discharges from the chamber into a water tank.

Criteria developed by Burrows and Combs, (1968) at the Abernathy Salmon Cultural Development Center, requires that each aspirator be supplied with 125 gpm at not less than 10 psi water pressure. Each aspirator is to have 4 ft² of tank surface area

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and discharge into a minimum of 5-foot tank water depth. The aspirator discharge pipe to be 6 inches above the **tank** water surface. Owsley, (1979) does not recommend this system to deaerate, or where water supplies are at or near dissolved nitrogen saturation, because aspirators tend to increase dissolved nitrogen in the water.

Advantages:

- Low cost
- Low maintenance-no moving parts
- Good water aeration

Disadvantages:

- Requires a pressurized water supply at the aspirator
- Requires a tank to contain the aeration operation

Cost:

The cost per aspirator is about \$120, including connection to a header pipe. Does not include costs for header, tank, or water to and from the facility. Life expectancy is 50 years.

Information Sources:

U.S. Fish and Wildlife Service Kooskia NFH, Idaho, and Leavenworth NFH, Washington
Oregon Fish and Wildlife Bonneville Fish Hatchery
U.S. Fish and Wildlife Service Abernathy Salmon Cultural Development Center, Washington

3. Paddle Aerators These are motor driven paddles mounted on a fixed elevation support system at the pond water surface of the aerator tank, or a floating support system on the aerator tank water surface. Dworshak National Fish Hatchery uses multiple 25 HP aerators to each aerate 8,000 gpm of water.

Advantages:

- Excellent water aeration
- Excellent water deaeration

Disadvantages:

- Requires a standby power source during power outages
- Requires a tank to contain the operation
- Requires extremely high equipment maintenance and operating costs
- Constant tank water surface elevation required for a fixed elevation paddle aerator support system

Cost:

A motor driven paddle aerator costs about \$1250 per HP. This does not include the aerator tank or costs of water delivery in and out of the system. For continuous use, heavy maintenance can be expected every three years, and with a good rehabilitation program this equipment could last 15 years.

Information Sources:

U.S. Fish and Wildlife Service Dworshak NFH, Idaho for the fixed elevation support system, and Kooskie NFH, Idaho for the floating support system
Pacific Water Works Supply Co.
Infilco-Degrémont, Inc.

4. **Spray Aerators** This system is similar to the aspirator detail discussed above except that the spray supply taps in the header pipe are on 12-inch centers. The aspirator attachment is deleted and is substituted with a small **3-inch** plastic lawn sprinkler head screwed into the free end of the tapered pipe. **The** sprinkler head is secured in a face down position to sprinkle water directly on top of the aerator tank's water surface. Water pressure of 20 psi in the header pipe sprays out 2 to 3 **gpm** at each sprinkler head. Increasing the water pressure will increase head spray output. Do not use metal sprinkler heads which contain heavy metals.

Advantages:

- Low cost
- Easily installed
- Low maintenance, no moving parts
- **Good** water aeration and deaeration

Disadvantages:

- Requires a pressurized water supply at the spray heads
- Requires a tank to contain the aeration operation
- Require overhead housing for severe weather conditions because of heavy icing with the water spray

Cost:

The cost is \$25 per sprinkling head connection. Does not include costs for header, tank, housing, or water to and from the facility. Life expectancy is 50 years, but the sprinkler heads require replacement at two-year intervals.

Information Sources:

U.S. Fish and Wildlife Service Lahotan NFH, Nevada, and Dworshak NFH, Idaho.

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5. Floating Aerator This system consists of a pump and motor mounted on a float that is anchored to the pond bottom or attached by shore lines. The aerator has a screened intake on its underside at about the 4-foot water depth, and lifts water above the pond surface to discharge back to the pond (Fig. 10). The discharge falls against plates in a turbulent manner to aerate the water. This equipment (Fig. 11) is primarily used to maintain pollution abatement pond wastes in an aerobic condition where water exchange rates are low, or it may be used in a small lake to improve the DO. It lifts about 400 gpm per horsepower.

Advantages:

- ° Easily installed
- ° Equipment is portable provided electric power is available where aerator is to operate
- ° Retards icing of pond surfaces during cold temperatures
- ° Used in emergencies at various hatcheries to aerate fish ponds during critical low dissolved oxygen periods

Disadvantages:

- ° Maintenance required for moving parts
- ° Poor efficiency in aerating and de-aerating fish hatchery water supplies

cost:

The cost is about \$1,500 per HP for 3 HP units and larger, and about \$2,000/ HP for smaller units. With good maintenance, this equipment has a ten-year life expectancy.

Information Sources:

U.S. Fish and Wildlife Service Eagle Creek NFH, Oregon (to aerate a pollution abatement pond)

Washington Department of Game Skamania Steelhead Hatchery (to aerate a pollution abatement pond)

H.D. Fowler Co., Inc.

Agri-Glass

6. Vacuum Degassing Vacuum degassing increases differential pressures in an airtight chamber between the air and the liquid's dissolved gases. Lowered air pressures reduce the liquids capability to maintain dissolved gases in solution. Air pressures are lowered by vacuum-type air pumps that maintain the chamber's air pressure significantly below atmospheric. A problem associated with this system is that the degassing removes all dissolved gases, including dissolved oxygen. Therefore, aeration of the degassed water is essential both before and possibly after vacuum degassing to obtain the dissolved oxygen saturation for fish cultural needs. buck, (personal communication) reports that operators of vacuum degassing systems have widely divergent opinions of its effectiveness for solving their gas

Figure 10. A floating aerator in use at Allison Springs Rearing P o n d (WDF).

Figure 11. A 'floating aerator in use at a pollution abatement settling pond at the Big Creek Fish Hatchery (OFW).

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saturation problems. Some biologists believe that vacuum degassing is necessary when chronic low level gas problems occur and certain species/life stages are cultured, i.e. Atlantic salmon fry, brown trout, and lake white fish. This equipment and system is expensive with high energy requirements, and therefore, is not considered a viable process for low-cost developments and operations.

Cost:

A vacuum degassing chamber with support equipment will cost about \$200 to \$500 per gpm of systems flow, and has a 25-year life expectancy.

Information Sources:

Michigan State Fish and Game Department Wolf Lake Fish Hatchery
U.S. Fish and Wildlife Service White River NFH, Vermont; La Crosse National Fishery Research Laboratory, Wisconsin; and National Fisheries Center, Leetown, West Virginia

7. Multicone Aerator The multicone aerator is an aspirating, multi-stage type aerator used in water and sewage treatment plants for the removal of dissolved gases or aeration of the water supply (Fig. 12). This equipment is constructed of cast aluminum for mounting to a bolt-on horizontal flange connection on the incoming water supply. The manufacturer indicates that the water flows up through the aerator's central inlet riser into the top inlet bowl of the primary cone and discharges into the primary aspirator chamber through multiple primary distribution **orifices**. The jet action of these many small streams of falling water, and the shaping of the aspirator chamber causes air to be brought in through the side of the primary cone. This aspirator air action with the falling water is repeated through three stages of vertically stacked cones, and then spills out in a waterfall into a basin or container for distribution.

This equipment is available in 100 to 2800 gpm capacities. Equipment height varies from 63 inches for the small capacities to 76 inches for the larger sizes. Cone diameters vary from 15 inches on the small 100 gpm unit to 76 inches for the largest 2800 gpm size.

Figure 12. A multicone aerator at the **Beaver Creek Steelhead Hatchery (WDG).**

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Advantages:

- 0 Easily installed
- ° Low maintenance no moving parts
- ° Very good water aeration and deaeration
- ° Low operating cost

Disadvantages:

- ° Relatively high cost equipment

Cost:

The cost of the 100 gpm aerator is approximately \$10,000, the 1200 gpm aerator is about \$28,500, and the 2800 gpm unit is about \$43,000. Life expectancy for this equipment is 50 years.

Information Sources:

Washington Game Department Beaver Creek and Cowlitz Steelhead hatcheries
Infilco Degremont, Inc.
Pacific Water Works Supply Co., Inc.

8. Dissolved Gas Measurement **There** are numerous dissolved oxygen measuring instruments and chemical kits developed for monitoring hatchery water supplies, but relatively few instruments are available for dissolved nitrogen monitoring. Measuring of the dissolved gas levels are discussed below.

Dissolved Oxygen The DO levels in hatchery water supplies are easily measured with DO meters that provide for direct read-out of milliliters of DO per liter of water. Chemical titration kits are also often used by hatcherymen to measure the DO in water supplies. The titration kit system takes more time to make the measurement, but is more reliable. The problem with the meter is the periodic fouling of the sensor probes and a need for frequent calibration. We recommend that all hatcheries be equipped with DO measuring titration kits sold by **Hach** Chemical Co. of Loveland, CO., for about \$150. Direct read-out DO meters can also be purchased from the above company for \$800 and up.

Dissolved Nitrogen Analysis of dissolved gases, including nitrogen, in water traditionally has been difficult and required that the analysis be made in a laboratory. In recent years the Weiss "**Saturometer**" and the **Bouck** "Gasometer" were developed to more conveniently and easily measure gas saturation in water. **Bouck, (1982)** compares these two instruments and provides details for assembling the inexpensive Gasometer. Both instruments measure air pressure in the water similar to an air gauge that measures air pressure in an automobile tire. We do not advocate that all hatchery operators build or be trained in the use of this gas saturation measuring equipment. But

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all operators should be knowledgeable and recognize that supersaturated nitrogen waters are highly lethal to fish, cause gas bubble disease, and the use of such water must be avoided. If this condition is noted, a person qualified to analyze the water for nitrogen should be contacted. See **Bouck, (1980)** for cause and effect relationships for better understanding of gas bubble disease.

The cost of materials and supplies to assemble the Gasometer is less than \$200. Information sources on the assembly and use of gas saturation measuring equipment are USFWS Abernathy **Salmon** Cultural Development Center, WA and Dworshak National Fish Hatchery, ID; also the Bonneville Power Administration, Division of Fish and Wildlife, Portland, OR.

C. WATER STERILIZATION

Water sterilization systems are costly and relatively new to fish culture. They should be unnecessary for new hatchery developments in the Columbia River Basin if proper water source selection is made. Each method has specific use requirements which should be researched if treatment is necessary. Power outages, power surges, and other unforeseen events concern the culturist. Besides being costly, these systems have the possibility of equipment failures.

The methods that are available include electric grids, ozone, chlorine, and ultra violet light (UV). The electric grid has been tested (Combs, 1968) and used by the USFWS Abernathy **Salmon** Cultural Development Center. Combs reported that the principal factors affecting the power demand of a parallel-plate-type electrical grid are the quantity of water treated, the specific conductivity of the water, the voltage gradient, and the area of the plates. It could be used to control the cercariae of the trematodes (Sanguinicola sp and Nanophyetus salmincola).

Ozone is very effective against **micro-organisms**. The equipment is very costly and in 1977 the operational cost was \$0.043-0.049 for 1000 gallons of inflowing water at the USFWS Abernathy Salmon Cultural Development Center (Anderson, 1982). Ozone presents the risk of toxic overdose to the fish, is also very corrosive, and potentially dangerous to human health (Anderson, *ibid.*). The system would involve prefiltering, ozone contacting, and then deozonation; the latter by retention, aeration, activated carbon filtration, or a combination of these. Information sources are Dr. Gary Wedemeyer at the National Fish Research Center in Seattle, the WDG Cowlitz Trout Hatchery personnel, or A.R. Anderson at the USFWS Abernathy Salmon Cultural Development Center, Washington.

A water chlorination system is extremely corrosive, but has the advantage that electrical power is not required. Like ultra-violet light, it is effective on micro-organisms. The water system requires de-chlorination prior to use on fish. R.W. Beck and Assoc., Seattle, WA has incorporated this into the discharge system of the Medvejie Creek Hatchery at Sitka, Alaska. Oregon Aqua foods operates a chlorination system at their Springfield, Oregon facilities. Both are sources of current information.

Ultra-violet light modules are available that handle 5 to 4,000 gpm. When treating the supply water U-V is reported to be effective on bacterial reduction at the 99% kill level and for the control of the virus causing IHN (infectious hematopoietic necrosis) (Wedemeyer, personal communication). **Fortier** of R.W. Beck and Associates (personal communication) related that the ultra-violet module they will install in the inflowing water at the Medvejie Creek Hatchery costs around \$30,000. This will treat about 2 cfs of water and we calculate it will cost \$400 per month for electrical power (based on **\$0.04/kwhr**). Anderson, (1982) reports that the 1977 cost was (\$0.035) per 1000 gallons of inflowing water. The replacement of the bulbs would be an additional cost. Clear water is a requirement for this unit to be efficient. Sources of information are USFWS Dworshak NFH; USFWS Abernathy Salmon Cultural Development Center; Department of Microbiology, Oregon State University; Syndel Laboratories Ltd.; and **EMA** Marketing, Inc.

D. TEMPERATURE CONTROL **TECHNIQUES**

As suggested in Chapter 1, water temperature considerations should begin with the source of supply. However, if the desired temperature ranges are not available, we believe that some temperature adjustments are economically feasible through the mixing of natural water sources, and to a limited extent, the use of heating and chilling systems.

Because the rearing of juveniles and the holding of adults take large volumes of water, direct heating or chilling is not considered a viable low-cost technique. Warming 1 cfs of water **10F**, would cost **\$19,959/month** (based on a **\$0.04/kwhr**). Thus, we consider that water temperature adjustments for rearing water should be limited to the use of natural sources such as springs, wells, or streams. The temperatures of off-station surface water sources, for example, that are used for acclimatization ponds, net pens, or net enclosures, usually are ideal for production and conditioning of fish prior to and during the smoltification process.

If temperature control for incubation is not possible at the site, one should explore the potential of using the waters of near-by facilities. Generally, we do not recommend alevin incubation with heated or chilled water because of the cost, however, because the eggs require extremely small amounts of water, a water heater or chiller may be feasible. A 16-40 gpm recirculating chiller system capable of reducing and maintaining water temperatures from 47F to **37F**, and with 10% make-up water, costs between \$6,000 and \$12,000 (R.W. Reck and Associates, Seattle, personal communication). The 16 gpm will incubate 2.0 million **coho** eggs. The monthly energy consumption for a 16 gpm system with a 10% makeup water, and chilling the water **10.8F**, would cost \$80 (based on **\$0.04/kwhr**).

An 8F differential in temperature (**45F** vs 37F) changes the hatching time on **coho** from 65 to 160 days, a delay of three months. With regard to egg incubation water, chilling has its greatest benefit with **coho** and spring chinook, while heating has its greatest application for accelerating steelhead trout and fall chinook. A potential problem occurs if the accelerated fish are placed in rearing waters where the temperatures are too cold for initial feeding. A heating system using 16 gpm, with 10% make-up water would have a \$195 monthly electrical billing if the water was heated **10.8F** (SC). At the Eagle Creek NFH, Oregon they use two swimming pool heaters that cost \$250 each and heat 50 **gpm**

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of water 3F for a monthly electrical cost of \$2,000 (Jim Holway, personal communication). This system does not recirculate the water. Many techniques for water manipulations exist, and it is suggested that agencies be contacted for further information. Again, we caution that heating water may cause supersaturation of gases, and that the heating elements may have the potential of giving off toxic ions.

CHAPTER 3

ADULT COLLECTION, HOLDING, AND SPAWNING

The capture of adult salmon and steelhead trout and the collection of their sex products **marks** the beginning of a new season for the fish culturist, and the success of the program depends upon effective capture, proper holding until ripe, and then careful spawning.

This Chapter introduces the various methods used to guide the fish to the hatchery from the native stream, or to block their upstream passage for subsequent capture; and further discusses hand methods of capture, and the use of imprinting as a tool to influence migration patterns.

We also discuss large formal holding ponds and compare their advantages, disadvantages and costs. Informal holding facilities most suitable for low-cost operations are described, as well as general spawning techniques, tools and facilities required, and the use of anesthetics and maturation control.

PART I. ADULT COLLECTION

Many different collection systems or methods are available to intercept the upstream migration of adult salmon and steelhead trout to obtain spawning stock. These can be either permanent or temporary structures, and range from simple **instream** weirs to formal concrete barriers and **fishways** that lead adults to permanent holding ponds; or relatively simple hand methods that work well for low-cost operations. All are discussed under barriers, fishways, and hand methods.

A. BARRIERS

All barriers discussed here can conflict to some extent with navigational and recreational uses of a stream. This situation must be considered early in the planning stage.

1. Single and Double Racks A rack is simply a fence installed across a stream to stop upstream migrations (Fig. 1). Racks are installed singly or in pairs. In the former case, an opening in the fence leads the fish into a trap. This opening is termed a "**V**" trap tunnel (Fig. 2), and once fish enter the trap they seldom find their way back through the tunnel. This fence, "**V**" tunnel, and trap arrangement is very effective for collecting small groups of spawning stocks; particularly on small streams.

A double rack system uses two racks spaced across the stream to form an adequate holding area. The lower rack has a "**V**" tunnel opening to lead fish into the holding impoundment. This is a popular method to collect and hold adult salmon, and in many cases, spawning is accomplished on the adjacent river bank.

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Racks can be permanent or temporary, and the former usually are constructed of 2- x 4-inch metal pickets supported by metal frames and counterforts anchored into a reinforced concrete apron spanning the entire stream. These facilities are usually used at large stations which handle many fish, and where the cost can be justified by the long life of the project. Temporary racks are constructed with 2- x 4-inch lumber, but broomstick weirs (Fig. 3) or metal poles (Fig. 4) are more portable and are good low-cost materials. These are framed and secured to three- or four-legged horses set into the stream bed (Fig. 5). The horses are heavily weighted with rocks, concrete blocks, or cement bags to anchor them firmly to the stream bed. Tie-back cables secured to deadmen on the stream banks provide added rack stability. A walkway on top of the rack permits access to remove debris build-up on the upstream side. The spaces between the pickets vary between $\frac{3}{4}$ and $1 \frac{5}{8}$ inches according to species (see Table 2). It is essential that the spacing be correct. It should be as large as possible to pass small fish, water, and small debris, yet small enough to stop the desired fish species without gilling, as illustrated in Fig. 6.

Advantages:

(Temporary rack)

- Low cost
- Temporary; can be rapidly and easily installed by hatchery operators
- Spacing of rack pickets allows **instream** movement of smolts

(Permanent rack)

- Generally easier to clean, easier access, and can withstand flooding

Figure 1. Single wooden fish rack at Cascade Fish Hatchery (OFW). Upstream face on left.

Figure 2. "V" trap tunnel at Big Creek Fish Hatchery (OF\<). Looking upstream.

Figure 3. Broomstick weir in British Columbia (DFO).

Figure 4. Metal pole weir at Red River Rearing Pond (IFG). Looking downstream.

Figure 5. Small temporary weir (A) Four-pod horse, (B) 2- x 4-foot picket section. Looking downstream.

Disadvantages:

(Temporary rack)

- Requires seasonal installation and removal, depending on fish species
- Subject to washout during high water or ice conditions
- Requires frequent cleaning and maintenance

(Permanent rack)

- May require provisions for fish passage
- **Bedload** may accumulate above, requiring periodic removal

cost:

The estimates are based on the fabrication and installation of temporary racks by hatcherymen.

Temporary rack 6 feet high: **\$75/lin ft.**

Temporary trap (8 x 12 x 6 feet high): \$2,000.

"V" trap tunnel: \$300.

Permanent rack 6 feet high: **\$1,200/lin ft.**

Dismantling, salvaging, and storing temporary racks, traps, and "V" trap tunnel: **\$35/lin ft.**

Re-installation of temporary rack: **\$40/lin ft.**

Re-installation of trap: \$800.

Re-installation of "V" trap tunnel: \$100.

Life expectancy: 5 years for the temporary rack, and 20 years for the permanent rack.

Information Sources:

Oregon Fish Wildlife Cascade Salmon Hatchery

Washington Department of Fisheries Kalama River Rack

Idaho Fish and Game Department Red River Facility and Pahsimeroi **Steelhead** Collection Facility

Figure 6. Pink salmon gilled in a pole rack.

2. Electric Fence The electric fence (Fig. 7) diverts adult salmon and steelhead trout by mildly shocking them when they enter a stream-width electric field between a set of suspended electrodes and a groundline. An adjacent **fishway** that is eventually found by the fish leads them upstream into a trap. When properly

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operating, this system does not harm either the adult fish or downstream migrants. Operated by 110 volt, 60 cycle, single-phase alternating current, the electrodes are spaced on 3-foot centers and are located 15 feet upstream and **parallel** to a ground line staked flush across the stream bottom. The factors which influence the efficient operation of the **electrical** barrier are water velocity and voltage gradient. The water velocity within the electrical field should be 3 **ft/second** or greater to wash the stunned fish downstream from the electrical field to prevent mortality. To provide a positive barrier, the minimum barrier voltage, should be 0.5 volts per inch with a field length of 10 feet, in which the voltage gradient may vary from 0.3 to 0.7 volts per inch. This barrier has **satisfactorily operated** in streams up to 200 feet wide and 8 feet deep. The electrical demand varies with the number of electrodes submerged and the depth to which they are submerged. This averages approximately 10 watts per foot of electrode submergence. A **100-foot barrier's** electric demand averages approximately 300 watts. Therefore, at **\$0.04/KWH**, electricity costs will be about **\$0.30/day** to operate.

Figure 7. Electric fence and fishway at the Quinault NFH.
(Wooden planks over fishway can be dangerous if slippery
or if deterioration occurs.)

Advantages:

- ° Low construction cost compared to permanent racks
- ° Easily installed and dismantled
- ° Low **maintenance and** operating costs
- ° Passes debris
- ° Passes downstream migrating fish without harm
- ° Positive barrier to adult fish even during flood stage

Adult Collection, Holding, and Spawning

Disadvantages:

- The minimum water velocity of 3 feet per second or greater may require bank abutments to confine stream flow
- Concrete or wooden stream apron may be necessary to eliminate uneven bottom or large boulders that could trap stunned adults or cause uneven flow conditions and alter barrier field voltages
- Electrical power outages inactivate the barrier in the absence of standby emergency power
- Area must be fenced and posted to protect the general public
- Adult females penetrating the electrical field can receive sufficient shock to induce spinal curvature, which might cause problems for those that spawn naturally

Cost:

An electric fence without bank abutments or stream bottom apron, and with electric power on site is costed as follows:

Streams over 75 feet in width: approximately **\$165/lin ft.**

Smaller streams 75 feet or less in width: approximately **\$275/lin ft.**

Life expectancy is 25 years.

Information Sources:

U.S. Fish and Wildlife Service Quinault NFH, and **Abernathy** Salmon Cultural Development Center, Washington
Oregon Fish and Wildlife Bonneville Fish Hatchery

3. Velocity Barrier A velocity barrier can be described as a sill type structure installed across a stream and designed to hydraulically produce water velocities of 16 feet per second across the downstream apron. This velocity approaches the swimming abilities of salmon and steelhead trout and effectively stops them from moving upstream through the barrier (Fig. 8). They are used in conjunction with **fishways** to direct fish to holding ponds and are a high-cost unit.

Advantages:

- Low maintenance
- Minimal damage to fish as they attempt to swim past this barrier
- Passes debris

Disadvantages:

- High-cost and not recommended for low-cost facilities
- Moderately difficult to construct in a flowing stream
- Barrier submerges during high flow and may allow fish to pass
- Structure usually requires upstream fish passage for native fish

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- Structure creates slightly higher upstream water levels and may require easements for water backing up in sensitive areas
- Barrier may require removal of **bedload** build-up upstream of structure at **two- or three-year** intervals
- Navigation must be considered

Figure 8. Concrete velocity barrier at Klaskanine Fish Hatchery (OFW).

Cost:

For a 30-foot wide stream, the cost is \$30,000 or **\$1,000/lin** ft. This includes a reinforced concrete sill, apron, and two bank abutments with rip-rap. The structure has a 50-year life expectancy.

Information Sources:

U.S. Fish and Wildlife Service Coleman NFH, California
Idaho Fish and Game Rapid River Hatchery
Washington Department of Fisheries Elokomin Salmon Hatchery

4. Vertical Barrier Dam The upstream migration of salmon and steelhead can be stopped by a vertical **6- to 8-foot** water drop if the fish are prevented from sounding to enhance their jumping ability. Any one of a number of dams can produce the above waterfall. However, many of these structures injure fish when they continuously jump at the falling water and fall against the dam's hard surfaces. A recommended vertical barrier is an **"Ambersen"** type dam (named after the

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designer). The Ambersen dam's face is sloped upstream, and jumping fish fall into water flowing across the downstream apron. This dam is constructed with concrete counterforts, stop logs, and a poured-in-place concrete leveling apron. Openings in the counterforts allow fish access across the entire apron width (Fig. 9). These structures are used in conjunction with **fishways** to lead fish to holding ponds, are high cost and not applicable for low-cost facilities.

Figure 9. Cross-section of a concrete vertical barrier dam.

Advantages:

- Low maintenance
- Minimal damage to fish as they attempt to swim past this barrier
- Passes debris

Disadvantages:

- High cost
- Moderately difficult to construct in a flowing stream
- Upstream and downstream water elevation differences are minimized during high flows, enabling fish to move upstream
- Usually requires provision for upstream fish passage for native fish, which increases the cost

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- Structure creates higher upstream water levels and may require **flowage** and/or flood easements in sensitive areas
- If necessary, **bedload** build-up above barrier may require removal at five- to ten-year intervals

Cost:

For a **30-foot** wide stream, the cost is \$51,000 or \$1,700 per linear ft. This includes a reinforced concrete dam, apron, and two bank abutments with rip-rap. The structure has a **50-year** life expectancy.

Information Sources:

Washington Department of Fisheries **Kalama #2** Salmon Hatchery

B. **FISHWAYS**

Fishways are used to pass fish over natural stream obstructions and man-made structures, but they can also be used at fish facilities to help collect fish for spawning purposes. The usual application is to lead the fish from the stream to the **fishway**, which in turn directs the fish to formal adult holding facilities. The fish are intercepted in the stream by velocity barriers, weirs, or electrical fences, as previously described, which lead them to the **fishway** entrance.

Three types of **fishways** are used in the Columbia Basin: the pool-and-weir, vertical slot baffle, and the Denil or its variation, the Alaskan Steep Pass. The three types are described in the publication "**STREAM ENHANCEMENT GUIDE**" by KWL and Associates, and D. B. Lister and **Associates** (1980) as follows:

"The pool-and-weir type **fishway** consists of a series of vertical partitions installed at intervals down the length of a specially constructed channel or flume. Water flows over the top of the successive partitions, each **12"** lower than its predecessor, creating a series of step-like pools which the mature fish can ascend with ease. Pool-and-weir **fishways** are most effective where water levels remain fairly constant. Where water levels fluctuate, regular adjustments are required at the upstream end to provide the optimum rate of flow."

"The Denil **fishway** is a second type and is essentially a short section of flume with baffles affixed to the sidewalls and floor. The energy of water passing through this structure is dissipated in turbulence caused by the baffles which leave a narrow zone of low velocity flow. Denil **fishways** can be installed at much steeper slopes and, for a given height of obstruction, they can be substantially shorter than other types. A modification of the Denil **fishway**, the Alaskan Steep Pass, is smaller, uses less water, reduces velocities more effectively, can be prefabricated from aluminum, and is easily installed."

"The vertical slot **fishway** is the third type and also creates a series of pools and drops. The water flow passes from pool to pool through narrow slots extending the full height of the vertical partitions. The vertical slot **fishway** is self-adjusting to flow levels. This **fishway** provides passage for fish through a range of changing volumes or levels of water in the stream, without requiring adjustments of **stoplogs** or baffles. This is a great advantage, in view of the extreme discharge fluctuations of many streams."

Perhaps the most famous **fishways** on the North American continent are the vertical baffle **fishways** located in the Fraser River canyon at Hell's Gate in British Columbia, Canada. Vertical baffle **fishways** are very costly and are not considered applicable for use in conjunction with low-cost adult holding facilities.

Fishways that might be applicable for low-cost fish facilities and could be used to transport fish from a stream to a pond are evaluated below and in Table 1. For cost comparison, a 6-foot vertical rise from the streams to the holding pond was assumed. The estimated costs do not include costs for facilities to direct fish into the **fishway**.

1. Pool-and-Weir The most commonly used **fishway** in the Columbia River Basin is a concrete pool-and-weir **fishway**. The **fishway** of study is 48 feet long, 6 feet wide, and 8 feet high; constructed on a 1 on 8 floor slope with 6- to 8-foot long pools (Figs. 10 and 11). These **fishways** also are found to be constructed on 1 on 6 and 1 on 10 floor slopes. Weirs are wood. stop logs 6 feet wide with a cut, or overflow width, depending on the available water supply. Each 12-inch width of overflow weir flows about 3cfs of water at 12 inches of weir overflow water depth. The fish enter the holding facilities over a finger weir or through a "V" trap weir.

Figure 10. Pool-and-weir fishway in operation.

Advantages:

- Low maintenance

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- Requires small water flows for operations
- Easy to maintain flow when used at a hatchery

Disadvantages:

- High cost
- Does not adjust to varying water stages without weir adjustments
- Not difficult to construct except for the cofferdam-dewatering required to pour the fishway stream entrance

Cost:

The cost for this fishway is \$33,000 or \$5,500/ft of lift. This structure has a 50-year life expectancy.

Information Sources:

U.S. Fish and Wildlife Service
Spring Creek National Fish Hatchery, Washington
Washington Department of Game
Skamania Steelhead Hatchery
Oregon Fish and Wildlife Cascade Salmon Hatchery

Figure 11. Empty pool-and-weir fishway showing general construction details.

2. **Denil-Type** or Alaskan Steep Pass As previously noted, the Denil fishway (Fig. 12) is **very** similar in design and operation to the Alaskan Steep Pass fishway. The major **differences** are that the Denil is about 5 feet wide while the Alaskan Steep Pass is 2 to 4 feet wide. The Denil **requires** large water flows of 10 to 40 cfs while the Alaskan Steep Pass requires flows of less than 10 cfs. In our example, both are 36 feet long and installed on a 1 on 6 slope. **Because** of width and height difference, the Denil is usually installed **on-site** while the Alaskan Steep Pass is prefabricated from aluminum plate and then installed **on-site** as a portable unit. Both produce low water velocities allowing for fish passage through the middle of the structure.

Advantages:

- Low maintenance
- Easy to install

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- Passes debris and sediments
- Self-adjusts to varying upstream and downstream water stages
- Alaskan Steep Pass is portable and can be relocated as required

Disadvantages:

- Resting pool for adults required after each 6-foot vertical fishway lift

cost:

The cost of the Denil fishway is \$36,000 or \$6,000/ft of lift, and the Alaskan Steep Pass is \$30,000 or \$5,000/ft of lift. Life expectancy is 50 years for both fishways.

Information Sources:

State of Alaska Department of Fisheries
Washington Department of Fisheries Simpson Holding Pond for the steep pass ladder
Oregon Fish and Wildlife Lookingglass Creek fishway for the Denil fishway
Idaho Fish and Game Rapid River Hatchery for the Denil fishway

Figure 12. General outline and operational characteristics of Denil fishway. Reprinted courtesy of Kerr, Wood, Leidal and Assoc. Ltd., and D.B. Lister and Assoc. Ltd., Stream Improvement Guide, p. 33. March 1980. Vancouver, B.C.

Table 1. A comparison of fishway characteristics

<u>Fishway type</u>	<u>Cost/ft of lift⁽¹⁾</u>	<u>Life expectancy</u>	<u>Percent salvage for relocation-</u>
Concrete pool-&-weir	\$5,500	50 yrs.	0
Denil	6,000	50	33
Alaskan steep pass	5,000	50	100
Plastic pool & weir	3,000	20	100
Rock channel pool & weir	3,000	25	0
Wood pool & weir	1,667	10	80

(1) Based on a unit to lift fish six feet.

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3. Plastic Pool-and-Weir This fishway is a 5 x 48 x 5-foot deep channel of fiberglass-reinforced polyester plastics with a durable, opaque, external surface-coat to protect against ultraviolet light and provide a non-toxic environment for fish. The channel is equipped with six equally spaced fiberglass weirs, and a welded-wire cyclone-type fence on top of the channel's walls to contain the adult fish. This unit is prefabricated and then installed on-site with a 1 on 8 floor slope.

Advantages:

- Low maintenance
- Easily installed
- Portable and can be relocated to another area as required
- Requires small water flows for operations

Disadvantages:

- Has fixed weir heights and does not adjust to varying upstream water stages to maintain required channel flow
- Adults moving through this fishway can easily jump over the channel walls unless a barrier type fence is used for containment

Cost:

The cost for this fishway is \$18,000 or \$3,000 per ft of lift. This structure has a 25-year life expectancy.

Information Sources:

Alaska Fish and Game
Chemical Proof Corporation
Corrosion Controllers, Inc.

4. Rock Blasted Fishway No standards are available. However an excavated channel augmented with wood or concrete sills capable of allowing fish passage is required. Channel bottom must be rock, hard pan or erosion resistant material.

Advantages:

- Economical
- Passes debris
- Operates over a wide range of flow

Disadvantages:

- Extreme care required not to overblast and fracture excessive rock
- May only pass fish through small flow range

Cost:

The cost for this **fishway** is \$18,000 or **\$3,000/ft** of lift. This structure has a **25-year** life expectancy.

Information Sources:

None known to be in operation for bringing adults into holding ponds. However, rock excavated-sill **fishways** are operating at several natural barriers installed by Oregon Fish and Wildlife on the North Fork Klaskanine, Minam, and Lostine rivers, and Plymton Creek.

5. **Wood Pool-and-Weir Fishway** This Fishway is constructed with a 1 on 8 floor slope and framed with treated wood members similar to the framing **system** suggested for wood raceways in Chapter 5, and lined with marine plywood. **Fishway** dimensions are 4 x 48 x 4 ft high with six equally spaced pools separated by wood **stoplog** overflow weirs. Wire mesh fencing is necessary on wall tops to prevent adults from jumping out of the facility. It is important not to allow newly treated wood to be in direct contact with ladder flows as this may delay fish movement due to **odors**.

Advantages:

- Low cost
- Easily assembled and installed
- Small water flow requirements
- Small leakage is not a problem

Disadvantages:

- High maintenance costs
- **Fishway** may require ballast to prevent floatation

Cost:

The cost for this **fishway** is \$10,000 or **\$1,667/ft** of lift, and it has a 10-year life expectancy.

Information Sources:

Idaho Fish and Game Red River Rearing/Holding Area
Alaska Department of Fish and Game
Province of British Columbia, Ministry of Environment, Vancouver, B.C.

C. HAND METHODS

Usually adult fish collection facilities are provided at a hatchery, but in some instances a station is supplied with eggs from another source. Even though formal collection

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facilities are available, it may be necessary to collect other selected stocks to meet program goals. An example would be the collection of adults native to a particular tributary to maintain the genetic integrity and enhance production. In these cases, informal collection techniques are available that may be particularly useful at “low-cost facilities”. These methods, discussed below, usually require more labor, but generally the capital investment is minimal. If the fish are collected at or near maturity, adult holding facilities may not be required, resulting in further savings in capital costs and investment in both security type facilities and **personnel**.

1. Nets Gill nets and seines are commonly used to collect adult salmon for hatchery purposes. Gill nets are fished either set in a fixed position, or as drift nets and we recommend they only be used when fish are nearing sexual maturity. The former method captures fish migrating upstream while the latter method is used primarily on spawning beds. Both techniques generally necessitate transporting the adults to a holding facility at the hatchery because the fish usually are not completely sexually mature. When fish are nearing sexual maturity their firmly embedded scales protect them from injury, and with proper handling minimal losses will occur.

Seines are generally classified as beach or purse seines. The latter are used primarily in the marine environment, particularly in Alaska, and would have little practical application for collecting adults for spawning purposes in the Columbia Basin. Beach seines, the type of seine mainly used in hatchery work, are used extensively in hatchery holding ponds and can be used to collect adults from slow moving areas within streams. Generally they are used where fish are pooled prior to spawning. These nets have a heavily weighted lead-line to hug the bottom, and are usually set from a boat encircling a school of fish. Both gill nets and seines are available in a variety of standard sizes, but are often custom made to fit particular needs. A typical hatchery adult pond seine is illustrated in (Fig. 13). Further information can be obtained from fish agency personnel and the dealers noted in Appendix 2.

2. Snagging and Gaffing These are highly effective methods for collecting adults in smaller streams. Snagging works best when the fish are heavily schooled-up in pools. Figs. 14 and 15 illustrate equipment successfully used by the WDF. Usually the fish are “green” when captured and require transportation to holding facilities. At the WDF Humptulips Salmon Hatchery, the manager has taken 500,000 eggs in a single season in this manner.

Gaffing is used by some WDF hatchery managers to collect adults, particularly chinook. These are usually taken directly from the spawning beds, and a major advantage over some of the other collection methods is that the fish are almost always sexually mature and can be spawned immediately. Thus the costs of holding facilities and security measures are eliminated.

Gaffing requires good equipment (Figs. 16, 17) and clear water in order to see the fish. This method can be used to select stock and fish size; and one person can collect and spawn the adults.

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Figure 13. Typical hatchery adult pond seine.

Figure 14. PVC pipe used as pole for snagging at the Humptulips Salmon Hatchery (WDF).

Figure 15. Terminal hooks used for snagging: (A) weighted, (B) not weighted.

Figure 16. Terminal attachment of gaff hook to long pole.

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3. **Hook-and-Line Capture** The capture of adult fish with sport fishing gear is restricted almost exclusively to steelhead trout. It has been successfully used by DFO, and by WDG and their affiliated volunteer groups. Fish caught on sports gear are either tethered or placed in adult tubes (Fig. 17, Chapter 6) or floating pens (Fig. 16, Chapter 6); then transferred to transport trucks and hauled to hatchery ponds.

Hook-and-line capture is an excellent system for obtaining selected steelhead stocks for a new program, or to increase egg and fry survival for enhancement of a specific stream. It is relatively economical when used in conjunction with volunteer groups, and enhances good communications between management and user groups. The method is not practical for large egg taking programs.

4. **Electro-shocking** **Electro-shocking** is extensively used to capture adult pink, chum, chinook, and **coho** in shallow Alaska streams. Two culturists are required; one to operate the backpack electro-shocker (Fig. 18), and the other to dip the fish as they drift downstream. In Alaska it is common to obtain over one million eggs daily in this manner.

This method, like gaffing, works best on spawning riffles. The shocker is effective for capturing adult steelhead and **coho** from hiding places that would be inaccessible with other methods. It is also an advantage in a situation where returning adults enter a small hatchery stream but refuse to enter the adult trapping area. This trait applies to all species, but is particularly typical of chinook salmon. A compact, battery-operated shocker costs about \$2,000. Further equipment information can be obtained from Smith-Root Inc., or the Alaska Department of Fish and Game.

D. ARTIFICIAL IMPRINTING

Artificial imprinting is a method of artificially altering the homing response of salmon or steelhead (Scholtz, et al., 1975) so that the returning adults can be attracted to specific sites. One important application of this method would be to attract adults into a side-stream trap or collection site, and thus avoid the need for high-cost collection structures. Other potential management applications might be attracting surpluses to underutilized spawning areas, decoying adult surpluses to facilitate their harvest, or directing fish away from a potential overharvest area.

Figure 17. Gaff hooks on pole (A) improper angle on hook, (B) recommended angle.

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Artificial imprinting has been successfully conducted on **coho** and steelhead by introducing the fish to morpholine during stages of smoltification. Morpholine is a synthetic chemical that does not occur in natural waters. It is highly soluble in water, stable in the natural environment, and can be detected by the fish in very low concentrations (1×10^{-6} mg/l). Operational exposure rate, maintained during imprinting and in the receiving waters to which returning adults are to be attracted, is 5×10^{-5} mg/l. This very dilute concentration makes this technique very inexpensive.

Figure 18. Backpack electro-shocker, Bear Cove, Alaska.

Morpholine may be purchased from chemical supply houses and further information can be obtained from the National Marine Fishery Service, Seattle. A second chemical successfully used, and similarly available, is phenethyl alcohol. Exposure concentrations required are slightly higher (1×10^{-3} mg/l).

PART II. ADULT HOLDING FACILITIES

This section describes the salmon and steelhead adult holding criteria, systems and techniques employed in Pacific Northwest fish culture operations. The function of a holding facility is to hold adults in a secure area until spawning. Adults can be successfully held in most water containers provided the fish have sufficient water flows with proper levels of temperature and dissolved oxygen. The container must not physically injure the fish, and proper operating procedures must be used. A number of hatcheries have holding ponds specifically constructed for adults, while many installations have ponds used for both holding and rearing. We recommend that holding ponds also be

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used for rearing. Techniques of holding pond partitioning are valuable aids in **efficiently** and **effectively** accomplishing holding and spawning operations in **all** ponds. These systems are further explained below in greater detail, including miscellaneous informal-type holding facilities and techniques.

A. BIOLOGICAL REQUIREMENTS

The necessary holding time varies by species from a few days to six months. Successful long-term holding (over 30 days) is difficult, because it can result in mortalities associated with fish diseases, especially where water quantity and quality is sub-standard. Vaccinating each adult for internal disease control and periodically treating the holding pond water source with chemicals for fish fungus growth control, are operational procedures used with varying degrees of success. Loss to poaching is also more probable with a longer holding period.

Because the size of fish being held varies greatly even within the same species, long-term holding criteria (Table 2) are recommended, based on units of fish weight. As a rule, at 50F water temperature, one ft^3 of holding space is required for each 2 pounds of fish; and 1 gpm of water is required for each 15 pounds of adult fish. For each degree of water temperature below and above 50F, the poundage can be increased or decreased 5%, respectively, without flow adjustment.

Table 2. Space and flow criteria for long-term holding of adult salmon and steelhead trout in 50F water and suggested spacing for rack pickets. ⁽¹⁾

<u>Species</u>	<u>Average assumed weight/fish (pounds)</u>	<u>Water flow per fish (gpm)</u>	<u>Pond space per fish (ft³)</u>	<u>Suggested picket spacing for traps, etc. (inches)</u>
Spr. Ch.	15	1.0	8	1 5/8
Fall Ch.(2)	15	1.0	7	1 5/8
Fall Ch.(3)	18	1.0	8	1 5/8
Coho	8	0.5	4.0	1
Steelhd.	8	2.0	2.5	1
Sockeye	6	0.4	4.0	3/4

(1) From a pending publication of the Salmon and Steelhead Conservation and Enhancement Facility Design Group (Zook, 1984). A panel comprised of all Northwest fishery agencies, except Idaho; plus Indian tribal representation.

(2) Early spawners

(3) Late spawners

According to agency personnel, holding adult salmon and steelhead in temperatures in excess of 56F during the last several weeks of ripening will cause poor quality eggs and should be avoided.

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For short-term holding, the above density criteria can be exceeded, provided the dissolved oxygen level measured at the water discharge maintains 6-7 ppm. Coho, for example, held a week or two before spawning, have exceeded the long-term fish density criteria by a factor of three. As a rule, stream water temperatures fluctuate daily, and operators should be conservative in their loading of holding facilities.

B. HOLDING PONDS

Holding ponds with capacities for several hundred fish are constructed of various surfacing materials including dirt, gravel, concrete, asphalt, or shot-crete. Fish culturists are in substantial agreement that "long-term" holding ponds should be constructed with an upwelling water supply on the pond bottom and sloping banks around the pond periphery. The fish generally circle the upwelling water seeking openings for upstream migration and the sloping banks tend to eliminate fish jumping. Overhead water spray systems are also employed to refract light and thus reduce persistent fish jumping (Fig. 19).

Figure 19. Spray system to refract light and prevent fish jumping at Wells Salmon and Trout Hatchery (WDF and WDG).

Short-term holding ponds also operate well with an upwelling water supply and sloping bank design. However, they usually have vertical walls and water is supplied at one end and drained out the other. Fish jumping in the corners and along the vertical walls are frequently a problem, but this can be controlled by overhead spray systems (Fig. 19), floating rafts, and by placing plywood or other opaque materials over the troublesome areas. These light-diffusing materials also provide shaded areas for the fish to rest. Fencing and vertical walls are sometimes covered with a resilient material to prevent injury to jumping fish (Fig. 20).

Figure 20. Adult holding pond with neoprene apron along sides to prevent injury to jumping fish at Bonneville Salmon Hatchery (OF W).

There are two methods, each associated with the theoretical behavior of adult fish, for collecting ripe fish held in holding facilities. The first method is based on the theory that these fish will move to the upstream end of the pond. Therefore, attraction water will lead them into an upstream trap for collection. The second method is based on the premise that if fish cannot move upstream, they will move downstream in search of a spawning area. Therefore, the ripe fish will drop back and can be collected at the downstream end of the pond. This method has been used successfully at the OFW Bonneville and Big Creek hatcheries, and is especially effective with fall chinook. In most adult holding ponds the fish are either seined or crowded into areas for sorting, testing, and spawning.

Adult long-term holding ponds are generally designed to provide for the following:

- Minimum of pond water seepage

- Stable pond sides and bottom

- Clean water

- Meet the biological criteria in Table 2

- A pond drain sized to permit water levels to lower while maintaining the incoming water supply for operations

- A drainage system (uplift relief) must be provided if a high ground water table is present

- A system for anchoring pond partitioning materials

- A method to easily move fish to the spawning area

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Elimination of all sharp objects that could injure fish
Maintain all holding area openings to not exceed the maximum allowable spacing noted in Table 2.
Drainable for cleaning and disinfecting
Operation and maintenance accessibility
A 100 ft² covered open air spawning house equipped with overhead lighting, water, and a broom-finished concrete floor
Protection from poachers

Long- and short-term holding ponds surfaced with different materials are described below, along with their advantages, disadvantages, and costs. Water supply and drain systems are not included in this evaluation. For comparative purposes, each pond is dimensioned to contain approximately 4,000 ft³ of water. Where pond dimensions are given, they represent a typical size to meet the 4,000 ft³ water capacity.

1. Long-Term Dirt Holding Pond A rectangular dirt pond constructed with materials available from on-site excavations. Pond dimensions at the water surface are 40 ft wide x 55 ft long with an average depth of 5 ft, and with 3:1 bank slopes. An upwelling water supply is located in the upper end of the pond floor, and has two 24-inch screened outlet riser pipe-drains in the lower end (Fig. 18, Chapter 5).

Advantages:

- Simple construction
- Low construction cost

Disadvantages:

- Automatic crowders cannot be installed
- Requires bank vegetation control
- Pond difficult to clean if silt accumulates
- Working in the pond muddies the water
- Pond should be thoroughly cleaned, and if possible, disinfected if juveniles are to be reared

cost:

The estimated cost is \$8,800, or **\$2.20/ft³** of holding water; and the pond has a **50-year** life expectancy.

Information Sources:

Idaho Fish and Game Red River Pond, Rapid River Hatchery, and Hayden Creek Research Station
Washington Department of Fisheries **Washougal** Salmon Hatchery

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2. Long-Term Graveled Holding Pond This is a rectangular **gravel-surfaced** holding pond constructed identical to the dirt pond, except that the pond bottom is surfaced with 4 to 6 inches of round river gravel and the bank side slopes are surfaced with 2-inch minus crushed rock.

The gravel holding pond is very similar to the dirt holding pond regarding advantages and disadvantages. One advantage of the gravel bottom over dirt is that turbidity is lower when work is being done on the gravel surface.

Cost:

The estimated cost is \$9,800, or **\$2.45/ft³** of holding water; and the pond has a 50-year life expectancy.

Information Sources:

Washington Departments of Fisheries and Game

3. Long-Term Asphalt Holding Pond This rectangular, asphalt-surfaced pond is constructed identical to the dirt holding pond, except that the bottom and banks are surfaced with a 3-inch asphalt lining made up of two 1-1/2-inch lifts over an under-drain of **8-inch** thick granular base material and a **2-inch** thick sand leveling course (Fig. 20, Chapter 5). Bank slopes are also **3:1** and the water volume capacity is the same as the two previously described ponds. Bank slopes greater than this are optional; however, consideration should be given in the design to providing an inclined area sufficient to allow small tractors to enter.

Advantages:

- Easy to remove silt and disinfect if juveniles are to be reared.
- Easier and more efficient manpower operations with dividers
- Few bank vegetation problems

Disadvantages:

- Necessary to eliminate all bank vegetation growth to maintain asphalt seal integrity

Cost:

The estimated cost is \$13,600, or **\$3.40/ft³** of holding water; and the life expectancy is 15 years.

Information Sources:

U.S. Fish and Wildlife Service Eagle Creek NFH, Oregon

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4. Short-Term Concrete Holding Pond A rectangular concrete pond with vertical side and end walls. Its typical dimensions could be 15 x 54 x 8 feet deep. The water is supplied across the upper end of the pond width through a pipe manifold with a number of outlets, and drained out of the lower end. An aluminum tube-type screen with spacing applicable for the species (see Table 2) is installed to retain the adults.

Advantages:

- Low maintenance
- Automatic crowders can be incorporated
- Easy to clean silt and disinfect if juveniles are to be reared
- Easy to install dividers

Disadvantages:

- High cost
- Pond needs cover or fencing to prevent fish from jumping out

Cost:

The estimated cost is \$35,000, or **\$8.75/ft³** of holding water. Life expectancy is 50 years.

Information Sources:

Washington Department of Game Skamania Steelhead Hatchery
Oregon Fish and Wildlife Gnat Creek Fish Hatchery
Washington Department of Fisheries Kalama Salmon Hatchery #2 and Grays River Salmon Hatchery

5. Short-Term Shot-Crete Holding Pond This rectangular steel mesh reinforced **shot-crete** (sand, cement and water) holding pond is constructed identically to the preceding concrete holding pond, but surfaced with **shot-crete**.

Advantages:

- Same as for short-term concrete holding pond

Disadvantages:

- Same as for short-term concrete holding pond, and also requires specialty construction contractor

Cost:

The cost is \$32,000, or **\$8.00/ft³** of holding water; the life expectancy is 50 years.

Information Sources:

Oregon Fish and Wildlife Klaskanine Fish Hatchery

C. INFORMAL ADULT HOLDING FACILITIES AND TECHNIQUES

When formal adult holding ponds do not exist, many other methods are available to accomplish the task. These include portable tanks and pens, live boxes, traps and rearing ponds, compartment holding, and tethering. All are discussed in this section.

1. Portable Tanks and Net Pens Any of the portable tanks and pens described in Chapter 4 can be used to hold adults at densities set forth in Table 2. Portable rearing facilities have little freeboard, and provisions are usually required to contain jumping fish. A seine or netting, properly installed, usually suffices. An opaque floating material also aids by providing a place for the fish to hide. Techniques described earlier in this chapter are applicable with these units.

A major advantage of portable facilities over formal ponds is that they can be quickly installed and removed. This is particularly advantageous for temporary programs or where smaller numbers of fish are involved.

Net pens are used to hold adults in marine waters, but are seldom used in freshwater areas. They may, however, afford one of the best low-cost methods for certain Columbia River programs. Suitable sites include within large rearing ponds, lakes and forebays, and backwater areas of rivers. One pen 20 x 20 x 5 feet deep has the capability of holding 400-500 adult steelhead or coho and costs about \$4,000, including flotation. The various types are described in Chapter 5.

2. Live Boxes Live boxes are considered temporary holding facilities and are often used in conjunction with the spawning process. They are portable and easily handled by one or two people. Construction materials vary from heavy netting to vinyl-coated wire mesh (Fig. 21). Both are non-abrasive to the fish. A live box is especially useful when spawning steelhead. The selected males can be held and used several times. Live boxes are often used to hold immature adults to prevent excessive handling as the main population is sorted.

Floating live boxes (Fig. 16, Chapter 6) serve as excellent temporary holding facilities in ponds, or when fish are captured in remote river areas. They are flexible, can be easily transported to a remote site to hold fish, and then serve as a transport system (Chapter 6).

Material cost for a PVC-coated wire box 3 x 5 x 3 feet deep would be \$100.00. Coated wire comes in **50-** and **100-foot** rolls up to 6 feet wide. Vendors have mesh sizes from **1/4-inch** to 4 inches and four colors costing about \$1.50 a running foot. Contact agency personnel for further information and refer to Appendix 2 under Shepherd, C.E. Company, and Valentine Equipment Co. for vinyl-coated wire mesh.

Figure 21. Adult live box constructed of wood and vinyl-coated wire mesh.

3. Traps and Juvenile Rearing Ponds If the number of adults to be held is small, partitions can be placed in existing traps, rearing units, or adult ponds. When using a trap, for example, a small, sectioned-off area allows selected fish to be held while others are passed upstream. The selected fish can be spawned on site or transported as appropriate. The WDF Simpson Salmon Hatchery uses this method on **coho**, and the WDG uses it at their South Tacoma Steelhead Hatchery.

Managers sometimes hold adult steelhead or salmon in a pond containing juvenile fish, which are retained below normal pond carrying capacities during the fall and winter months. Given this situation and a raceway 10 x 100 x 4 feet deep, the lower 10 feet can be sectioned to provide 400 ft³ of holding space. Fish have been held in these situations for several months.

4. Compartment **Holding** Techniques The Canada Department of Fisheries and Oceans uses two methods to hold individual steelhead to maintain genetic integrity. One is called condominium holding, (Fig. 22) and the other, tube holding (Fig. 23).

The condominiums are aluminum modules, each with a separate water supply to prevent the spread of disease.

The method of holding fish in tubes appears most applicable for low-cost facilities. Inexpensive PVC, ABS plastic, or acrylic pipe is used. The length and diameter of the tube should only be several inches greater than the dimensions of the fish.

Figure 22. Condominium unit for adult holding: (A) cover to several condo units, (B) single condo.

Figure 23. Tube holding apparatus.

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Individual tubes are banded together and a perforated wood or acrylic diffuser is placed over the inlet and outlet ends. Heavy netting can be used in place of a wood or acrylic diffuser on the downstream end, for ease of access to the fish when checking for maturation. The bundle of tubes is placed in any trough or rearing pond that has a normal water flow. This system has worked well with pilot facilities, and DFO reports that egg-takes of 100,000 ~ 200,000 are manageable and disease has not been a problem.

We recommend this tube method for holding small numbers of adult steelhead. When placed in a standard deep trough inside the incubation building, the fish will be secure and readily available when needed. With a water flow of 30 gpm, up to 15 adults could be held in this manner in each trough.

Instead of the modular tube holding apparatus as shown in Fig. 23, DFO sometimes uses a single tube to hold individual adults, Fig. 17, Chapter 6, which is similar in purpose to the tethering technique used by WDF.

5. Tethering Tethering or tying a fish to a fixed object for in-stream holding has been conducted during the gaffing operations in the Elwha River, Washington, for over a half century. A strong cord is passed through the gill arch and tied to the lower jaw of the fish. The cord is then attached to a fixed object such as a springy tree limb, or when this is not available, strong rubber tubing is placed in-line. For chinook salmon, tuna snubbers work well.

This system is especially advantageous in conjunction with the hook and line capture system used on steelhead, because the fish can be temporarily retained for later transportation. It is also used for both salmon and steelhead where quick recapture of a particular fish is necessary during the spawning process.

PART III. SPAWNING

The physical process of artificially spawning salmon and steelhead has changed little since hatchery systems began to evolve a hundred years ago. The facilities for performing the task, however, have become sophisticated, particularly in those situations where large numbers of adults must be handled in a given day. Tools and methods have improved as fish culturists have sought to improve efficiency. Finally, new techniques are being utilized which will accelerate or delay the maturation process, and hence may have a direct bearing on improving the efficiency of hatchery operations. These are discussed in this section as they apply to low-cost systems.

A. FACILITIES

The facilities required for spawning fish depend on the complexity of the program and the number of fish being handled. Where large numbers of fish must be congregated and separated by degree of maturity, elaborate systems with anesthetic tanks, conveyor belts, automatic crowders, holding ponds, and **killing** devices have been devised. While costly, they were developed as time and laborsaving techniques but they are not necessary for

Adult Collection, Holding, and Spawning

low-cost operations. We anticipate that a low-cost operation will handle fewer than one thousand fish per year, and that simple techniques are available to congregate, sort, and spawn the fish. Salmon and steelhead can be collected from **in-stream** traps and racks, and spawned directly on the site. Fish held between racks or in ponds can be congregated with seines, sorted, and the green fish returned to the pond. This necessitates sorting fish several times as they do not all reach sexual maturity at the same time, but if only a few fish are involved, it is a simple task. If larger numbers of fish are involved, then the technique illustrated in Fig. 24 is an efficient and relatively inexpensive spawning facility. Here, adults enter a pond from the river through a **fishway** and are held until maturity. Then the pond is sectioned with pickets to create several holding areas, where immature females and males can be held for later sorting and spawning. This technique requires less handling of the fish and therefore reduces egg losses. As the fish mature, they are congregated in a channel between the sections and crowded toward a spawning area. Here the fish are sorted and spawned or the excess fish returned to the river through a tube. The spawning area consists of a concrete slab with a shed roof to protect both the workers and buckets of gametes artificially spawned. This site also provides containers to hold the spawned fish, and is easily cleaned. Frequently, concrete bins are used to hold the carcasses, but simple plastic totes are suitable for most operations.

The facilities described above are relatively inexpensive, yet even these are sometimes **unnecessary** for small operations. **Many** examples of successful programs exist where fish are spawned directly from traps, or on gravel beaches. Generally, however, consideration is given to protecting the gametes from rain and freezing conditions. A low-cost facility to protect from these elements is illustrated in Fig. 25.

Because most salmon spawning is completed between late August and mid-November, freezing is more likely during steelhead spawning. The Japanese address freezing conditions by transporting freshly killed salmon from the holding area to buildings used for other purposes, such as the room where eggs are processed. Small portable buildings, or old truck vans (Fig. 26), would be examples of other low-cost working areas if required. Because the numbers of spawning steelhead would likely be less than 500, these procedures and buildings seem applicable.

If the facilities are located in areas where heavy rains prevail, the area where the spawning takes place should be protected, as mentioned earlier. A small shelter with an 8- x 12-foot concrete slab and frame type roof would suffice. The cost of any of these units would be less than \$1,000. A spawning shed as illustrated in Fig. 24 would cost \$1,800.

B. MATURATION CONTROL

The time span of fish spawning can be accelerated or prolonged. This is done by controlling the amount of light, or by injecting hormones to induce spawning. Simulating longer days accelerates ovulation in steelhead trout and prolongs it in salmon. The reverse is true if shorter days are simulated (Piper et al., 1982).

Hormone injections, if given approximately one month prior to the normal spawning time, will accelerate ovulation by several weeks (Fitzpatrick et al., 1983).

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Figure 24. Sketch of a **relatively** low-cost adult holding and spawning facility.

Figure 25. A relatively low-cost spawning area at the George Adams Salmon Hatchery (WDF). For lower cost operation, we recommend plywood or plastic totes for fish storage.

Some of the advantages of accelerated ovulation are:

- Shorter holding period will result in lower pond mortality
- Less time for security is required
- The holding pond will be available sooner for the rearing program
- Controlled induced spawning results in more fish spawned at a given time, and provides easier programming at the hatchery

The WDG has successfully demonstrated the value of both light control and hormone injection with their steelhead program at the **Wells** Trout Hatchery (Zook, personal communication). DFO personnel are most knowledgeable on hormone injection to induce spawning.

Few advantages have been determined for prolonging the spawning time. One that might be considered with salmon, is that if they must be held in high water temperatures, a delay to a later period when holding waters are cooler may enhance egg quality. This concept is presently being tested on chinook salmon in Australia (Johnson, 1983).

C. SPAWNING METHODS

Fish are spawned by hand stripping, incision, or air injection. Salmon females are generally always incised and the sperm is taken by hand stripping. Steelhead males and

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females may not be killed before spawning, thus they are either hand stripped or sometimes, in the case of the females, the eggs are removed by injecting air just posterior to the pericardial cavity. Two to four psi of air pressure are used, forcing the eggs downward and out the vent. It is used only on steelhead, and is said by some to be superior to hand stripping, because the fish remain in better condition.

For more detailed information on spawning procedures, we recommend visitations to hatcheries or a review of the publications by Leitritz et al., (1976) and Piper et al., (1982).

Figure 26. Truck van used as storage and work area at the Squaxin Tribal Hatchery on Elsey Creek.

D. ANESTHETICS

Anesthetics are used to relax fish at the time of spawning to make handling easier and reduce damage to the fish and their eggs. Few hatchery programs in the Columbia Basin use anesthetics, and we do not recommend the general use of it at low-cost facilities.

Numerous chemicals can be used, the more common being tricaine methane sulfonate (MS 222) in a concentration of 1 gram to 7-10 gallons of water. All anesthetics should be tested to obtain the reaction of the fish before use. The sale or immediate release of fish after being anesthetized with chemicals is usually prohibited.

Carbon dioxide (CO_2) has been used at the WDF Cowlitz Salmon Hatchery as an anesthetic. The use of CO_2 does not prohibit the sale or immediate release of live fish. It is more economical than MS 222 but is reported to be less desirable, as the fish, when handled, have an immediate quivering reaction.

TOOLS USED IN SPAWNING

The tools commonly used for the incision spawning process are; a woolen glove, a fish club (Fig. 27), a bleeding rack (Fig. 28), a spawning vessel (Fig. 29), a spawning knife (Fig. 30), and several carcass storage bins (Fig. 31). A clean water supply from a pump or supply system is desirable.

Figure 27. A typical fish club.

Figure 28. Spawn-taking equipment: (A) bleeding rack, (B) stand for holding spawning pan.

Figure 29. Tools used for egg taking: (A) bleeding rack with fish, (B) spawning pan with eggs, (C) stand for j-gallon pail which holds spawning pan and eggs.

Figure 30. A Zak spawning knife.

Figure 31. Totes for adult fish storage: (A) wooden, (B) plastic.

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INCUBATION

Numerous methods are available for incubating salmon and steelhead eggs, ranging from a simple bucket technique to the more sophisticated vertical incubators which require Buildings and extensive plumbing systems. Some methods are only used to eye eggs, others to only hatch eggs, while still others are used for both. The various methods have evolved as fish culturists sought to reduce labor costs and increase survival rates and improve fry quality. We have chosen to illustrate all the popular methods, including the more expensive techniques, because the ultimate choice in selecting a method depends on local conditions, program goals, cost, and to a large extent, on individual preference. Egg and alevin incubation can be a simple process where significant savings in capital and operations costs can be achieved without affecting the quality of the product. Numerous "low cost" techniques are available to incubate large numbers of eggs and alevins. A brief description of egg incubation biological requirements follows to facilitate the understanding of the incubation process and the methods described in this chapter. The material presented is general; greater detail can be obtained from salmon and trout fish cultural manuals.

PART I. BIOLOGICAL REQUIREMENTS OF EGG INCUBATION

Salmon and steelhead trout eggs become fertilized when the eggs and sperm are mixed together and water is added to insure even distribution of the sperm. The sperm penetrates the egg through a small opening in the shell called the micropyle. Water is also absorbed through the micropyle and the porous outer shell. The water absorption process takes approximately 30 minutes and adds approximately 12 percent to the weight of the eggs. The fertilized eggs become increasingly fragile during the first 48 hours, and until the pigmented eyes of the embryo can be seen through the egg shell, they are easy to damage by even a slight jar. When the eyes become visible, the development is called the "eyed egg stage", and healthy eggs are very resistant to mechanical damage and may be handled and shipped if desired. During this stage, but prior to hatching, the eggs are deliberately "shocked" so the dead and infertile eggs can be identified and removed. Eggs should never be exposed to direct sunlight and alevins do best when incubated in the dark.

The rate of egg and alevin development and fry quality is a function of water temperature, and the time required to reach various developmental stages is expressed in temperature units (TU). A TU is defined as one degree of temperature above freezing for 24 hours. Accordingly, at a 50F water temperature, 18 TU are accumulated in one day. The TU requirements or developmental rate from egg fertilization to hatching and from hatching to yolk absorption at 50F varies by species (Table 1).

Table 1. Temperature unit requirements for salmon and steelhead trout eggs and alevins at 50F.⁽¹⁾

<u>Species</u> ⁽²⁾	<u>To hatch</u>	<u>To first feeding</u>
Chinook	900	1665
Coho	850	1375
Sockeye	1260	1900
Chum	900	1550
Pink	1370	2150
Steelhead	570	975

(1) Source: Combs and Burrows, 1957, University of Washington School of Fisheries, and State of Washington Departments of Game and Fisheries.

(2) Racial differences, if any, are judged to have no impact on program management.

Chinook **coho** and chum eggs require about 900 TU from fertilization to hatching. The rule of thumb is 50 days at 50 degrees and the temperature units are derived as follows: 50F - 32F = 18 units per day x 50 days = 900 TU. Chinook at the same temperature require another 800 TU from hatching to egg absorption, while **coho** require only 500 TU. Sockeye require 1260 TU to hatch and another 640 TU to feed, for a total of 1900 TU.

The requirements for steelhead are less than for salmon. At 50F, only 570 TU are required from fertilization to hatching and 405 TU from hatching to egg absorption.

Although each species has a different TU requirement prior to complete yolk absorption, this requirement is not constant. Salmon take less **TUs** as the water temperature is decreased, while steelhead take proportionally more. The preferred incubation temperature for salmon and steelhead is from 45-55F. Temperatures above 56F may cause mortalities or affect the quality of surviving fry. High temperatures during early incubation are injurious. (Gearheard [WDG] and Parrish [IFG] personal communications.)

Often managers need to know the time required to reach the eyed stage when the eggs can be safely handled. Generally this takes about 1/2 the TU necessary to reach hatching. Temperature also has a tremendous influence on egg and **alevin** incubation densities. While we found no documented data available, it is believed that for each degree below 50F the numbers can be increased by two to four percent. As the temperature increases above 50F, the carrying capacity of the system would decrease accordingly.

The volume of water required to incubate eggs is small compared to other life stages because the oxygen demand and waste products given off by the eggs are **minimal**. At 50F, 10 gpm is sufficient to incubate one million salmon eggs (Table 2). It is common to use 50 gpm for one million salmon alevins. Because steelhead eggs and alevins are approximately 2/3 the size of salmon, 25 percent more steelhead are normally incubated in a given water supply or unit.

Table 2. Number of salmon and steelhead trout eggs and alevins that can be incubated under ideal conditions using 10 gpm of water at 50F. Data based on present usage at 80 sites visited.

<u>Species</u>	Numbers	
	<u>Eggs</u>	<u>Alevins</u>
Chinook	1,000,000	150,000
Other Salmon	1,200,000	180,000
Steelhead	1,300,000	200,000

The rate at which water moves through the incubator is also very critical for eggs and alevins. If it is too great and the eggs are disturbed, they can be killed. Excessive velocity will also erode the yolk sac on alevins, likely resulting in lesser quality fry. It also causes them to utilize yolk material for energy rather than growth. For alevins, as a general rule, the water velocity should not exceed 5 gpm/ft² of incubating surface; and for eggs, velocity levels can be variable but must stay below the point where the eggs are disturbed by rolling. Table 3 expresses these general levels. Equally as important as the quantity and velocity of water are the design and operational procedures of all units which must achieve a uniform distribution of water flow past the eggs and alevins. Often, air bubbles, including supersaturated gases, entering with the water supply are trapped on screens or plates, grow in size and distort water-flow patterns. This causes losses by smothering.

The foregoing material on the incubation process demonstrates that both the egg and alevin incubation stages must be considered when selecting an incubation method. Far more eggs than alevins can be incubated in a given area and water supply, and the number can vary according to species and water quality. Further details on egg and alevin capacities of individual incubators and information on tools and equipment follow.

PART II. INCUBATION UNITS

Seven general egg incubation methods were chosen to separate, identify and describe the various incubation units involved. They include vertical incubators, trough incubators, pond incubators, box incubators, cylindrical incubators, channels for spawning and egg incubation, and *instream* planting. Egg and alevin capacities and water flow requirement by type and size of incubation unit are shown in Table 3.

A. VERTICAL INCUBATORS

Only two types of vertical incubators are available. They are the vertical cabinet and the NOPAD. Both are expensive to install and logically would not be classified as a low-cost method as compared to other available units. However, they do have certain advantages that merit their being considered for a low-cost facility, if only on a small scale.

1. Vertical-Cabinet Incubator This incubator consists of a cabinet designed to hold eight to ten trays in which the eggs and alevins are incubated. One cabinet

stacked upon another is often preferred, giving a **multiple-tray** unit. This may require the use of a secondary water induction system that can be installed in the lower cabinet. In this case the draining of water from the top section is accomplished with a catch tray. Fig. 1 shows a series of **two-high** eight-tray cabinets, while Fig. 2 is a close-up photo of a single tray and the component parts.

Table 3. Salmonid incubation capacities and water flow requirements in gpm by type of incubator unit.

<u>Type of incubator</u>	<u>Eggs⁽¹⁾</u>		<u>Alevins</u>	
	<u>Number</u>	<u>GPM</u>	<u>Number</u>	<u>GPM</u>
<u>Vertical</u>				
Cabinet (8-tray)	56,000	2-5	40,000	2-5
NOPAD (single tray)	320,000	8-12	160,000	12
<u>Trough</u>				
Deep (10 compartments)	1,000,000	2-10	250,000	7-10
Shallow (7 compartments)	175,000	4-7	20,000	2-7
<u>Pond</u>				
Single tray(30X48 inches)	20,000	(2)	same	same
<u>Box</u>				
Deepmatrix				
4X8X4 feet ⁽³⁾	500,000	75	same	same
2X8X1.25 feet	75,000	12	same	same
Shallow-matrix (Netarts)				
4x8x1.3 feet	96,000	30	same	same
Montana		2-6	75,000	3-b;
Freestyle (single)	500,000 100,000	20	150,000	20
<u>Cylinder</u>				
Modified jar	20,000	2-5	same	same
Gallon jug	30,000 4,000	0.8	2,000	0.8
5-gallon bucket		2-3	15,000	2-3
55-gallon drum	200,000	12	80,000	10
R-48 barrel	1,700,000	40	725,000	40

(1) The numbers are based on an average egg size of 1400 per pound and water temperature of 50F.

(2) No less than 8 gpm/ft^2 of cross sectional area as measured by water depth x tray width.

(3) The measurement sequence is width x length x depth throughout this report.

Cabinet size in inches is 24.88 wide, 24.25 long, 31.5 high. The unit within the tray containing the eggs has an inside dimension of 13 x 16 x 2 inches.

Loading levels vary by species. Common alevin levels per tray for complete incubation are: 7,000 coho, 5,000 chinook, and 8,000 steelhead. For eyed eggs, this capacity can be slightly greater. To improve fry quality, many WDF stations are now using folded heavy plastic netting within the trays as a standard procedure.

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Also, it is common for managers to cover the cabinets with black plastic to prevent startling the alevins with external light sources.

Figure 1. Vertical-cabinet incubators, 16 trays high

The amount of water necessary to incubate eggs and alevins in an eight-tray unit is generally 2-5 gpm depending on the developmental stage and water quality. As the water flows from one tray to another it **upwells** through the eggs.

Advantages:

- Some aeration occurs between trays
- A clean out is provided below each tray for removing silt
- Small egg lots can be handled and kept separate
- The trays easily pull out for inspection of the eggs and alevins
- The maintenance cost is relatively low
- Fry quality is good for all species when substrate is used
- The water flow in the trays can be modified to isolate egg lots

Disadvantages:

- A building is generally used
- Handling small lots is time- consuming
- The floor space requirement is high for eyeing eggs because of the small tray size
- Wide aisles are required in order to pull the trays from the cabinets
- The plumbing system is complicated and expensive

- Initial unit cost per egg is high
- 0 A separate trough is required for shocking eggs and removing mortalities

Cost:

An eight-tray cabinet costs approximately \$700. The life expectancy of the cabinets is 25 years plus, but the screens may require replacement every 15 years.

Information Sources:

Fisheries agency and tribal biologists and hatchery managers

Heath Tecna Corporation

Tricor Plastics

FAL Productions, Inc.

Figure 2. Vertical-cabinet tray (A), with inner tray (B).

2. **NOPAD Incubator** The NOPAD or Zenger incubator is manufactured from aluminum and designed to permit the stacking of individual units up to five high. A single unit is 4 x 4 x 1 (Fig. 3).

When stacked, there is about 12 inches between each unit. Water **upwells** into the incubator after passing through a perforated plate, substrate and eggs, and finally a pressure plate which prevents the eggs from rolling. The plastic substrate is placed 4-inches deep on the perforated plate and the eggs are poured over the substrate. Plastic saddles or **bio-rings** are common substrates.

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Twice as many eggs can be incubated to the "eyed" stage in these units than can be carried through the complete hatching process. For the latter 160,000 chinook, coho or steelhead can be incubated in each unit. The water requirement at this loading density is 12 gpm per unit.

Advantages:

- Can be stacked in modules to conserve floor space
- Maintenance costs are low
- Less labor required compared to the cabinet incubator because the larger trays provide greater capacity
- Require less time to clean than a tray-type incubator for a given number of eggs
- Can be operated to permit volitional migration if desired
- A clean-out system to backflush silt is provided

Disadvantages:

- Building generally required
- When the incubators are stacked, access to the lower incubators is restricted
- Egg lots of less than 50-100,000 are not practical
- The plumbing system is complicated and costly
- Almost 5 feet of aisle space is required to remove empty units

Cost:

Approximately \$800 per incubator. The life expectancy is 25 years.

Information Sources:

Douglas Island Pink and Chum, Inc, Juneau, Alaska
Medvejie Central Incubation Facility, Sitka, Alaska
Tulalip Indian Tribe, Marysville, Washington
North Pacific Aquaculture Development Company, Juneau, Alaska
Alaska Department of Fish and Game

Figure 3. NOPAD aluminum incubator.

B. TROUGH INCUBATORS

Trough incubators were one of the first egg incubation techniques used by fish culturists and are commonly used in modern fish hatcheries. The troughs have removable dividers so they can be used as rearing areas for fry. These units are usually described as "deeps" or "shallows"; those greater than 12 inches deep are called deeps. Otherwise the two troughs differ only in the way they are used.

Troughs were originally constructed of wood, but concrete was later employed, and today fiberglass and metal troughs are common. Various types and sizes of troughs are available as shelf items. There is great diversity in **trough types** between and within fish agencies, Indian tribes, and the private sector. The choice in most cases is usually dictated by individual preference, program goals, and cost.

1. Deep-Trough Incubator Figure 4 illustrates a deep trough that measures 1.33 x 16 x 1.30 feet and contains ten compartments. This unit is excellent for egg incubation, but inefficient as an alevin incubator. They are a **multiple-use** unit, excellent as disinfectant and rearing tanks, and as a place to shock and sort eggs.

Figure 4. Deeptrough incubator illustrating: (A) trays, (B) perforated plate, (C) compartment for eggs only, (D) basket for eggs.

The water hydraulics in all troughs is similar, in that an **upwelling** flow is created in each compartment by the use of baffles (Fig. 4). In the unit illustrated, water entering the trough is directed by a baffle to the floor of the first compartment

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where it **upwells** and exits the compartment over a second baffle. This flow pattern is repeated until the water leaves the trough through a drain pipe. The amount of flow depends on the area of the compartment. The unit illustrated in Fig. 4 generally requires 2-10 gpm for eggs and 7-10 gpm for alevins. Recent data suggests that a flow in excess of 10 gpm for alevins may be excessive and may tend to produce inferior fry.

Eggs can be incubated in the compartments by placing them directly on the perforated plate, or by placing the eggs in screen boxes or net bags and placing these in the compartments. We favor the first method because it is effective, requires less equipment and is less costly. Up to 100,000 salmon eggs can be eyed in each compartment of the unit illustrated.

To incubate alevins, eyed eggs are placed directly on trays with or without substrate. The trays are constructed with a 12-mesh screen bottom, and a heavy plastic netting is commonly used for substrate. Five trays, each containing 5,000 eggs, can be placed in a compartment. The total capacity of the unit illustrated is 250,000 salmon alevins.

Advantages:

- One of the most economical methods to eye eggs
- 0 Most troughs are portable
- 0 Have several uses in a hatchery other than incubating eggs
- 0 If plumbed with bottom drains or clean-outs in each compartment, silty water can be managed
- 0 Plumbing system is less complicated and less expensive than vertical incubators
- 0 Can be stacked two high vertically to save floor space
- 0 Can be temporarily placed in dry rearing ponds and covered with temporary shelters

Disadvantages:

- Incubation densities of alevins per unit compared to floor space used are low because water flows must be reduced to maintain quality fry
- 0 Isolation of smaller egg lots is not practical because of plumbing cost
- Access to the alevins is more difficult than vertical cabinet incubators
- Building usually required

Cost:

The cost varies, depending on the vendor and material type. The estimated cost of the fiberglass unit illustrated in Fig. 4 is \$900, and it has a **25-year** life.

Information Sources:

Most hatchery managers
Sims Fiber Glass Co.
Ranger Boat Co.

2. Shallow-Trough Incubator Shallow troughs vary in size but a common one measures 1 x 15 x 0.5 feet (Fig. 5). Usually they have six or seven compartments and the eggs are incubated in specially-constructed wire baskets (Fig. 6). These are made about 1-inch smaller than the compartments.

Figure 5. Aluminum shallow-trough incubators stored outside Yakima Trout Hatchery (WDG).

The eggs remain in the baskets until they hatch, after which the alevins drop through the baskets to complete the incubation process on the floor of the trough. Some agencies use trays as in deep troughs. Hydraulically, the water flow in a shallow trough is similar in principle to a deep trough. The compartments are separated by removable baffles which create an upwelling flow through the eggs. The water, however, does not pass through a perforated plate as in the deeps. Rather, the wire baskets and the eggs create the proper flow pattern within the compartment. A flow of 4-7 gpm is required during the egg stage and 7 gpm is the maximum flow for alevins. Approximately 35,000 steelhead or 25,000 salmon eggs can be incubated in each compartment of the trough. The capacity to incubate alevins is limited to approximately 20,000 steelhead and 12,000 salmon in a trough. The troughs can be stacked as illustrated in Fig. 7 and are generally made of fiberglass.

Figure 6. Wire egg baskets used in shallow-trough incubators.

Advantages:

- Portable
- Used for both incubation and rearing
- Can be stacked
- Can be positioned in rearing ponds empty of fish
- The plumbing system is relatively simple and inexpensive
- Easy to observe, handle, and treat eggs and alevins
- Generally suitable for a small-scale operation

Disadvantages:

- Not practical for a large-scale salmon production facility because of the low incubation capacity compared to the floor space required
- Only small lots can be fed in the troughs
- It is more difficult to shield the alevins from light than in the "deeps"
- The alevins tend to congregate at the upper end of each compartment and smother unless they are frequently re-distributed
- More expensive per/ft^3 of rearing area than deep troughs
- Difficult to remove heavy silt when trays are used

Cost:

A 15-foot plastic trough costs approximately \$300. The wire baskets sell for \$80 each. Life of the trough is 25 years.

Information Sources:

Most hatchery managers
Sims Fiberglass Co.
Ranger Boat Co.
Heath Tecna Corp.

C. POND INCUBATION

Pond incubation is a method of incubating eggs in existing ponds where the water flow system is horizontal rather than upwelling, as used in most other methods. Its use evolved as fish culturists sought to make dual use of rearing areas, reduce the need for large incubation buildings, and improve the quality of fry. These points have been successfully demonstrated, though fry quality has improved in all incubation systems, particularly when substrates are used. We recommend that ponds not be designed solely for incubation purposes.

The pond method consists of using circular or rectangular rearing ponds that have a uniform flow distribution and pond trays on which to incubate the eggs. The trays resemble window screens (Fig. 8) but the frame is generally constructed of metal or 2-x 2-inch lumber and the screen has 10-14 openings to the inch. Larger openings are required if the fry are to be permitted to drop through and incubate in the pond. Nylon netting can also be used as the screen material (Fig. 9). The trays should extend the width of the pond to get the proper hydraulics. Thus the size of the trays depends on the pond size and individual preference. A 2.5-x 4-foot tray is convenient to handle.

The eggs are placed on the trays one egg deep; however, two layers are commonly incubated by the WDF. Depending on egg size, 2,000 salmon eggs can be incubated on each square foot of screen. The recommended densities for a pond should be no greater than initial rearing densities.

Figure 7. Shallow-trough incubators stacked five-high (Quinault Tribal Hatchery).

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Figure 8. Typical metal-frame pond tray for drop-through or alevin retention.

The trays are stacked in the pond with a 0.5 to 1-inch spacer between them. This provides an opening for water circulation and for the fry or alevins to leave the trays. A custom tray has been patented that uses a cabinet-and-traysystem which can be set in a pond as a unit (Fig. 10).

The water flow should be no less than 8 gpm/ft^2 as computed by the water depth times the width of tray in the area of incubation. Maximum flows are of no concern, provided they do not move the eggs. Eggs and alevins are successfully incubated in ponds without a uniform flow distribution; however, lower egg densities are required. Clean water is mandatory for this method of egg incubation because the horizontal water flows allow silt to settle more readily than vertical flows. Since light must be prevented from entering the trays, a 4-mil black plastic sheeting is generally used to cover the trays and areas of alevin incubation. Incubation in circular ponds is successfully used by Swecker Salmon Farms near Rochester, Washington.

Advantages:

- Large incubation buildings are unnecessary
- Fry quality is acceptable
- Labor cost is relatively low

- Capital cost is low
- The trays are easily fabricated

Disadvantages:

- Eggs tend to pile up and smother in **poorly** constructed trays
- The incubating **eggs** and alevins are not readily visible
- The survival rate is slightly less than in some other units
- Unless spring water is available, the units **may** require special care in freezing weather
- The ponds cannot be used for both incubation and rearing at the same time unless the trays are isolated in the pond by a screen

Cost:

A 2.5-x 4-foot tray with screen costs \$20 (wood) and \$80 (metal). Life expectancy is seven or eight years for wood frames and 15 years for metal.

Information Sources:

Washington Department of Fisheries, Hoodport Salmon Hatchery
Swecker Salmon Farm, Rochester, Washington
Oregon Aqua Foods, Springfield, Oregon

Figure 9. Pond tray constructed of wood and nylon netting (Swecker Salmon Farm).

D. BOX INCUBATORS

A variety of box incubators have been developed and successfully used in the Pacific Northwest, British Columbia, and Alaska. They have become popular because of the low construction and installation costs, and their flexibility of use in meeting a variety of production and management goals. Boxes are frequently used as temporary streamside incubators to augment natural production and as satellite production stations where large numbers of high-quality fry are produced. The WDF and other agencies are presently using box incubators at conventional hatcheries (Fig. 11) for incubating large numbers of eggs and alevins for a very low capital investment.

Figure 10. Pond tray-incubation unit at Oregon Aqua Foods.

Figure 11. A deep-matrix box installation to incubate 10 million salmon eggs at McKernan Salmon Hatchery (WDF).

The several types of incubation boxes described offer adaptability to a wide array of incubating requirements.

1. False Bottom, or Deep-Matrix, Incubator False bottom or deep-matrix incubators are boxes in which eggs or alevins incubate within a gravel or artificial substrate. Water is introduced at the bottom of the box in a manner that produces an evenly-distributed upwelling flow pattern. Deep-matrix incubators simulate natural salmon and trout incubation habitat, and they are capable of producing fry comparable in size and quality to wild fish.

Box incubators can be virtually any size desired and can be made from plywood, concrete, foam polyethylene, or fiberglass. One low-cost unit is a cargo box from the apple industry adapted for use as an incubation box (Fig. 12). Program goals, cost, and portability are major considerations in selecting materials.

Figure 12. Heavy-duty plastic cargo box used as a box incubator.

In most boxes, water is delivered into a small header section and then flows downward beneath a false bottom. False bottom construction is usually of narrow-spaced wooden pickets or aluminum angle, aluminum grating, or perforated aluminum sheets. In the incubation chamber a 2-to 4-inch layer of pea gravel is often placed over the false bottom and then filled to the desired level with 0.5-to 1.5-inch gravel. The pea gravel layer acts as a pressure plate to distribute uniform water flow and upwelling velocities throughout the box (Fig. 13). An optional water delivery system, more common in smaller units, uses a grid of perforated plastic pipes in lieu of the false bottom (Fig. 14).

Figure 13. Typical large deep-matrix box.

Figure 14. Typical small deepmatrix box.

Dimensions for perforations or spacings in a false bottom should be no greater than 3/32-inch to prevent the passage of alevins. Smaller spacings should be used for sockeye or steelhead.

Gravel substrate has been most frequently used in box incubators, but two plastic alternatives, saddles and bio-rings, have been used successfully. They are more expensive, but are lighter and easier to handle than gravel during cleaning of the substrate.

In areas where freezing conditions are common, useful precautions include burying the boxes in or adjacent to the stream, insulating the walls and cover, and insulating the watersupply system. Also, units may be buried in a natural stream to increase hydraulic head; and bottomless, or pit incubators, have been buried to take advantage of natural upwelling. Either of these options require streams with very stable flows and maintenance is more difficult. All boxes must be securely covered for protection from predators and light.

Loading rates for box incubators are normally the numbers of eggs that can be carried completely through fry emergence, and will vary according to species. A 4-x 8-x 4-foot box with 75 gpm could be stocked with 500,000 chinook, **coho**, or chum eggs, while the smaller 2-x 8-x **1.25-foot** box with 12 gpm incubates up to 75,000 eggs. If sockeye or steelhead eggs are used, the numbers can be increased 25 percent.

Alternate layers of gravel and eggs (either green or eyed) may be placed in the incubator, although the procedure presently used is to place the eggs on plastic screen trays positioned above the gravel so that observations may be made and dead eggs removed. After hatching, the alevins drop through the screen to the substrate. When using trays for egg incubation in this unit, the water supply need only enter and circulate above the substrate, thus keeping it clean until the alevins require the upwelling water.

The box incubator allows the fry to freely migrate into a stream or pond; however, the operator may delay them or divert them into a collection system.

Advantages:

- Low capital costs, and can be left unmanned if water supply is secure
- Easy to construct
- Flexibility of usage
- Production of high quality fry
- Does not require housing or support structures
- Plastic units can be moved by hand
- Can be used where space is limited

Disadvantages:

- No access to fry after hatching
- Risk of egg and alevin loss is higher when used in remote areas.
- Cleaning gravel substrate is laborious
- Fry may work through false bottom and perish in sump area

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Cost:

One wooden box 4 x 8 x 4 feet costs \$1200 (includes perforated aluminum false bottom). Ten wooden trays 4 x 4 x 1-inch deep costs \$300. One box, 2 x 4 x 1.25 feet of wood costs \$225 (with perforated PVC pipe water supply bottom grid). Ten 2 x 4 x 1-inch deep wooden trays cost \$150. The plastic cargo box costs \$130 plus \$200 for plumbing. Wooden boxes have a ten-year life and plastic, a 15-year life.

Information Sources:

Skokomish Indian Tribe, Shelton, Washington
Washington Department of Fisheries
Canada Department of Fisheries and Oceans
Colossus Multi-Tainer Corp. (plastic box)

2. Baffled, or Shallow-Matrix, Incubator The shallow-matrix, or **Netarts** incubator is similar to a deep trough with two or more compartments (Fig. 15). Construction may be of high quality overlay plywood, fiberglass or concrete (Fig. 16). The incubators can be any desired size, but a common dimension is 4 x 8 x 1.3 feet with two compartments. Several units may be set up end-to end and share a common water supply.

Figure 15. Shallow-matrix incubator.

Water enters one end of the box and is directed downward to the bottom of each compartment by baffles. A shallow layer of gravel substrate is used, usually about 1-inch deep. Eggs are incubated on trays suspended above the substrate. Water upwells through the trays. After hatching, the alevins drop through the spacings in the trays to the substrate. The box should be covered for protection and the exclusion of light.

The density that alevins are incubated, per 4x4 foot compartment, ranges from 35,000 to 48,000 for chum, pink or **coho**. The Nisqually tribal biologist recommends the lower number (Svoboda, personal communication). About 30 gpm of water are used during incubation.

Figure 16. Shallow-matrix incubator at Skokomish Tribal Hatchery.

Advantages:

- Low capital costs
- Easy to construct
- Flexibility of usage
- Production of high quality fry
- Does not require housing or support structures
- Portability, if necessary can be moved by hand
- Can be used where space is limited
- Can be used for rearing

Disadvantages:

- Risk of egg and alevin loss is higher when used in remote areas
- Requires more space than deep-matrix box

Cost:

A wooden unit 4 x 8 x 1.3 feet costs approximately \$350, and has a ten-year life.

Information Sources:

Nisqually Indian Tribe
Skokomish Indian Tribe

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3. Montana Hatching Box The Montana hatching box is used for egg and alevin incubation and is essentially one compartment of a deep trough set free as a separate unit. It is very **similar** in principle to the jar or bucket incubator describea later in this chapter. The box is built in various sizes, however, a typical unit is 1 x 1 x 1.5 feet. They are constructed of waterproof plywood, fiberglass, or plywood with plexiglass on two sides. Substrate is not used in this box.

The water flows into a false bottom, up through a perforated plate, through the eggs and out the top. The unit observed at the Niagara Springs Steelhead Hatchery in Idaho (Fig. 17) uses manifold pipes to deliver water evenly below the perforated plate. On top of the plate Scotchbrite pad is used as a filter. Maximum water flows used were 6 gpm.

The number of steelhead eggs that can be incubated is limited by the space in the incubator. The Niagara Springs Hatchery manager suggested 100,000 alevins for the unit described above. As the alevins absorb their yolk material, they may freely leave the incubator to be captured in rearing tanks or troughs.

Advantages:

- A tested and proven unit for steelhead incubation
- Portable; can be placed into rearing units
- Low cost
- Easy to construct
- Square units fit well in modules

Disadvantages:

- 0 Blue sac disease is reported at the lower preferred incubating temperature range

Figure 17. Montana hatching box at Niagara Springs Steelhead Hatchery (IFG)

Cost:

The typical unit described has an estimated cost of labor and material of \$200 and has a ten-year life. There are no reported vendors.

Information Sources:

U. S. Fish and Wildlife Service
Idaho Fish and Game

4. **Free-Style Incubation Box** The freestyle incubator is a single plastic unit identical in principle to a module of a deep trough described earlier in this chapter. They are successfully used in Japan, and were recently introduced in the Pacific Northwest. Commonly manufactured from polyethylene or polypropylene plastic, the incubators measure about 2-x 2.5-x 2-feet deep (Fig. 18). They are used in tandem (Fig. 19) for egg incubation and singly for alevins. When used together, the water flows from one to the other.

Figure 18. Free-style incubator.

Twenty gallons per minute is used for both egg and alevin incubation (Table 3). The recommended densities for salmon incubation are 500,000 eggs and 150,000 alevins per individual unit. As with deep troughs, eggs can be incubated on trays or poured directly into the unit. When using trays, the alevins drop through to a substrate below. The latter method allows alevins to volitionally move to rearing areas.

Figure 19. Free-style incubators set in tandem within pond.

Free-style incubators have not been tested sufficiently to recommend them for incubating alevins. The WDF indicates problems with water flow patterns and early emergence of fry. We suggest following the procedures illustrated in Fig. 20 for barrel incubators to eliminate or reduce both problems. A top pressure plate would eliminate early emigration. To start the feeding of all fry simultaneously, we recommend the same procedures used by Mariculture NW for barrel incubators, where plastic bio-rings in net bags are used for substrate. (See Section C - Substrates.)

Advantages:

- Efficient for incubating large numbers of eggs
- Portable; can be readily set-up in rearing ponds
- Require little maintenance
- No building required

Disadvantages:

- Not practical for small egg lots

Cost:

One plastic unit costs approximately \$600, and has a life expectancy of 25 years.

Information Sources:

Washington Department of Fisheries George Adams and McKernan Salmon hatcheries
Canada Department of Fisheries and Oceans

E. CYLINDRICAL INCUBATORS

Cylindrical incubators are made in various sizes and are practical for both small and large incubation programs (Fig. 20). They function on the same principle as the Montana and Free-style box incubators.

Simple models are made from stock plastic or metal containers; however, they can be manufactured from acrylic or PVC pipe, wood, or metal. For this reason the concept offers a variety of low-cost applications to incubate very small and very large numbers of eggs and alevins. Cylindrical incubators are described under the unit headings of jars, jugs and buckets, and barrels.

1. **Jar incubator** Hatching jars were developed to incubate small egg lots; a modified version is shown in Fig. 21. This unit has a 6-inch pipe set in the center of the 12-inch pipe. Water is forced down the larger pipe, then flows up through the smaller pipe, the incubating eggs and alevins. This jar is more efficient in preventing losses from occurring at the time of hatching than earlier designs.

Alevin density within the modified hatching jar should not exceed 20,000 salmon and 25,000 steelhead. Inflowing water used at the Dworshak NFH is 2-3 gpm on green eggs, 5 gpm on eyed eggs, and 4 gpm on alevins. The manager at this station believes that this unit handles silty water better than vertical cabinet incubators. Fig. 22 illustrates the jar incubators at Dworshak.

Advantages:

- Construction is simple
- Clear cylinders allow visual contact when necessary
- Units are portable and can be placed so the fry exit directly to rearing areas
- Practical for use in isolating egg takes from individual females or small egg lots

Disadvantages:

- Incubating large numbers of eggs in many small units is labor consuming
- Smaller size fry and erosion of the yolk sac may occur

Cost:

Cost of labor and material is \$100.

Figure 20. Illustration of a typical cylindrical incubator.

Information Sources:

Idaho Fish and Game
u. s. Fish and Wildlife Service,
Dworshak NFH, Idaho, and Eagle Creek
NFH, Oregon

2. **Jug and Bucket Incubators** A jug or bucket incubator is identical in principle to the jar incubator described above. The units are modifications of existing containers. A 1-gallon jug (Figs. 23, 24) or a 2-to **5-gallon** plastic bucket (Fig. 25) are examples of some containers **used**.

A perforated **plate** is used to serve **as** a water diffuser and contain the eggs. The plate in Fig. 23 is made of perforated polyethylene sheeting cut to fit; however, perforated bucket **lids** have been used for this purpose. At the WDG Elokomín Trout Hatchery, the system was further simplified by directing the water from the top to the bottom of the bucket through a tube. No manifold was used and a house-hold sieve (Fig. 25) was used to contain the eggs. A diffuser plate is recommended and a Scotchbrite pad or 1 inch of pea gravel should be placed on the plate to serve as a filter and diffuser (**Fig.20**). Substrate is recommended for alevin incubation. Any container can be constructed to allow the alevins to escape.

Figure 21. Hatching jar used at the Dworshak National Fish Hatchery (**USF WS**).

Substrate is recommended for alevin incubation. Any container can be constructed to allow the alevins to escape.

The steelhead egg capacity of a **1-gallon** jug and a **5-gallon** bucket is approximately 5,000 and 35,000 eggs, respectively. **Salmon** egg capacities would be about **3/4** this amount. Alevin capacities would be one-half of these amounts for each species. Water flows for alevin incubation should be 0.8 gpm for the 1-gallon and 2-3 gpm for the **5-gallon** container.

Advantages:

- Easy to construct
- Containers available in various sizes
- Low **cost**
- Excellent for volunteer and classroom projects
- Portable; can be set next to or in a rearing unit
- Practical for use in isolating egg-takes from individual females or small egg lots

Figure 22. Jar incubators in series at Dworshak National Fish Hatchery (USFWS).

Figure 23. One-gallon jug incubator noting: (A) inlet, (B) outlet, (C) perforated bottom plate

Figure 24. Operation set-up for 1-gallon jug incubators at Medvejie Creek, Sitka, Alaska.

Disadvantages:

- 0 Visual observations are limited
- 0 Hound containers require more space than modular units
- 0 Small egg lots are time-consuming

cost:

Estimated material cost is less than \$20 for a j-gallon unit

Information Sources:

Washington Department of Game
Northern Southeast Aquaculture
Association, Sitka, Alaska
U. S. Fish and Wildlife Service
Alaska Department of Fish and Game

3. Barrel Incubators The principle of barrel incubators is illustrated in Fig. 20. Any clean metal drum can be used, although AFG uses manufactured units that measure 29 x 48 inches and 48 x 48 inches and are called R29's and R48's, respectively. Common commercial barrels, 15-55 gallons, make excellent units which are used successfully by Mariculture NW of Rochester, Washington. Also, sections of adequate diameter plastic pipe will serve as well.

AFG culturists place 2 inches of plastic saddles upon the perforated aluminum manifold to act as a water diffuser, while Mariculture NW uses 8 inches of pea gravel for a water diffuser. A 12-mesh screen is placed on top of the saddles and is held in place by a stainless steel ferrule. Newly fertilized eggs are placed on top of the screen and are held in place by a perforated aluminum pressure plate.

Trays can be used to hatch eggs; however, it is most common to place eyed eggs in the barrels layered in plastic substrate. ADF prefers saddles, while Mariculture NW uses **1.25-inch bio-rings**. The units can be constructed to allow the alevins to move freely to rearing areas and can serve as streamside incubators.

Alaska Department of Fish & Game programs 600,000 salmon eggs for the **R29's** and **1,700,000** for the **R48's**. A **55-gallon** drum would hold about one-third of the **R29's** capacity.

Recommended **alevin** densities for chinook and **coho** are 80,000 in the 55-gallon drum, 250,000 in the R29, and 725,000 in the R48.

Figure 25. Three-gallon bucket incubator noting: (A) sieve to hold eggs, (B) main water delivery pipe, (C) tube to bottom of bucket.

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For alevins, the water inflow rate is 4 gpm/ft^2 of perforated plate used. The R48 uses 40 gpm, and a 55-gallon drum 1 O-1 2 gpm.

Advantages:

- Many sizes of barrels are available
- Construction is simple
- Labor requirements in handling large egg lots are minimal
- Small units are portable and would not require a building unless there is danger from freezing

Disadvantages:

- Visual contact is minimal
- Require more floor space than rectangular units
- Building recommended for large units

Cost:

The approximate cost of each barrel unit is: 55-gallon drum \$100, and R48 \$1800.

Information:

Alaska Department of Fish and Game
Mariculture NW, Rochester, Washington
Indiana Fish and Game

F. CHANNELS AND **INSTREAM** INCUBATION

Natural incubation is often achieved by placing eggs into prepared channels with a controlled flow of water. **Mature** salmon may be allowed to spawn naturally, as in a spawning channel, or eggs may be manually buried in an incubation channel. Japanese style channels, or “Keeper Channels”, are used in conjunction with production at some hatcheries. Eggs may also be planted directly into a natural streambed.

1. Spawning Channel Channels constructed adjacent to natural spawning streams provide optimum gravel bed and waterflow conditions for spawning and incubation. If a natural cycle of development is allowed, the egg and alevin survival rate is usually several times that of the native stream. Channels vary in size and specifications according to the amount of available land, water, program goals, and species. They also vary in complexity, from inexpensive side channels (Fig. 26) to massive concrete-lined structures (Figs. 27, 28). In Fig. 26 a side stream has been created and stabilized to increase the spawning gravel area and provide more uniform stream flow.

While detailed engineering and design depend upon the site, species, and program goals, certain general criteria and basic requirements are consistent for all spawning channels. A clean water supply is particularly important. Transport of sediments

Figure 26. Typical low-cost side channel development in British Columbia for salmon spawning.

Figure 27. Salmon spawning channel at Wells Dam, Columbia River (WDF).

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into a channel reduces egg survival, increases maintenance, and can lead to costly rehabilitation. Settling ponds are commonly used to help maintain clean gravel habitat. Gravel size typically ranges from 0.5 to 6 inches. The channel requires a gradient of 0.2 to 0.5 percent to promote interchange between surface and intragravel water. Interchange of water can also be accomplished by varying the gravel depth, (usually 12-18 inches) or by burying impermeable baffles. During spawning, the desirable water depth is 1.5 feet with 6 inches being minimum. Velocity should be between 1 and 3 fps, with 1.5 being most desired. Preferred flows per foot of mean channel width are 2.2 cfs for spawning, and 1.5 cfs for incubation.

Figure 28. Salmon spawning channel constructed at Priest Rapids Dam, Columbia River (WDF).

Advantages:

- Increased survival over natural production because of controlled flow and clean habitat
- High quality fry in sync with wild populations
- Labor not needed for spawning adults and handling eggs
- Minimal need for support buildings
- Provides natural mating and genetic responses
- Reasonable cost where physical conditions allow informality in development

Disadvantages:

- Large **spacial** requirement

Incubation

- Difficult to observe egg and alevin development, and to treat any problems
- Formal channels have large capital cost
- Survival rate lower than in “intensive” fish cultural facilities
- Superimposition of eggs must be controlled

Information Sources:

Washington Department of Fisheries
International Pacific Salmon Fisheries Commission
Canada Department of Fisheries and Oceans

2. Incubation Channel Incubation channels (Fig. 29) differ from spawning channels in that eggs are buried artificially (usually by hand) rather than allowing the fish to spawn naturally.

Physical features are similar to those of spawning channels, except that stocking densities are higher. Densities of 500 eyed eggs/ft² of surface area yield high survival to the fry stage. Eyed eggs are most commonly used due to their substantially higher survival rate than newly fertilized eggs. Covered pond trays can be used to eye the eggs within the channel, provided water velocity is not prohibitive. Dead eggs can then be removed before burial. Alternative techniques would be to allow the alevins to drop through the egg tray and work their way into the substrate, or to pour the eggs evenly on top of the gravel shortly before hatching. If eggs cannot be eyed within the channel, space at another facility is required. Preferred flows are 1.0-1.5 cfs per foot of channel width. The incubation channel is effective for all salmonid species, but is more commonly used for those with no stream rearing requirement.

Advantages:

- Higher survival of quality fry than spawning channels
- Requires less space than spawning channels
- Increases survival over natural production because of controlled flow and clean habitat
- Minimum need for support buildings
- Less capital cost than spawning channel

Disadvantages:

- Requires more space than most forms of incubation
- Requires a facility to eye eggs, if this cannot be done within the channel
- Labor required for spawning adults, handling eggs, and enumerating production

Information Source:

Washington Department of Fisheries.

Figure 29. Low-cost eyed-egg channel, at Satsop Springs, (WDF).

3. Keeper Channel (Japanese style) The typical Japanese keeper channel is about 6 feet wide, 90 feet long, and 12 inches deep. They are usually constructed entirely of concrete, but the bottoms of some are earth. The slope of the floor is approximately 0.2 percent with 0.5-to 2-inch gravel placed one rock deep (Fig. 30).

Eyed eggs are placed two deep on pond-width trays which have a screen bottom. The screen retains the eggs, but allows the alevins to drop through to the rock substrate below. Approximately 12,000 alevins are incubated per square yard of channel floor. When the alevins are ready to feed, they drop downstream to rearing areas.

The WDF and DFO have designed channels where water levels can be raised in order to create rearing ponds. The Japanese and DFO often cover the channels with a building. This protects the facility from freezing and allows light control. Light control is also accomplished by using boards or plastic materials.

The water volume supplied to each channel is about 60 gpm. Spring water or relatively silt-free water is a requirement. The water should flow evenly along the width of the channel at a depth of only 2 or 3 inches, barely covering the eggs, alevins, and the rock substrate.

The channels were designed for chum salmon incubation, however, DFO has successfully incubated eggs and alevins of steelhead and some species of salmon.

Figure 30. Japanese keeper channel (Chehalis River Hatchery, British Columbia)

Advantages:

- None can be listed over other incubation methods for the species considered

Disadvantage:

- Very costly
- Fry tend to migrate to head of channel, creating low dissolved oxygen conditions and high mortality
- Loading densities, gravel size, and depth of water very critical
- Water flow patterns must be monitored closely

Information Sources:

Tulalip Indian Tribal Hatchery, **Marysville**, Washington
 Washington Department of Fisheries **McKernan** Salmon Hatchery
 Canada Department of Fisheries and Oceans

4. Planting of Eggs Salmonid eggs can be planted at either the green or eyed stages directly into redds dug by shovel in the stream gravel. A patented device, (Ova, Inc., Appendix 2) has also been successfully used to bury eggs by AFG. **Egg** plants will be most successful where flows are stable and **suitable** clean spawning gravel exists. Survival rates will be less than artificial production methods.

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Another approach to egg planting is the use of perforated boxes, such as the Whitlock-Vibert box. This affords some protection to the developing eggs or alevins from either predators or shifts in the gravel beds. About 200 to 300 eyed eggs are placed in this translucent plastic box measuring approximately 6 x 3.5 x 2.5 inches. Fry are able to emerge through slots or perforations in the **walls** of the box.

Modifications of the **Whitlock - Vibert** box have been made to accommodate larger numbers of eggs, such as the “sandwich box”, considered for use by Grant County PUD, and the perforated drainfield pipe whose use was studied on the Chehalis River in western Washington State by Dr. E. **Brannon**, University of Washington.

Advantages:

- Low cost material investment
- Production of high quality fry
- **Means** to handle small egg lots for evaluation and bioassay

Disadvantages:

- Survival rates lower than other artificial production techniques
- **Whitlock - Vibert** boxes not efficient for handling large lots of eggs

Information Sources:

Alaska Department of Fish and Game
Canada Department of Fisheries and Oceans
Washington Department of Fisheries
Ova, Inc. - Wrangell, Alaska
Oregon Fish and Wildlife
Grant County Public Utility District, Ephrata, WA
University of Washington, School of Fisheries, Seattle, WA

PART III. INCUBATION TOOLS AND EQUIPMENT

Nearly every fish culturist has his own version of tools and equipment for handling salmon and steelhead eggs during the incubation period. Some of these he makes, while others are commercially manufactured. Both types, as well as techniques for their use, are discussed in this section under (A) egg sorters, (B) egg counters, and (C) substrates.

A. EGG SORTERS

The four common methods used to remove infertile eggs are hand picking, floating, mechanical sorting, and bouncing. All require that egg “shocking” be conducted before sorting to allow the infertile or dead eggs to be identified from the viable eggs. To do this, eyed eggs are sufficiently **rough-handled** to rupture the yolk membrane in the infertile eggs. As the yolk comes into contact with water it precipitates and turns white. Besides turning color, shocked infertile eggs have less resiliency and less specific gravity.

Shocking does not harm viable eggs. This change in physical properties of the infertile eggs is the basis for **all** of the sorting procedures used.

1. **Hand Picking** Hand picking involves the removal of the opaque dead eggs, one at a time, directly from the incubator. The three commonly used pickers are the siphon and bulb (Fig. 31) and tweezer (Fig. 32). The first two are usually used with small eggs, while the tweezer is used to pick large eggs. They are similar in that they are inexpensive and easy to develop; they can be used to remove some dead eggs during the tender stage prior to shocking; they require a certain degree of operator skill; and an experienced person can remove 10-15,000 dead eggs in an 8-hour period.

Figure 31. Tools used in egg picking: (A) bulb pickers, (B) siphon.

There are various types of siphon egg pickers. The simplest has only two parts; a length of flexible tubing and a 6-inch glass tube selected to the egg size for the picking end. Once the siphon is started, the glass tube is directed to an individual egg for removal. One hand of the operator controls the glass tube while the other pinches off the power of the siphon as required. The dead eggs lead through the tube and fall into a bucket below.

The bulb picker functions similarly to the siphon system. As the bulb is hand-squeezed and relaxed, the egg is sucked into the bulb and later dispelled with a squeeze of the bulb.

Fig. 32 (B) illustrates a wooden (cedar) tweezers. The wire loop on the end of each leg is sized to fit the egg. This tool is universally used and available in plastic or metal.

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Advantages:

- They are cheap and easy to hold
- Ideal for picking small egg lots
- Usable during the tender stage
- Used in combination with all other methods
- Electric power not required

Disadvantages:

- Time-consuming methods to pick large numbers of dead eggs

Cost:

Only a few dollars for any of the methods.

Information Sources:

Contact steelhead hatchery managers for siphon and bulb pickers; salmon hatchery managers for wooden tweezers; Washington Department of Fisheries, Priest Rapids Salmon Hatchery manager for plastic tweezers
Roe, Inc.

Figure 32. Tools used in egg picking: (A, C) skimmers, (B) tweezers.

2. Ploitation Method This method is based on the fact that shocked infertile eggs have a specific density slightly less than shocked fertile eggs. By altering the specific gravity of water to a point where it is slightly greater than the dead eggs, but slightly less than the live eggs, the dead eggs will float. Sugar, table salt, and epsom salts are all used to alter the specific gravity, but the use of table salt is the most common. To change the specific gravity of water and keep it at the proper level is difficult, since fertile eggs have a specific gravity of 1.02 and water 1.00. Weithman and Anderson (1977) successfully tested these three solutions using a specific gravity of 1.075. Any watertight container can be used in this process but generally an incubation trough is employed. As the dead eggs float they are immediately skimmed off with small hand skimmers (Fig. 32). Care must be taken to remove the live eggs from the solution within minutes, as the solution can be lethal or cause weakness in the shell of viable eggs. In an 8-hour day, a person can remove dead eggs from a 500,000 egg lot.

Advantages:

- Special equipment or electric power is not required
- Very low cost

Disadvantages:

- The very narrow range in the specific gravity between dead and viable eggs make complete separation difficult
- Too long in the solution can be lethal or cause weakness to the egg shell on viable eggs, particularly if table salt is used
- It is difficult to regulate the specific gravity of the medium

Cost:

Several dollars of table salt would be sufficient for a million eggs. Sugar and epsom salts are slightly more expensive.

Information Sources:

Most hatchery managers

3. Mechanical Pickers (optical density method) There are several optical egg pickers on the market and the newer ones can be adapted to count eggs. All the units are reasonably accurate, require a water and electrical supply, and can pick three to four times the number of eggs in a day as any of the methods previously discussed. Three brands commonly used in the Northwest are the Roescan, Jensorter, and Sustaf. The disadvantage of these and other brands is their high cost. Accordingly, they are not applicable for use at a low-cost facility. The Roescan and Jensorter cost \$7,000 each while the two models of the Sustaf cost \$10,000 and \$13,000 respectively. Further information is available from vendors in Appendix 2.

4. Bounce Method (Buzzell sorter) The Buzzell sorter consists primarily of two inclined boards and operates on the principle that shocked infertile or dead eggs have less resiliency than live eggs. Accordingly, when dead and live eggs fall a foot or two, the live eggs bounce many times further. To operate the sorter, eggs are rolled one layer deep down the upper board. When they fall from the upper to the lower board, they bounce, and the fertile and infertile eggs are separated by the distance bounced. Generally the eggs are sorted twice to achieve good results, but some units provide for two sortings of the same egg lot on a single pass. The sorter can be constructed of plywood, but the surface should be smooth. One person can sort approximately 500,000 to 700,000 eggs per day.

Advantages:

- Can be constructed in the home workshop, but is reportedly patented
- The units are portable
- The labor cost to operate the sorter is half that of hand picking and similar to flotation methods
- Electrical power is not required

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Disadvantages:

- ° The last few remaining dead eggs may require hand picking

cost:

Material cost is \$100 for a plywood unit.

Information Sources:

Washington Department of Fisheries, Dungeness Salmon Hatchery
U. S. Fish and Wildlife Service, Quilcene NFH, Washington
Oregon Aqua Foods

B. EGG COUNTERS AND ENUMERATION METHODS

There are many ways to count or estimate egg numbers. **Mechanical** counters are usually the most accurate; however, they are subject to operator error. Estimations based on known numbers by weight or volume are adequate for most fish cultural programs since the degree of error usually falls within 5%.

The three common egg enumeration methods described are mechanical counters, paddle counters, and the tools and equipment for estimating.

1. Mechanical Counters Several good electronic egg counters are available that count eggs at a rate of 5,000 per minute. **Most** units are adaptable to any physical layout and accurately determine egg numbers (Fig. 33).

Counters are used extensively by AFG and OFW. Cost ranges from \$2,000 to \$5,000. A recently developed model operates on 12-volt batteries. **Local** suppliers are Northwest Marine Technology, Inc., and Denny **McLarry** (contact through **OFW**).

2. Paddle Counter The paddle egg counter is used at most hatcheries (Fig. 34). By passing this unit through a basket of eggs, a sample of 100 are readily obtained. It is an excellent tool to accurately count large egg lots and works well on all species. One fish culturist can count 50,000 eggs per hour. A counter without a handle costs approximately \$15.00 (Demorest, Appendix 2).

3. Estimation Tools and Methods Estimating the number of eggs by weight or volume is reasonably accurate for large lots and is the least costly method. Only a few of the many ways are discussed here. To approximate total numbers by weight, a scale or balance (Fig. 35) is used to weigh four or five random samples of known numbers of eggs. Once a number per unit weight is established, the total number of eggs can be estimated after weighing the entire lot.

A slightly faster procedure is to count or use the above method to estimate the number of eggs per given volume, such as in a coffee can or a **5-gallon** bucket. The total egg count is then equal to this figure multiplied by the number of cans or buckets of eggs comprising the entire lot.

Figure 33. Mechanical egg counter used at many OFW hatcheries.

The water displacement method is another technique, and tables are available that show the number of eggs it takes to displace a given volume of water in a vessel. Also used is the ratio of the number of eggs per unit of length. Here, too, a table will allow the numbers to be estimated.

Hatchery personnel sometimes make gross egg estimates using the average number of eggs per female, or eggs held by an incubation unit of known capacity. These are reasonably accurate as an interim procedure; however, once the eggs are eyed and shocked a more accurate estimate is made.

C. SUBSTRATES

Substrate, or a medium in which alevins incubate, was originally conceived to be used for pink and chum salmon. Recently, fish culturists have begun to use it for incubating

Figure 34 Paddle egg counter of 100-egg capacity.

Figure 35. Spring scale and perforated scoop for weighing eggs.

chinook and coho, and to a lesser extent, steelhead trout. The reason for using substrate is to produce a higher quality fry and a better smolt. The former has been well-documented, but, the latter has not, especially in regards to a long-term reared fish. Regardless, most culturists agree that the improved fry quality has one definite benefit. That is, the extra cost and labor required to use substrate is offset by having less pond mortality during the early stages. Gains, if any, in the quality of smolts would be an additional benefit.

There are four substrates commonly used for incubation: gravel, plastic netting, plastic saddles, and plastic bio-rings. Fish culturists often differ in their selection of the substrate even for the same type of incubation unit. In cabinet incubation, all substrate types described seem to produce equal quality fry. This is substantiated by the recent work of Banks (1983). For other incubation units, a more careful choice of substrate should be considered. Cost, availability, personal preference, and ease of use are factors affecting choice.

1. Gravel Substrate Gravel substrate is most commonly used in egg-boxes, the Japanese keeper channel, egg-incubation channels, and spawning channels. A good gravel size for salmon egg-boxes and keeper-channels is 5 % or less under 1 inch or over 2.5 inches, by weight, and the remainder ranging in size between these parameters. Steelhead are successfully incubated in Japanese keeper channels with this size gravel (Fig. 36).

Advantages:

- The material is economical and readily available in the Columbia River basin

Disadvantages:

- It requires more physical effort to clean than other substrates
- The transportation of gravel to remote areas may be difficult

Cost:

The price is approximately \$12/cubic yard at most sand and gravel companies.

Information Sources:

Washington Department of Fisheries
Canada Department of Fisheries and Oceans

Figure 36. Typical gravel composition used in egg boxes and keeper channels.

2. Plastic Netting Polyethylene netting is used in vertical cabinet incubators and other tray-type incubators. The netting is a heavy gauge with mesh sizes of 0.75-1.25 inches. Each tray receives three folded layers tied to form a mat.

Advantages:

- Requires little space within the incubator
- The material is easily removed and separated from the fry
- Suitable for use in shallow tray incubators

Disadvantages:

- The material is more difficult to clean than other artificial substrates because it cannot be run through a fish pump.

cost:

The material is \$150 per 48-inch, 150-foot roll.

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Information Sources:

U.S. Fish and Wildlife Service
Abernathy Salmon Cultural Development Center, Longview, WA
Washington Department of Fisheries
Internet, Inc.
Memphis Net and Twine Co., Inc.

3. Plastic Saddles Plastic saddles, illustrated in Fig. 37, are constructed of poly-propylene and should be manufactured with a greater specific gravity than water. The width of the saddle commonly used is 1 inch. Saddles often are placed in **3/4-inch** mesh net bags so they can be easily removed from the incubators. If the saddles have sharp edges, they are mixed with sand and turned in a cement mixer until acceptable. They can be used in most incubation units.

Advantages:

- ° The material is light, easy to handle and transport and can be stored in bags
- ° They can be washed and transported with a fish pump
- ° Saddles have more total void spaces than gravel per volume of material

Disadvantages:

- ° The saddles tend to pack in the incubators
- ° The material is expensive compared to gravel
- ° More difficult to clean than **bio-rings**
- ° The fry are more difficult to remove from saddles than bio-rings

Cost:

Approximately **\$16-\$30/ft³** or **\$640-\$1200** per 4 x 8-foot deep-matrix box (cost varies by vendor and is based on order of 100 **ft³**).

Information Sources:

Alaska Department of Fish and Game
Canada Department of Fisheries and Oceans
Glitsch, Inc.
Norton Company

4. Plastic **Bio-Rings** Plastic bio-rings (Fig. 37) can be used in most incubation units. A 1.5-inch diameter ring appears best for salmon while a 1-inch ring would likely be best for steelhead. The rings should be ordered to sink in water.

For salmon **alevins**, fish culturists place bio-rings in loose bags made of 1-inch mesh plastic netting. Mariculture Northwest places three bags of rings in a **50-gallon** incubation barrel. They are removed from the incubator during the latter phases of yolk absorption or when the fry are ready to pond. The bags are easily removed with

a short hook, leaving only fry. The rings can be stored in these bags. They can also be made up in long strings for easy removal.

Advantages:

- ° The same as those listed for saddles
- ° **Bio-rings** do not pack in the incubators

Disadvantages:

- ° Bio-rings are more expensive than gravel

Cost:

The lowest price obtained was \$12.10/ft³ in 100 ft³ lots for 1-inch weighted rings and \$7.35 for 1.5-inch rings.

Information Sources:

Washington Department of Fisheries
 Mariculture Northwest, Rochester, Washington
Glitsch, Inc.
 Norton Company

Figure 37. Plastic substrate materials used in incubators: (A) saddles, (B) 1-inch bio-rings, (C) 1.2-inch bio-rings.

PART IV. SUMMARY

Table 4 summarizes information presented in this Chapter on the various types of salmonid incubators and compares their initial unit capital costs and floor space requirements in terms of egg and alevin production.

Table 5 grossly rates these same incubators on several practical features that are important in selecting a suitable incubation method. These features deal with their suitability for other uses, complexity of plumbing, ease of operation, and unit longevity. These tables show substantial differences in the relative cost, space requirements, and multipurpose functions of various units.

We feel that all the incubation units considered can be used successfully and, when differences between units are minor, we suggest that staff preference be considered.

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Table 4. Comparison of capital costs and floor space requirements versus potential production for 16 different **salmonid** incubators.

<u>Type of incubator</u>	<u>Unit cost⁽¹⁾ per 100,000⁽²⁾</u>		<u>Production per square foot of floor space⁽³⁾</u>	
	<u>Eggs</u>	<u>Alevins</u>	<u>Eggs</u> (in thousands)	<u>Alevins</u>
Vertical				
Cabinet (16 trays high)	\$1250	\$1750	10	7
NOPAD (5 units high)	250	500	62	31
Trough				
Deep (2 units high and 2 wide)	90	460	54	13
Shallow (3 units high and 4 wide)	491	4300	23	3
Pond				
Wooden tray 2.5 x 4 ft.	100	100	outdoors	
Metal tray 2.5 x 4 ft.	400	400	outdoors	
Box				
Deep-matrix				
4 x 8 x 4 feet	300	300	13 or outdoors	13
2 x 8 x 1.25 feet	500	500	outdoors	
Shallow-matrix				
4 x 8 x 1.3 feet	667	667	outdoors	
Montana	200	267	50	37.5
Free-style (single)	120	400	71 or outdoors	21
Cylinder				
Modified jar	500	500	10	10
1-gallon jug (3 high)	83	167	10	5
5-gallon bucket (2 high)	33	67	35	18
55-gallon drum	50	125	33	13
R-48 barrel	106	248	65	28

(1)Includes all costs, except external plumbing, necessary to make unit ready to operate, including trays or baskets.

(2)Calculations based on average egg size of 1400 per pound.

(3)Floor space includes aisles between rows of units but not end walkways.

Table 5. Summary analysis of **salmonid** incubator units to compare practical features and aid in the selection process.

<u>Type of incubator</u>	<u>Rearing capability</u>	Labor intensity per no. of eggs	<u>Multiple usage</u> ⁽¹⁾	<u>Plumbing requirement</u>	<u>Bldg.</u>	<u>Unit Maintenance</u>	Unit life <u>in yrs.</u> ⁽²⁾	Tray life <u>in yrs.</u>
<u>Vertical</u>								
Cabinet (fiberglass) (16 trays high)	no	high	no	complex	yes	minimum	25	15
NOPAD (aluminum) (5 units high)	no	avg.	no	complex	yes	minimum	25	25
<u>Trough</u>								
Deep (fiberglass) (2 units high & 2 wide)	yes	low	yes	semi-complex	opt.	minimum	25	15
Shallow (fiberglass) (3 units high & 4 wide)	yes	high	yes	semi-complex	opt.	minimum	25	25
<u>Pond</u>								
Wooden tray 2.5 x 4 ft.	yes	avg.	no	simple	no			8
Metal tray 2.5 x 4 ft.	yes	avg.	110	simple	no			15
<u>Box</u>								
Deep-matrix (wood) 4 x 8 x 4 ft.	yes	avg.	no	semi-complex	opt.	minimum	10	8
2x 8 x 1.25 ft.	yes	high	110	semi-complex	opt.	minimum	10	8
Shallow-matrix (wood) 4 x 8 x 1.3 ft.	yes	high	110	semi-complex	110	minimum	10	8
Montana (wood)	110	avg.	110	semi-complex	opt.	minimum	10	
Free-style (fiberglass) (single)	no	low	no	simple	opt.	minimum	25	15
<u>Cylinder</u>								
Modified jar (acrylic)	no	avg.	no	complex	opt.	minimum	25	
1-gallon jug (plastic) (3 high)	no	high	110	complex	opt.	minimum	15	15
5-gallon bucket (plastic) (2 high)	no	avg.		complex	opt.	minimum	25	15
55-gallon drum (metal)	yes	low		simple	opt.	minimum	15	15
R-48 barrel (metal)	yes	low	110	simple	yes	minimum	25	15

(1) Can be used for egg shocking, picking and sorting, as disinfectant tanks, and for **holding** fish for marking or other experiments.

(2) Maintenance for each **type** of incubator is deemed **minimal** or about the same, and not an **important** factor in selection. Those with longer unit life usually require **less** maintenance.

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Based on our visits to numerous salmon rearing facilities in the Northwest, and knowing the ingenuity of the culturist, we expect that some will find exceptions to our ratings. Regardless, we feel that our work is reasonably representative of the actual conditions and practices that currently exist.

CHAPTER 5

REARING

This Chapter includes biological requirements for rearing, descriptions of various rearing facilities, information on fish feeds, and support equipment. It was largely derived from direct contacts with fish culturists, visitations to Northwest facilities (Appendix 3), and from the aquaculture suppliers listed in Appendix 2. Further information was obtained from the Facility Design Work Group, consisting of Federal, State, and Tribal representatives in Washington and Oregon formed under the Salmon and Steelhead Conservation and Enhancement Act (SSCEA) of 1980 (PL 96-561).

PART I. BIOLOGICAL REQUIREMENTS

We have selected two criteria to determine the fish production capacity of a salmonid rearing facility. These are:

- (1) The maximum pounds of fish to be reared with a water supply of 1-gallon per minute (gpm) and adjusted for species, fish size, and water temperature (Table 1).
- (2) The maximum pounds of fish to be reared in 1 cubic foot (ft³) of rearing water and adjusted for fish size (Table 2).

We believe that choosing these two criteria will:

- (1) Allow realistic prototype facilities to be designed and programmed by ourselves as in Chapter 9, and
- (2) provide a guide for facility selection and realistic programming by the reader. Thus we have attempted to identify the specific levels of production for each criterion that is representative of current fish culture programs conducted by Northwest tribal and agency culturists.

We recognize that other biological factors have been used for design parameters, some of which include: oxygen consumption rates, accumulation of metabolic products (Haskell, 1955), production of un-ionized ammonia (NH₃) (Willoughby et al., 1972; Burrows, 1964; Trussel, 1972), disease considerations (Wedemeyer and Wood, 1974), and historical conditions of existing stations (Banks et al., 1979). More recently, all Northwest agencies have been attempting to develop rearing criteria based on survival levels to adult.

To reduce risk, a new station is usually managed conservatively for the first few years until its performance characteristics are developed. This performance record is then used to adjust future production levels. A part of this performance record is how the species

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Table 1. Hatchery pond loadings expressed in pounds of fish per gpm of inflow.⁽¹⁾

<u>Species</u>	<u>Temperature</u> (F)	<u>1,000</u>	500	Number of fish per pound			
				<u>50</u>	<u>25</u>	<u>15</u>	<u>6</u>
				<u>Pounds of fish per gpm</u>			
Coho	38	3.5	5.0	8.8	16.0	20.0	-
	48	2.7	4.0	8.0	12.8	14.4	-
	58	2.2	3.0	5.6	9.6	12.0	-
	63		2.0	4.0	7.2	8.0	-
	68			1.6	2.4	3.2	-
Fall/spring chinook, steelhead & sockeye ⁽²⁾	38	3.0	4.0	6.4	9.6	10.4	-
	48	2.5	3.0	5.2	8.0	8.8	-
	58	2.0	2.2	3.6	7.5	7.2	7.2
	63				4.0	4.4	-

(1) Source: The basis for this table is primarily Wedemeyer and Wood (1974); however, it has been modified to show less pounds of fish per gpm with fish larger than 50 per pound (9 grams each). Modification was made after conferring with the Facility Design Work Group of SSCEA (Zook, 1984).

(2) The data for sockeye and steelhead were not presented by Wedemeyer and Wood, (1974). We arbitrarily assumed it to be similar to chinook after conferring with members of the SSCEA Facility Design Work Group. See Zook, (ibid).

Table 2. Rearing criteria for salmonids in pounds of fish per cubic foot of rearing water for ponds less than 4,000 ft³ capacity⁽¹⁾ and assuming water temperatures are within normal recommended ranges for the species.⁽²⁾

Species	Number of fish per pound					
	<u>12</u>	<u>Maximum pounds of fish/ft³</u>	<u>15</u>	<u>1</u>		
Steelhead, coho, chinook and sockeye	0.3	.4	0.6	0.9	1.7	2.0

(1) The primary information source was Banks et al., (1979), however, for fish of a size larger than 100/lb. (4.5 grams), we reduced the pounds/ft³ of rearing space by approximately 20%. Banks did not include sockeye in his material, but we will assume sockeye to be similar to coho, chinook, and steelhead.

(2) The ft³ capacities are not affected by temperature as long as they are within the ranges recommended for the species.

Rearing

respond to conventional diets. Table 4, which follows in the Fish Food Section of this chapter, illustrates typical conversion rates of salmonids from first feeding to various release sizes and gives the manager a basis for comparison. For further discussion see Banks (ibid).

Recent studies by all Northwest agencies have suggested that rearing reduced numbers of salmonids in a given environment will produce a higher survival to adults and often result in a greater return for the dollar invested.

Zook (1984) showed that culturists in the Northwest often differ by 30% or more in the levels of a criterion used for rearing. In our opinion, this difference is to be expected in fish culture given the "state of the art" with all its variables. One can readily see, however, that if the functional criteria is for 30 percent more or less water or space for a given program the criteria is highly reflected in construction and design cost. Regardless of these differences, the least costly rearing facility **will** generally result if it is designed and constructed to approach the maximum recommended fish production levels established for each criterion. For example, the required amount of water (Table 1) should match the required amount of space (Table 2). Several approaches to address this concern exist, but the one we chose to use is to first determine the space requirement, and then program the required amount of water.

In a non-theoretical situation, where the desired amount of water may not be available, cost savings will result by reducing our original space conception.

Our recommended maximum pounds of **smolts** per cubic foot of rearing space (density) in ponds less than 4,000 **ft³** is illustrated in Table 2. For larger rearing ponds and for the purpose of this report, densities in Table 2 are reduced by one percent for each additional 1,000 cubic feet of rearing space, up to 50% (see Appendix 6). These density levels correspond generally with the current programming by agencies and tribes. This reduced level will decrease the possibility of disastrous loss by risking many fish in a single pond. When water is re-used (i.e. flows from one pond to another with larger fish), we have used an equivalent value of 60% of new water. This value is based on the practice of the USFWS and WDF who both use a new water equivalent of about 66%. Table 2 provides information for pond design based on the volume of water in the rearing pond as related to fish size.

The "interchange **rate**" is a term often provided to the design team by the **culturist** that relates to the number of times a pond is filled each hour by the inflowing water. For example, an interchange rate of "2" means the pond will be filled twice during a 1-hour period. The rate can be calculated by multiplying the inflowing water in cubic feet per second (**cfs**) by the seconds in an hour and then dividing by the cubic feet of rearing space in the pond. The formula is as follows:

$$\frac{\text{rate of inflow (cfs)} \times (\text{seconds in 1 hour})}{\text{cubic feet of rearing space}}$$

A pond containing 1,350 **ft³** of rearing space with a water flow requirement of 338 **gpm** (0.75 **cfs**), has an interchange rate of "2".

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$$\frac{(0.75)(3600)}{1350} = 2$$

Interchange rates are often expressed incorrectly if the gallon per minute requirements are not carefully analyzed. If, for example, the rate is expressed to the design team as "3" and the space and flow requirements are the same as in the previous example, the facilities water flow will be over-designed by 50%, because of the limitation with the pounds of fish that can be reared in a ft³. Most interchange rates fall between 1 and 2.5. If we calculated for 15 per pound coho at 58°F, the interchange rate would be 1.1 (based on tables provided) and 2,295 pounds of coho could be reared in the 1350 ft³ pond using 191 gpm of water.

Because we have insufficient data to show that there are differences in production capabilities between raceway and circular troughs and ponds of equal size, we will assume them to be identical for the purpose of this report.

PART II. REARING FACILITIES

Fish rearing facilities are one of the most expensive components of a fish cultural station because of the space and water requirements that increase dramatically once incubation and early development stages are complete. Fortunately, many types of facilities are available and experimentation continues as fish culturists seek to reduce costs and improve fish quality. The options for multiple use must always be considered in selecting and costing a rearing facility. Some rearing facilities are also used for holding adults, housing incubation units, or as settling ponds to precondition incubation water. Generally, rearing ponds are designed to provide for the following:

- A uniform water flow to minimize stagnant water areas and to flush metabolic wastes.

- A screened water supply to prevent the entrance of debris and wild fish.

- Stable sides and bottom.

- Drainable for removing fish, cleaning and disinfecting.

- Pond drain sized to permit the water to be lowered while maintaining the incoming supply during low-water operations.

- A minimum of water seepage.

- Access around the pond periphery for operations and maintenance.

- Installation of predator control measures.

- Protection from freezing weather, especially units above ground.

Rearing ponds are usually not classified by type of facility and rearing stage as most ponds can be used for all phases of rearing. But, for the purpose of discussion in this report, they are described as: troughs and tanks, raceways, circular ponds, large rearing ponds, and net pens and enclosures. A summary of the costs and usable life of the units described in the following sections is shown in Table 3.

A. TROUGHS AND TANKS

Most troughs and tanks that have been used for the incubation stages of salmon and steelhead trout development have limited use in volume rearing. The initial feeding of salmon and steelhead trout at many hatcheries occurs in deep or shallow troughs, in concrete tanks which resemble deep troughs or small raceways, and in small circular tanks. Most fish culturists use the shallow troughs for steelhead trout and some agencies use both shallows and deeps and/or tanks for salmon. Small lots of steelhead are sometimes isolated in smaller units with separate water systems if virus disease is suspected, or if it is desired to keep genetically unique lots separate. In our opinion, these small tanks are generally not required for starting salmon. At many hatcheries, salmon feeding is initiated directly in larger ponds or the fish are congregated in a section of a raceway or pond until they are accustomed to taking food. This technique saves the cost of the starter units, building space if units are housed, and labor because larger numbers can be fed at one time. If the starter units for steelhead are deemed necessary for low-cost facilities, we recommend the portable troughs that can be stacked two to four units high to save floor space (Fig. 1). Rearing densities and flow rates for both shallow and deep troughs are shown in Chapter 4, Table 3.

Figure 1. Fiberglass troughs used to rear fish at the Cowlitz Trout Hatchery (WDG).

General Trough Advantages:

- ° Small lots can be easily handled
- ° Special lots can be kept separate or isolated
- ° The initial feeding can be conducted under close observation

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General Trough Disadvantages:

- Time consuming to feed small lots and clean units
- Require considerable in-house floor space if not stacked
- If stacked, automatic feeders may be difficult to use

cost:

See Chapter 4 (Incubation) for details. A fiberglass shallow trough costs about \$300, and a fiberglass deep trough costs approximately \$900.

1. Capilano Rearing Trough The Capilano rearing trough was developed at the Capilano Hatchery, Vancouver, British Columbia. Constructed primarily of 12-gauge sheet aluminum or fiberglass, they are parabolic in cross-section, and approximately 1.75 x 21 x 1.5 feet (Fig. 2). They are very efficient for raising small lots of fish from the emergent -stage to approximately 90 fish/pound. Consequently, these units have been popular for rearing steelhead trout fry, 90-day chinook smolts, chum fry to 450/pound, and advanced coho fry for out-planting at 90-180 fish/pound. The special requirements for fish larger than 90/pound tends to negate their use because they become very labor intensive. The Capilano trough has also been used for holding adults, and may be set up as an incubator by vertically baffling into compartments, loading with gravel, and thus creating several upwelling incubators in series. Estimated incubation production would be approximately 450,000-600,000 alevins based on 10-15 gpm/100,000 alevins. Unless one is dealing with small numbers, adult holding tends to be inefficient due to the limiting capacity. On average, one trough will hold 100 pounds of adult fish based on a loading rate of 2.0 lb/ft³. Flow rates are adjustable up to 30-40 gpm.

Figure 2. Capilano rearing trough upside down to show construction (DFO).

Advantages:

- Easy to clean, and treat diseased stock
- Good laminar flow patterns
- Relatively high loading rates for fish up to 90/lb
- Relatively maintenance free
- Good usage when working with small remnant stocks destined for out-planting
- Quality control of fish easily monitored visually and through routine sampling programs
- Relatively portable

Rearing

- ° Multiple usage, i.e. adult holding, fry rearing, and incubation
- ° May be mounted above or adjacent to rearing raceways and used to stock raceways

Disadvantages:

- ° Expensive
- ° Tend to be restrictive with larger fish sizes and populations
- ° Bulky to move
- ° Occupy a large surface area
- ° Relatively labor intensive

Cost:

The cost of one aluminum trough is about \$1000, or \$18.14/ft³ of rearing volume. Life expectancy is 25 years. The fiberglass units cost more.

Information Sources:

Oregon Fish and Wildlife Lookingglass, Marion Forks, and Salmon River Fish hatcheries

Canada Department of Fisheries and Oceans

M & W Fabricators

PROMETCO

B. RACEWAYS

The most common salmon and steelhead trout rearing facility in the Pacific Northwest is called a raceway. They are a rectangular water container used for all phases of rearing, and range from 3-20 feet in width, 20-150 feet or more in length, and have a water depth of 1-10 feet. Water enters at one end of the raceway and flows out the other. The various sizes evolved as fish agencies designed units to meet specific needs. Recently the fish agencies adopted a standard size of 10 x 100 x 3.5 (mean water depth) which will be used at all hatcheries constructed under the Lower Snake River Compensation Plan.

Raceways are usually constructed with 6-12 inches of floor slope per hundred feet and built side by side so two ponds can utilize a common wall. Normally they are built in clusters of four, eight, twelve, or sixteen, and are referred to as a "bank of raceways". The most efficient water utilization occurs when the units are installed in tandem, and in consideration of disease problems the smaller fish are reared upstream of the larger fish. Managers generally prefer single water usage (single pass), especially on fish of similar size.

Because of their configuration, raceways have a distinct advantage in that the water flow patterns can be designed for optimal fish health and production density.

For the inlet supply water we recommend a diffuser across the upper end of a raceway (Fig. 3). This creates a uniform water velocity and flow pattern throughout the pond and

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eliminates “dead water” areas. For the drain or outlet structure we recommend the design illustrated in Fig. 4. The barrier (A), or the second standpipe (B), increases the water velocity along the bottom of the pond and creates a self-cleaning action in the area where most metabolic waste and unused food particles settle. This is especially beneficial if brush cleaning is used since most waste is pushed along the bottom. These inlet and outlet systems will optimize water quality and pond cleanliness.

Figure 3. Inlet water system on a 10-foot raceway at the Naselle Salmon Hatchery (WDF).

Raceways can be fixed or movable units. The former are usually constructed of concrete or dirt, while the latter include wooden, metal, and fiberglass units. The metal and fiberglass structures can be purchased as shelf items. The general advantages and disadvantages of all raceways and specific details on types of units are discussed below. Unit details and costs do not include the water supply and drainage systems.

General Raceway Advantages:

- Water velocity patterns can be optimal through proper design
- Can be used for fry, fingerling, and smolt rearing
- Ponds can be sectioned to accommodate small lots of fish and different species
- Easier to clean; diagnose and treat fish for disease; and control and handle fish, than most rearing units
- The design results in water-borne diseases moving rapidly through and out of the system
- Predator control measures are easy to incorporate
- If common walls are used, they are more cost efficient

Figure 4. Outlet drain of a rearing pond showing how water flow is directed along floor of pond with (A) baffle, (B) second stand pipe.

General Raceway Disadvantages:

- High space requirement when common walls are not used
- High unit development and manpower operating costs, particularly for small concrete units
- Sectioning of ponds generally requires vacuum cleaning unless short-term retention is programmed.

1. Concrete Raceway A typical USFWS-type reinforced concrete raceway is 8.75 x 80 x 4 feet and the walls and floor slab are 8 and 6 inches thick, respectively (Fig. 5). One cfs is the maximum designed water inflow and the mean water depth is maintained at 3 feet, providing 2000 ft³ of rearing water.

Advantages:

- Low maintenance
- Long life expectancy

Disadvantages:

- Difficult to construct; requires plumb, straight walls for fish crowding, and has numerous embedded screen and flashboard guides
- High cubic foot construction cost
- Pond cleaning requires 1 hour per week per pond

Figure 5. Typical concrete raceway at the Abernathy Salmon Cultural Development Center (USFWS).

Cost:

The capital cost is approximately $\$6.44/\text{ft}^3$ of rearing water, and the unit has a 50-year life expectancy.

Information Sources:

Federal and state fish hatchery managers

2. Earthen Raceways These ponds are usually constructed from materials available from on-site excavation, but sometimes material importing is necessary, particularly if surfacing is desired or if pond sealing is necessary. Gravel is usually used for surfacing and clay for sealing. Earthen raceways can be any size (Fig. 6) but a typical one is 20 x 80 feet and has a 3-foot water depth providing 2600 ft^3 of rearing area. The banks are constructed on a 3:1 slope or steeper. The water supply may be delivered through an upwelling facility at an elevation slightly higher than the pond surface (Fig. 7). However, we recommend a manifold system as illustrated in Fig. 17, which provides more favorable flow patterns. Pond drainage can be through a vertical riser pipe, or through a stop log facility with screening.

Figure 6. Earthen raceway at Garrison Springs Hatchery (WDF).

Figure 7. Water supply to earthen pond at Rapid River Salmon Facility (IFG).

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Advantages:

- Cleaning frequency requirements are less than with concrete ponds
- More economical and simple to construct
- More pond bottom area for nitrifying-bacteria to culture and convert ammonia to harmless nitrate ions

Disadvantages:

- Pond cleaning and fish collection and handling are more difficult because of the sloping pond sides and the lack of a hard bottom surface
- Ponds with sloping banks require about three times the land area as concrete raceways
- Bank vegetation control measures are required
- If good sanitation is not practiced, botulism can be a problem

Cost:

The capital cost is approximately **\$3.30/ft³** of rearing space for an unlined pond. A 4-inch gravel surface would increase the cost to about **3.50/ft³**. The units have a **50-year** life expectancy.

Information Sources:

Washington Department of Fisheries Willapa and Nemah Salmon hatcheries
British Columbia, Canada Corrections Service-Alouette River Unit
Private trout growers

3. Wooden Raceways Wooden raceways can be constructed of **3/4-inch** marine grade plywood sheathing or P-inch tongue and groove lumber, with construction grade treated lumber for supports (Figs, 8 and 9). The inside of the raceway may be lined with **1/8-inch** butyl rubber or PVC sheeting for water seepage **control**. We recommend butyl rubber. Alternate construction is treated tongue and groove planks with the liner **optional**. The ponds can be built in various sizes, and construction costs for one the size of the concrete raceway described earlier are shown below.

Advantages:

- Simple construction and assembly
- Units on top of ground are easily dismantled and reassembled for use in another locale

Disadvantages:

- High maintenance cost
- Difficult to work in because of slippery floors
- Multiple units require more land area when a common wall cannot be utilized

WOODEN RACEWAY SECTION

Figure 8. Cross-section of a wooden raceway.

Figure 9. Wooden raceway at Nelson Springs, Yakima (WDG).

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- Algae growth difficult to remove from sheet lining
- Liner can be punctured or slashed with a sharp object

Cost:

The capital cost is approximately **\$4.20/ft³** of rearing water, and they have a ten-year life expectancy.

Information Sources:

British Columbia, Canada Corrections Service-Alouette River Unit
Washington Department of Game **Naches** River Pond

4. Metal Raceways Two materials are used for metal raceways, aluminum and galvanized sheet steel. The **16-gauge** sheet steel raceways are available in many sizes as a kit package. The typical size used in the Columbia Basin is 8 x 83 x 3.5 feet. This unit is lined with 20-mil PVC and the water is 3 feet deep (Fig. 10).

Figure 10. Sheet-steel raceways at Priest Rapids Salmon Hatchery (WDF and Grant County PUD)

The corrosive resistant aluminum alloy raceway is custom built and if the metal prices are depressed (as in 1983), they may be competitive in price (Pflug et al., 1983). The units are factory prefabricated in transportable lengths and field welded together. Liners are not used. The only one we identified was at the Neets Bay Hatchery near Ketchikan, Alaska. Custom work and updated prices can be obtained by contacting PROMETCO (Appendix 2).

Advantages:

- Simple construction, can be assembled in two days with a two-man crew
- Pond is easily disassembled and moved
- Liner punctures can be repaired with an underwater pressure patch kit
- Pond can be dismantled and stored in a 10-x 15-foot space
- Low maintenance cost

Disadvantages:

- Algal type growth difficult to remove from sheet lining
- Liner can be punctured or slashed with a sharp object
- Difficult to work in pond because the liner is slippery
- **Must** be anchored to prevent wind displacement when pond is empty

Cost:

The capital cost is approximately **\$6.00/ft³** of rearing water, and the life expectancy of the vinyl sheet liner is 20 years.

Information Sources:

Washington Department of Fisheries Ringold Salmon Hatchery
Chelan County Public Utility District No. 1, Rocky Reach Dam, WA
Oregon Aqua Foods
ModuTank Inc.
PROMETCO (Aluminum raceways only)

5. Fiberglass Reinforced Plastic Raceways These units were observed at the WDF Puyallup and Skykomish Salmon hatcheries (Fig. 11). The units are built in modular form, are easy to transport, install, and care for; but the cost is \$15 per ft³ of rearing volume and is 2-3 times that of metal raceways or circular plastic ponds. They are usually used above-ground. Plastic raceways are noted here because they are available and further information can be obtained from vendors listed in Appendix 2.

C. CIRCULAR PONDS

Circular ponds and tanks are used for rearing salmon and steelhead trout by most fisheries agencies and are constructed of various materials including dirt, concrete, wood, and fiberglass reinforced plastics. They are constructed in various dimensions, usually not exceeding 30-foot diameters and 4 feet of water depth. Water is supplied in one or two locations on the pond's outside periphery and is drained out from a center bottom opening. The water is supplied with a jetting force to aid in aeration and for energy to cause the water to circulate around the pond (Fig. 12). Pond bottoms are usually sloped to the center. The slope, in conjunction with the circulating water, provides for bottom cleaning action to move settleable solids to the center drain.

Figure 11. Fiberglass raceway at the Puyallup Salmon Hatchery (WDF).

Figure 12. Concrete circular ponds at the South Tacoma Steelhead Hatchery (WDG).

Rearing

Circular ponds were one of the first rearing units developed for trout culture, and they apparently became popular across the United States because it was theorized that forcing the fish to swim in these ponds was more natural and produced a better quality fry. This theory has not been proven for salmon. In fact, WDF, and USFWS, who had built numerous rectangular rearing ponds with flow patterns similar to circular ponds, are converting these units to raceways because the latter are judged better for salmon production.

The general advantages and disadvantages of the various circular ponds and specific unit details are discussed below. The costs illustrated for the various units does not include the water supply and drainage systems. The units described are shown for comparative purposes, but we do not endorse circular pond use. The exceptions might be the plastic swimming-pool type pond, which is relatively inexpensive and portable; or for short-term] early rearing, the small fiberglass tanks.

General Circular Pond Advantages:

- Generally good flow conditions and velocities that require fish to swim in all areas of pond except adjacent to the center screen
- Generally good cleaning action depending on water velocity and drain screen design

General Circular Pond Disadvantages:

- If a water borne disease or suspended solids are present in the water, they may remain in the pond for an extended period and affect the fish
- Require additional space since they cannot be nested together as well as rectangular units
- Require additional piping to provide water and drain lines because of layout requirements
- Requires up to 10 feet of head or five pounds per square inch of pressure, for the incoming water supply jet action
- High unit development and manpower operating cost
- Access to the center screen is by wading or a special walkway must be installed
- Crowding fish and cleaning ponds is more difficult than in raceways

For comparative purposes, all the circular ponds discussed below contain 1,000 ft³ of water.

1. Concrete Circular Pond These units are constructed of reinforced concrete and the walls are 4 feet high and 8 inches thick. The floor slab is 6 inches thick. A pond with a water volume of 1000 ft³ would be about 20 feet in diameter, assuming a 5-foot average water depth.

Advantages:

- Low maintenance

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Disadvantages:

- Circular walls difficult to construct

cost:

The capital cost is approximately \$9.40/ft³ of rearing water, and the pond has a 50-year life expectancy.

Information Sources:

U.S. Fish and Wildlife Service Spring Creek NFH, Washington
Washington Department of Game Chelan and Vancouver Trout hatcheries
Oregon Fish and Wildlife Marion Forks and Cole River Fish hatcheries

2. Earthen Circular Pond These ponds are constructed from materials available from on-site excavation. The pond water surface of this particular unit is 28 feet in diameter and the bank slope is 3:1, or steeper (Fig. 13).

Figure 13. Dirt circular pond at Mariculture Northwest Hatchery, Rochester, Washington.

Advantages:

- Low construction cost
- Simple construction

Disadvantages:

- Pond cleaning and fish crowding difficult because of lack of a hard bottom surface, sloping pond sides, and circular shape
- Measures required to control bank vegetation

Cost:

The capital cost is approximately **\$3.60/ft³** of rearing water, and the pond has a **50-year** life expectancy.

Information Sources:

Mariculture Northwest, Rochester, WA

3. Plastic Circular Pond This is a fiberglass reinforced polyester tank with a durable opaque surface coat for protection against ultraviolet light (Fig. 14). The materials should be non-toxic to fish, and the tank, generally used above-ground, should be supported on treated lumber joists and sills. They can be obtained as a one piece unit or as a modular unit in a larger size. The latter allows for easier shipment and lower cost (Antipa, 1982).

Figure 14. Plastic circular ponds at Quinsam River Salmon Hatchery, B.C. (DFO).

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Advantages:

- Low maintenance
- Easy to erect
- Readily dismantled for relocation to another site
- Very smooth pond bottom and sides assists in cleaning

Disadvantages:

- Performance deflection tolerances should be specified when ordering because of the rather weak materials
- Fiberglass reinforced plastic products are relatively new and performance has not been totally established
- Pond anchors required to resist wind displacement when pond is empty

Cost:

The capital cost of a plastic tank 20 ft in diameter and 4 feet deep is \$13/ft³ of rearing water including center drain, exterior stand pipe for tank water level control, and treated lumber for the underside supports. Does not include costs for access walkways over the tank.

Information Sources:

Skokomish Tribal Hatchery, Washington
Chemical Proof Corporation
Corrosion Controls, Inc.
Red Ewald, Inc. (also handle modular tanks)

4. Plastic-Sheet Circular Pond This pond is available in a packaged kit sold as an ~~above-ground swimming~~ pool, and is constructed of galvanized structural steel members and lined with a 20-mil PVC plastic sheet (Fig. 15). The pond rests on a leveling pad of sand or gravel.

Advantages:

- Low cost of unit
- Simple construction and easy to erect in two days with a two-man crew
- Pond is easy to disassemble and move to another location
- Liner puncture can be repaired with underwater pressure patch kit
- Low maintenance

Disadvantages:

- Algal growth difficult to remove from sheet lining
- Liner can be punctured or slashed with a sharp object
- Must be maintained full of water to eliminate liner shrinkage
- Must be anchored to prevent wind displacement damage when pond is empty

Figure 15. Plasticsheet circular swimming pool used as a rearing pond.

cost:

The capital cost is approximately **\$3.12/ft³** of rearing water, and the life expectancy is 10 years for the liner and 15 years for the **steel**.

Information Sources:

Muckleshoot Indian Tribe, Auburn, WA
Northwest Indian Fisheries Commission, Olympia, WA

5. Wooden Circular Pond This pond is redwoodstave T&G side and bottom construction. It is supported on redwood floor joists over wood sill supports.

Advantages:

- Low maintenance
- Easy to construct
- Readily dismantled for relocation to another site

Disadvantages:

- High cost
- Requires pond maintained full of water to prevent wood shrinkage
- Pond floor slippery and difficult to work on

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Cost:

The capital cost is approximately **\$12.00/ft³** of rearing water, and the pond has a **40-year life expectancy**.

Information Sources:

Quinalt Tribal Hatchery, Washington
National Tank & Pipe Co.

6. Circular Painted Sheet-Steel Pond This pond (Fig. 16) was developed and constructed by WDG at their **Naches** and Yakima Trout hatcheries. The unit is 14 feet in diameter, 4 feet high, and the wall is constructed **of 18-gauge** steel. The floor slab is 4-inch reinforced concrete and requires **2 yd³** of material. The wall is held to the floor by using tank bands and **turnbuckles**. A sealant is required between the steel and concrete.

Advantages:

- Low cost

Disadvantages:

- Difficult to maintain tight seal between the steel wall and concrete floor

Cost:

Our estimated cost to build this pond is **\$4.90/ft³** using cost procedures as for other units; however, in 1984, the WDG build these ponds using their own forces for \$1,200, or **\$2.60/ft³**. The unit has a **15-year** life expectancy.

Information Source:

Washington Department of Game

D. LARGE REARING PONDS

Large rearing ponds are used by all the fishery agencies. The majority of these are dirt, but some are surfaced with river gravel, concrete, shot-crete, asphalt, and rubber or plastic impervious linings where pond water percolation losses are problems. These ponds can rear fish from the time fry respond to feeding to smolt release. Initially the large ponds were developed to provide additional fish rearing space at existing hatcheries. Then they were principally used for rearing during the advanced fingerling stages, and were often **referred to as** polishing, acclimation, or fish release ponds. Now 1/4-acre and larger ponds **are common**, and their popularity has resulted from improvements in fish culture practices that **have greatly** increased the capability to rear large numbers of **salmonid** juveniles in large ponds. The elements providing for this progress are quality fish food, **predation control**, improved fish disease control, and reduced fish rearing densities.

Rearing

Manpower and initial construction costs are less for larger ponds than smaller units to produce an equivalent number of **smolts**. The use of mechanical fish feeders are cost and manpower effective in a large-pond rearing operation.

Figure 16. Sheet-steel ponds at **Naches** Trout Hatchery (**WDG**).

Because they are difficult to clean, particularly the unsurfaced ponds, the potential for disease, including botulism, requires that operators maintain good fish culture practices. These practices include controlling bank vegetation, removing dead fish and fish excrement from the bottom, and minimizing dead water areas by maintaining adequate water flow patterns and exchange rates.

Large ponds should have the following design considerations:

- Water supply of sufficient quantity to provide for about one complete pond water change every two hours and minimize dead spots

- Water supplied through a manifold system or overflow weir that evenly distributes the water inflow across the entire pond width (Fig. 17)

- Pond should be no more than 80 feet wide if a pickup-mounted blower feeder is to be used

- A predator control system

- Surfaced access road around the pond periphery for operating and maintaining the pond

- Drainable with a collection facility to allow fish to be removed for transport, enumeration, and evaluation; or designed to allow free migration from the pond

- Compartments within the pond or smaller outside ponds available for early fingerling feeding because of the difficulties of managing small fish in a large pond

Figure 17. Water supply manifold for large pond at the Naselle Salmon Hatchery (WDF).

General Large Pond Advantages:

- Low unit capital development costs
- Low operating and maintenance costs

General Large Pond Disadvantages:

- Potential for botulism, particularly in unsurfaced ponds
- Large lots of fish exposed to a disease outbreak
- Disease treatment more difficult because of large water volume
- Bird and mammal predation can be a problem unless control measures installed
- Flexibility of rearing various species curtailed
- Capture of fish is more difficult than in small units

Large ponds with various surfacing materials are analyzed below. For ease of comparison all are identically sized at 80 x 250 feet with 3:1 bank slopes, 60,000 ft³ rearing volume, 3 feet of water depth at the upstream end and uniformly sloped to a 4.5-foot water depth at the drain end. The 3:1 bank slopes are used for pond comparisons only, and also allows for motorized equipment access in and out of the pond. Steeper bank slopes to 2:1 can be utilized if the operator desires to reduce the shallow water shoreline area, but a special ramped access road to the pond bottom is suggested for equipment use. Steeper bank slopes are also much more difficult to maintain. A water distribution manifold for 10 cfs is provided at the upstream end (Fig. 17) and two 48-inch screened riser drain pipes are

located at the downstream end (Fig. 18). A 10-foot wide perimeter **graveled** service road is included in the costs analysis. Water supply and drain systems are not included in the costs.

Figure 18. Screened riser drain pipes at George Adams Salmon Hatchery (W DF).

1. Large Dirt Pond A typical pond is constructed from materials available from **on-site** excavations (Fig. 19).

Advantages:

- Simple construction

Disadvantages:

- Difficult to handle fish because working in pond muddies the water

Cost:

The capital cost is approximately **\$1.40/ft³** of rearing water, and the life expectancy is 50 years.

Information Sources:

- Washington Department of Game Beaver Creek Steelhead Hatchery
- Washington Department of Fisheries Washougal Salmon hatchery

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- Oregon Fish and Wildlife Cedar Creek Fish Hatchery
- Idaho Fish and Game Red River Rearing Pond

Figure 19. Dirt rearing pond with Neilsen automatic feeders in place at the Rapid River Hatchery (IFG).

2. Large Gravel-Surfaced Pond This is a pond typically constructed from materials available from on-site excavations, except that the bottom is surfaced with 4 to 6 inches of 4-inch minus round river gravel, and 2-inch minus crushed rock is placed on the side slopes.

Advantages:

- Simple construction
- Rock provides excellent surface area for nitrifying bacteria that convert ammonia to harmless nitrate ions.

Disadvantages:

- Maintaining bank slope gravel could be an annual task
- Cleaning pond bottom during fish rearing is difficult

Cost:

The capital cost is approximately \$1.50/ft³ of rearing water, and the life expectancy is 50 years.

Information Sources:

U.S. Fish and Wildlife Service Carson NFH, Washington

3. Large Asphalt-Surfaced Pond This pond is constructed from materials available from on-site excavations, but is surfaced with a 3-inch asphalt lining placed in two lifts 1-1/2 inches thick over an underdrain consisting of 8-inches of granular base material and a 2-inch thick sand leveling course (Fig. 20). Pipe drains may be placed in the base material. The surfacing includes the sloping sides and bottom. Some scientists will not endorse the use of asphalt because of the phenols present in the material but we found no adverse effects that have been documented.

Figure 20. Asphalt-lined pond at Elokomin Salmon Hatchery (WDF).

Advantages:

- Surfacing increases the ability to clean the pond and capture fish

Disadvantages:

- Necessary to eliminate all bank vegetation growth to maintain asphalt seal integrity
- Bank slope becomes very slippery to work

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cost:

The capital cost is approximately **\$1.95/ft³** of rearing water, and the life expectancy is 15 years for the asphalt with patch-work sealing required every five years.

Information Sources:

Oregon Fish and Wildlife OxBow Fish Hatchery
Tulalip Tribal Salmon Hatchery, Washington
Nisqually Tribal Salmon Hatchery, Washington
Washington Department of Fisheries Elokomin Salmon Hatchery

4. Large Concrete-Surfaced Pond Like many other large ponds, this pond is also constructed from materials available from **on-site** excavations, but surfaced with a **4-inch** reinforced concrete lining placed over a 6-inch thick granular base underdrain and leveling course. Additional drain pipes may be necessary in the granular base. The surfacing includes the pond ends, sloping sides, and bottom (Fig. 10, Chap. 4).

Advantages:

- Surfacing increases the ability to clean the pond and capture fish

Disadvantages:

- See general large pond disadvantages

Cost:

The capital cost is approximately **\$2.50/ft³** of rearing water, and the life expectancy is 50 years.

Information Sources:

Oregon Aqua Foods, Springfield, Oregon
Oregon Fish and Wildlife **Wallowa** Fish Hatchery
Washington Department of Fisheries Hoodspoor Salmon Hatchery

5. Large Shot-crete-Surfaced Pond This pond is constructed from materials available from **on-site** excavations and surfaced with a **3-1/2-inch** reinforced **shot-crete** lining placed over a 6-inch thick granular base underdrain and leveling course (Fig. 11, Chap. 7). The surfacing includes the pond bank slopes and bottom.

Advantages:

- Surfacing increases the ability to clean the pond and capture fish

Disadvantages:

- See general large pond disadvantages
- Speciality contractor required for shot-crete placement

Cost:

The capital cost is approximately **\$2.25/ft³** of rearing water. Life expectancy is 50 years.

Information Sources:

Oregon Fish and Wildlife Klaskanine Fish Hatchery

6. Large Plastic Sheet-Surfaced Pond This pond is constructed from materials available from on-site excavations and lined with a 1/16-inch butyl rubber, or PVC plastic sheet placed over a 6- to 8-inch sand leveling course on the pond bank slopes and bottom. The lining is used to prevent pond water percolation losses.

Advantages:

- Simple construction
- Surfacing increases the ability to clean the pond and capture fish
- Liner punctures can be repaired with an underwater pressure patch kit

Disadvantages:

- Algal growth difficult to remove from sheet lining
- Liner can be punctured or slashed with a sharp object
- Personnel working in pond can damage liner
- Sides become very slippery

Cost:

The capital cost is approximately **\$2.00/ft³** of rearing water, and the life expectancy is 15 years for the butyl rubber sheet.

Information Sources:

Oregon Fish and Wildlife East Fork Trask River Fish Hatchery (Butyl rubber liner)

Washington Department of Game Cowlitz Trout Hatchery (PVC rubber liner)

Washington Department of Fisheries Klickitat Salmon Hatchery (Butyl rubber liner)

E. NET PENS AND NET ENCLOSURES

Net pens and net enclosures are a very economical method to expand the rearing capacity of a hatchery. They do not require the cost of such hatchery components as the water intake and supply lines, outlet structures, or the pollution control system.

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Survival rates of salmon and steelhead released from freshwater pens have been excellent. We discuss their applicability for rearing, advantages, disadvantages, and costs.

1. Net Pens For the purpose of this report, a net pen is defined as a floating structure whose sides and bottom are enclosed with knotless nylon netting. It is supported by a formal float structure, or logs, and used to rear juvenile salmon and trout. They are currently used in marine waters and freshwater lakes and reservoirs. In the Columbia River Basin, they could be used in the latter two locations and in backwater river areas where the effect of current is acceptable.

Set pens date back over 100 years in Europe, but they have only been used in the Pacific Northwest for the last 25 years. In the late-sixties, they were used to rear chinook in Lake Roosevelt, Lake Chelan, and Banks Lake; and currently, the Washington Department of Game rears steelhead trout in net pens at Lake Merwin (Lewis River), Skookumchuck Reservoir, and Lake Aberdeen. The Quinault Indian Tribe rears sockeye, steelhead, coho, and chinook in net pens placed in Lake Quinault. The tribal biologist and WDG personnel both consider net pen culture an economical way to expand existing fish facilities.

The most common shape of a net pen is rectangular, and because multiple groupings are easily designed, this configuration is recommended (Figs. 21, 22, 23). The pens can be built to any size, but since it is necessary to clean them periodically, and usually by hand, this should be considered in the design. The WDG uses a pen 16 x 20 x 15 feet at Lake Merwin (Fig. 24). Pens can be secured in position by anchors, or by tying to a dock or similar structure. Excessive flows will move the pens, and even if securely anchored, will tend to collapse the net. There is little written information on this subject and other net pen users should be consulted.

Figure 21. Illustration of a four-pen arrangement with Topper Floats.

A stable platform is usually used to support the pens; however, it is not a requirement. This provides a working space both to feed the fish and clean and repair the netting. The netting is usually knotless nylon or a similar material. Stretched mesh sizes used vary with fish size and the recommended sizes are: 0.125 inch for fish 1,000 to 500 per pound, 0.25 inch for 500 to 50 per pound, and 0.5 inch for 50 to 10 per pound. Since smaller-mesh nets impede water flow and foul more quickly, the largest mesh size that will retain the smallest fish should be chosen.

Predation problems can occur as with any rearing program. However, pens in freshwater present less problems than those in the marine environment. A 1-inch mesh bird net at water level will usually suffice unless otter are present (See Chapter 7).

Any size fish can be cultured in pens. Density levels are limited by the same factors described for other rearing procedures. A fish culturist should program maximum densities not to exceed 0.75-1.0 lb/ft³ of water for yearling coho and steelhead, assuming water conditions are very good. For yearling chinook or sockeye, 0.5 to 0.75 pounds may be attained. Fall chinook at 100 fish/per pound might best be reared at 0.25 to 0.4 lb/ft³.

Figure 22. Illustration of a single net pen with pole flotation.

Advantages:

- Economical means to rear fish
- An excellent method to expand rearing space for steelhead and salmon with low capital investment
- Net pens can be designed to fit the program
- Very suitable for community involvement
- Supports are portable, but require equipment for moving
- Nets can be made by culturists, volunteers, or purchased directly
- Intake and discharge systems, water supply lines, and electrical power sources are not required

Disadvantages:

- Algae fouling the net is common
- Nets must be replaced every five to seven years
- When large production programs are compared, the net pen facility is more labor intensive than net enclosures or rearing ponds
- Access to net pen complexes usually requires a boat

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- Transporting fish from net pens to planting tanks or from planting tanks to net pens may be cumbersome
- 0 Freezing weather and high summer water temperatures may limit their use east of the Cascade mountains

Figure 23. Styrofoam floats and a four-pen rearing complex - Clatsop County Pond, Astoria, Oregon.

cost:

A net 20 x 20 x 10 feet costs about \$1,000. A 20- x 20-foot aluminum frame with floats will add \$2,000 (Walkways not included). Special anchors are available up to 60 pounds each for \$1.50/pound. Several man days of labor would be required to place a pen. The cost per cubic foot of rearing space would range between \$0.40 and \$1.50. Net life is seven years, and floats, 20 years.

Information Sources:

Quinault Indian Tribe, Washington
Washington Department of Game
Skretting
Pacific Power and Light, Portland Oregon
Topper Industries, Inc.
See vendors for nets (Appendix 2)

2. Net Enclosures A net enclosure is a fish-proof barrier made of netting that extends from the water's surface to the bottom, and is positioned with the shoreline to form a large rearing pond. It must be able to withstand the current and wind

action. Fig. 25 illustrates typical locations where enclosures could be installed in the Columbia River Basin. Some of these concepts are used in the marine environment in the Scandinavian countries.

Figure 24. A net pen complex in Lake Merwin, Lewis River (WDG and Pacific Power and Light). PP & L Photo.

Basically, a net enclosure is similar to the large rearing pond concept, and our recommendation is that they be primarily used as acclimation ponds with two to three months maximum rearing time. Feeding is accomplished with a blower feeder mounted on a barge or by hand feeding from a boat. The only major net enclosure in the northwest is a 20-acre (approximate) development at Olympia, Washington, from which up to 200,000 pounds of yearling fall chinook have been released in one year.

The features (Fig. 25) of a good enclosure, besides those illustrated, are: the bottom under the net should be relatively flat in order to provide a fish-tight seal; currents directed against the net should be less than 0.2 feet per second; the net should be protected from floating debris; the enclosure should be drainable, but is not absolutely necessary; there should be a good water interchange; easy access should be available; and in very large enclosures the program should allow most of the fish

Figure 25. Typical locations where net enclosures can be used. Also shows general construction features.

Rearing

to be released directly from the enclosure to avoid the difficult task of crowding and capturing the migrants.

The lower edge of the net must be anchored to the bottom and the suggested method is with a heavy chain lead line. The upper edge of the net, or cork line, is supported by round Styrofoam logs, and anchored buoys or wires stretched from point to point are required to maintain the net in position. The enclosure is most manageable if the depth does not exceed 10 feet. At this depth 12 feet of netting should be considered, allowing slack for some current and wind action. The mesh size is the same as for net pens.

Net enclosures, like net pens, must have suitable environmental conditions. Freezing, warm water, flooding, and predation all must be considered.

The short-term rearing density in an enclosure is similar to a net pen, however, water interchange is difficult to assess. In this report we have assumed that rearing densities in an enclosure are approximately one-half that for net pens, or about 0.3 lb/ft^3 for fish under 25 lb .

Interchange can be aided by directing currents with deflectors or low head pumps. The WDF chinook rearing enclosure has the influence of water deflected from a creek and has about $1,000,000 \text{ ft}^3$ of rearing area. Because the capital cost of rearing space is so economical, ultra conservative fish density levels should be used. Fall chinook are transferred to the WDF enclosure in September and released in late **March** as yearlings. The Department personnel mention that the fall chinook salmon is a difficult species to rear for extended periods, however, the program has been very successful.

Advantages:

- Extremely low cost to develop and requires no water intake or discharge systems
- On a large production scale, labor cost is very low, or comparable with large earthen ponds
- Numerous sites are available for the use of net enclosures
- Excellent for short-term holding to allow the fish to recuperate from the stress of hauling or allow imprinting to aid homing
- Water intake systems, pipelines, and electrical power are not required

Disadvantages:

- Attracts predatory birds; therefore a strong predation control program is necessary
- Boat or barge feeding is usually required on large areas
- The ponds have to be sited where fish can be released directly into a waterway, since the capture of juveniles is very difficult
- Flooding, freezing and warm water restrict their use
- Nets should be removed annually for maintenance and protection from the sun and unnecessary wear

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- In areas that cannot be drained or lowered to remove all predator fish without using chemicals, excessive predation may be imposed on salmonids less than 4 or 5 inches long

Cost:

Total material cost for a net enclosure is about **\$8/linear** foot of net used. Stock **knotless** nylon netting 10 feet deep costs **\$3.00/linear** foot. Polyester netting, which has a little less stretch, costs 20% more; the chain to weight the net costs **\$2.00/linear** foot; and Styrofoam floats **\$2.00/linear** foot. Miscellaneous ropes and anchors may add another **\$1.00/linear** foot. Initial labor installation cost would likely be double material cost. On this basis, a 200,000 ft^3 rectangular enclosure with a maximum water depth of 8 feet, a mean depth of 4 feet, and a net size of 100 feet for each end, attached to the shoreside, 500 feet for the offshore outside, and 10 feet deep, would cost \$16,800 or 0.08/ ft^3 . The use of smaller areas would increase the unit cost by several times. Net life is seven years.

Information Sources:

Washington Department of Fisheries, Olympia
See Appendix 2 for supplies

F. REARING CHANNELS

Rearing channels are used by the WDF, DFO, and others. They are noted here only as an option, but in most cases they are expensive to construct because of their large size, and are not applicable for low-cost facilities. Generally, the channels are about 30-50 feet wide, 400-2,000 feet long, and often built in sections. For all practical purposes, channels that we observed were essentially very large raceways sometimes built in tandem. Examples of large successful channel rearing projects are the Big Qualicum Hatchery (DFO) and Elwha Rearing Channels (WDF).

G. SUMMARY - REARING FACILITIES

Table 3 illustrates comparable costs and life expectancy of common salmonid rearing units. These costs do not include the water supplies, drains, or buildings if required.

PART III. FISH FOOD

Salmon and trout require a complete diet containing all essential elements for proper nutrition. **Modern** commercial feeds introduced in the early 1960's are complete and provide the nutritional requirements in convenient forms. The quality of commercial diets is good for the simple reason that strict quality control is maintained. Some of the "**open**" formula feeds, that is, those made to published formulas such as Abernathy and Oregon moist pellets (OMP), are frequently subject to inspection by the agencies buying the feed as to content and quality of ingredients. Quality control on "**closed**" feeds having unpublished formulas is performed by the manufacturers, but whether outside inspection is performed or not, the food quality is under constant scrutiny by the users.

Rearing

Table 3. A comparison of relative costs and life expectancy of **salmonid** rearing units.

<u>Rearing Unit</u>	<u>Cost per ft^3 of rearing space</u>	<u>Life expectancy in years</u>
<u>Trough and Tanks</u> (sizes in feet)		
Fiberglass 1 x 15 x 0.5	\$40.00	25
Fiberglass 1.33 x 16 x 1.3	32.53	25
Capilano Aluminum 1.75 x 21 x 1.5	18.14	25
<u>Raceways</u>		
Concrete	6.44	50
Earthen	3.30	50
Wooden	4.20	10
Metal	6.00	20 (Liner, 20)
Fiberglass Plastic	15.00	25
<u>Circular Ponds and Tanks</u>		
Concrete	9.40	50
Earthen	3.60	50
Plastic (Fiberglass)	13.00	25
Plastic Sheet	3.12	10 (liner) (steel, 15)
Wooden	12.00	40
Painted sheet-steel	4.90	15
<u>Large Rearing Pond</u>		
Dirt	1.40	50
Gravel	1.50	50
Asphalt	1.95	15
Concrete	2.50	50
Shot-Crete	2.25	50
Plastic Sheet	2.00	15 (liner) (pond, 50)
Net pens	0.40 - 1.50	7 (netting) (floats, 20)
Net Enclosures (Measurements in feet) (Costs are variable depending on size and depth)	0.08 - 0.36	7 (netting)
2 sides 100 x one side 500 x 4 average depth; 200,000 ft^3 area	0.08	7 (netting)
2 sides 100 x one side 100 x 2 average depth; 20,000 ft^3 area	0.12	7 (netting)

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There are two types of commercial fish feeds: dry and semi-moist. Dry feeds have a moisture content of approximately 10% and do not require refrigerated storage. Dry feeds include the Abernathy salmon diet and several commercial brand-name diets. Semi-moist feeds, the most widely used being OMP, have a moisture content of approximately 30% or more, and require refrigerated storage. There are a few semi-moist pellets manufactured by special processes that permit their storage without refrigeration as long as the packages remain unbroken. These are becoming more widely used.

Both types of feed work well, but fill somewhat different needs. Generally, the more fastidious the species of fish, the easier it is to feed with OMP and the better the conversion rate. For instance, spring chinook salmon and summer-run steelhead trout are always difficult to feed, yet they take the OMP without hesitation and thrive on it. Also, where the water is below 50F, and/or low in mineral content, it is easier to grow salmon on OMP. Dry feeds work particularly well with trout and can be used on coho salmon when the water is above 50F. If sufficient information is not available, the choice of dry or semi-moist feed can best be determined by trial and error at each installation.

Conversion, i.e. the growth of fish relative to the amount of feed used, varies according to water quality, species, feeding techniques, fish quality, and others. However, a conversion rate of 1 : 1.5, ie., 1 pound of fish flesh gain per 1.5 pounds of feed used, is a reasonably attainable goal. Under ideal conditions, conversions of close to 1 : 1 may be realized, but under poor circumstances it may be difficult to realize a 1 : 1.5 conversion. In a situation where conditions are highly variable, an improved conversion rate may be gained by using dry versus semi-moist feeds. However, under most adverse circumstances, OMP is likely to out-perform dry feeds. Because of its soft consistency it is more readily acceptable, and the higher moisture content and the presence of raw undenatured fish flesh has a positive effect on fish growth. Whenever there is a feeding problem, whether it is poor water quality or fastidious and difficult species of fish, OMP would definitely be the feed of choice. Since fish accept it so readily, feeding techniques also do not have to be nearly so rigidly controlled as with dry feeds. A guide to salmonid conversion rates using OMP is shown in Table 4.

Costs:

Prices of feeds vary between types and sizes. Smaller pellet sizes of all fish feeds cost more because they contain higher levels of nutrients required by small fish, and the smaller particles are more difficult to manufacture. In general, dry feeds range between \$0.25-0.35/pound and OMP between \$0.35-\$0.45/pound. These are 1984 F.O.B. prices at a food plant.

Information Sources:

Moore - Clark Co., Inc.
Rio-products, Inc.
Sterling H. Nelson & Sons
Rangen, Inc.

Table 4. Conversion rates of salmonids from first feeding size (3000/lb) to various release sizes using the Oregon moist pellet (OMP) diet. Source: Moore - Clark Co., Inc. (personal communication).

<u>Fish size at release in fish per pound</u>	<u>Pounds of OMP required to produce one pound of fish</u>
2500	1.2
1500	1.3
240	1.4
60	1.6
15	1.8
4	2.0

Conversion rates computed by FMC for growth between the release sizes shown above are as follows:

2500 to 1500	1.4
1500 to 240	1.4
240 to 60	1.7
60 to 15	1.9
15 to 4	2.1

PART IV. SUPPORT EQUIPMENT

A. FEEDERS

Five feeding systems are feasible for use at low-cost fish facilities. These are: (1) hand feeding, (2) mechanical fry feeders, (3) stationary pond feeders that propel fish food, (4) demand feeders, and (5) mobile blower feeders. A stationary blower feeder is also available, but they are costly and of limited value for use at a low-cost facility. Feeders are supplied by many vendors and we recommend a careful analysis before making a decision.

Hand feeding is an acceptable procedure for all life stages and feeds, while the mechanical feeders were developed for specific uses, mostly for dry feeds. The mobile blower feeder works well with properly thawed moist pellets. Neilsen Metal Industries manufactures a stationary trough and pond feeder that is advertised as useable with moist feeds.

Factors to be considered when selecting a feeder include: (1) efficiency of the feeder, (2) manpower requirements for feeding, filling the hoppers, and cleaning and maintenance of the units; (3) type of ponds or troughs; (4) type of feed; (5) number and size of fish ponds; (6) storage space required; and (7) cost of the units.

1. Hand Feeding Hand feeding is the simplest method and feed can be distributed literally by hand, with a spoon, from a can attached to a pole (Fig. 26), or with a

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scoop (Fig. 27). The type of aid used depends on the size of the fish rearing unit. The advantages of hand feeding are that the equipment is inexpensive and the fish culturist will frequently observe the fish, noting problems and make adjustments in the amounts of feed to accommodate needs. A disadvantage is that the operator must be nearby if small fish are ponded, since they must be fed several times daily.

Figure 26. Coffee can feeder attached to long pole.

2. Stationary Mechanical Fry Feeders These feeders are usually suspended over troughs, small raceways, or small circular tanks. Food is distributed by shaking it on the water or by spreading it with a whirling blade as it falls from a hopper.

Skretting and Neilsen manufacture similar feeders for fry feeding. The Neilsen fry feeder is the most common mechanical fry feeder used in the Northwest. It is a long narrow unit, (Fig. 28), with several feeding slots. Feed is put into each hopper above the slot. The feeder can be suspended longitudinally over a trough or small raceway, or over a small circular tank. An electric timer is usually connected to the feeder which allows the slots to open as long and as often as required. The feed simply drops into the water. This unit allows frequent feeding of fry, but is not generally successful when used outside, as moisture causes food to build up around the slots. However, covers are available at extra cost. A 12-foot long feeder costs approximately \$350 for dry food and \$550 if moist food is used. They can be seen at many Columbia River hatcheries, particularly where steelhead and other trout are reared.

Figure 27. Hand scoop feeder made from a one-gallon plastic jug.

Figure 28. Neilsen mechanical fry feeder at the Beaver Creek Steelhead Hatchery (WDG). (A) food hopper, (B) fry in trough.

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3. Stationary Pond Feeders For larger fish, by far the most common unit is the Neilsen pond feeder illustrated in Fig. 29.

Figure 29. Neilsen pond feeders at Big Creek Fish Hatchery (OFW).

These units are stationary and feed automatically. The hopper (insulated ones available) holds about 100 pounds of pellets. The bottom is cone-shaped with a slide gate to allow pellets to fall out. Some units have agitator rods to make sure the pellets fall free. At the same time the slide gate opens, a small flat wheel turns directly below the hole. The vanes on the wheel pick up the pellets and throw them across the pond. The duration and the frequency that the pellets spill out is controlled by timers. This unit has been in use many years and is very reliable. Usually two to four units are placed on a 10- x 80-foot pond. The only manpower required is to fill the hoppers and occasionally adjust the system. These units can be used in inclement weather, electricity must be available, and there is a fairly high initial cost for purchase and installation. The Neilsen Metal Industries, Inc. have both a dry and moist pellet feeder. With controls, they sell for around \$1,000 to \$2,000, respectively. The feeders and controls can be adapted to almost any fish and pond situation. For precise costs, Neilsens should be contacted.

Smaller battery operated feeders of this type are available or can be custom built. Costs range from \$200 to \$400. See Appendix 2 for Aquafarms, Skretting, or Boatcycle Co.

Helnie Manufacturing, Inc. produces a small feeder satisfactory for feeding fish in small rearing units. It is called the Allen Feeder and is used at the Rapid River Salmon Hatchery (IFG)(Fig. 30). The 1984 cost was \$119.00 per unit.

Figure 30. Stationary automatic fish feeders on 6-foot wide raceways at the Rapid River Fish Hatchery (IFG).

4. Demand Feeders These feeders allow the fish to feed themselves. They are inexpensive and consist of a hopper with a hole in the center of the bottom. A small rod extends down through the hole and into the water. The rod has a small red ball on the end (Fig. 31). When the fish hit the red ball, the rod movement loosens the food, which then falls into the water. These units can be suspended along the pond walls or placed on brackets which can be moved out over the pond (Fig. 32). Three units are usually installed in a 10- x 80-foot pond.

These units do not require electricity, reduce manpower requirements, and are relatively inexpensive. They do not handle moist pellets well, especially in moist climates, and there are reportedly questions about the efficiency of the units in providing food to all the fish, since it is distributed in a confined area. They apparently are more suitable for the feeding behavior of steelhead trout. A demand feeder holding 8 pounds costs \$35, while a 125-pound capacity feeder costs \$65. See Appendix 2 for Babington Enterprises, Ken's Fish Hatchery, and others for feeder supplies.

5. Mobile Feeders A mobile feeder is an excellent choice for feeding fish in large rearing ponds. It consists of a food hopper, a blower, a gasoline engine to power the blower, and a pipe to direct the feed to the pond (Figs. 33 and 34).

The unit can be mounted in a boat or on a barge, large trailer, or pickup. To feed, the hopper is filled, the gasoline engine started, and the operator controls the feed

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discharge gate in the pipe as he drives along the pond. Depending upon the size of the unit, food can be distributed up to 40 feet across the water.

Figure 31. Illustration of a demand fish feeder.

These feeders are relatively simple and inexpensive to construct and maintain. They will handle both dry and moist pellets and can be adapted for feeding in raceways. For a large pond, this system precludes the installation of a large number of fixed mechanical feeders. They can be observed at most Columbia River hatcheries.

Most of the blower feeders now in use have been built by the hatchery personnel and the cost is dependent on the skill of the crew. See Appendix 2 for Herrington Manufacturing Co. for a mobile feeder that costs \$6,000 per unit.

B. PONDSCREENS

Pond screens are made from a variety of materials and are used to contain fish in desired locations. The screen material is usually mounted on metal or wooden frames. Vertical fixed screens are used for most purposes and are sized so that they can be manually handled for cleaning, repair, and replacement. Rotating screens, such as rotary drum and belt screens, are described in this section but we consider them too expensive for most low-cost facilities.

Important considerations in selecting a screen type and mesh size are fish size, water velocity approaching the screen, and the amount of area to be screened in relationship to the water requirement. We recommend the following hole sizes for slotted screens (Source: Piper et al., 1982):

1/16 x 1/8	fry up to 1,000/lb
1/8 x 1/4	1,000-200/lb
1/4 x 1/2	200-30/lb
1/2 x 3/4	30/lb and larger

We found that managers installed 15-30 ft² of screen material for each cfs of discharge water. Generally, this requires that the screens be brushed once each day to prevent plugging. The common pond screens and materials used in rearing facilities and their application are discussed:

1. Perforated Plate Perforated plate used by the Washington Department of Fisheries is 1 G-gauge aluminum with 3/16-inch holes in staggered rows at 1/4-inch centers, providing 52% of the plate open to pass water (Fig. 35). The perforated plate is available in 4- x 4-foot sheets and can be ordered with a plain edge border for better frame fastening. This material should be supported on 2-foot centers.

Cost:

A ready-to-use plate screen with support bar, (1-1/2 x 1/4 inches) and an aluminum angle frame (1-1/2 x 1-1/2 inches x 3/16-inch thick) costs \$12.00/ft² at the place of manufacture. Life expectancy is 10 years for the plate and 15 years for the frame. The hard waters east of the Cascade mountains sometimes cause corrosive action on aluminum. Special alloys to prevent this should be used.

Figure 32. Demand feeder on pond wall at Hagerman National Fish Hatchery (USF WS), Idaho.

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Information Sources:

Western Wire Works (Plate)

Pacific Metal Co. (Frame)

Figure 33. Mobile fish feeder mounted on a trailer at Puyallup Salmon Hatchery (WDF).

2. Slotted Plate There are several patterns and opening sizes available for slotted plate screens. One of the more common and popular all-purpose slotted plate is 14-gauge aluminum with 3/32-inch slots 1-inch long in a staggered pattern with 3/16 inches between slots and 1/8-inch between rows; providing 40% of the plate open to pass water (Fig. 36). The dual purpose screen shown in Fig. 36 can be used for both small and large fish, thus saving storage space and labor costs. In use, for small fish the small slots are under water; for larger fish the screen is rotated top to bottom and the large slots are in the water. Slotted screens are preferred by many operators because they are easier to clean than hardware mesh or round hole perforated plates. Stringy material, pine and fir needles, etc., all tend to pass through the slots without plugging.

Cost:

Sheets also come in 4- x 4-foot size with a plain edge border. When fastened to a 1-1/2 x 1-1/2 x 3/16-inch thick aluminum angle frame the unit costs \$14.00/ft² at place of manufacture. Life expectancy is 10 years for the plate and 15 years for the frame.

Figure 34. Pickup-mounted blower feeder (IFG).

Figure 35. Typical perforated plate.

Figure 36. Slotted plate screen for dual purpose use. (A) large slots down when rearing larger fish, (B) small slots down for smaller fish.

Information Sources:

Western Wire Works (Plate)
Pacific Metal Co. (Frame)

3. Hardware Cloth This name is given to wire woven into a mat that has uniform spacing, usually in both directions, and then rolled to flatten and hold the wire spacing. Cloth can be purchased that is galvanized after weaving which firmly locks the wires in their correct original spacings and improves durability. Zinc in the galvanizing can be harmful to fish, but the screen can be treated or aged to minimize this problem. A thin coating of coal tar or asphalt will reduce leaching of the zinc ions and maintain the screen openings. The lightest hardware cloth is 16 gauge and the heavy-duty cloth can go to 11 gauge. Hardware cloth is available in a wide variety of mesh openings and wire sizes. Perhaps the most common mesh sizes used for pond screens have 1/8-1/4 inch square openings, with the wire size dependent upon the amount of wear and strength required. These screens normally have 1/8-inch openings providing 60% openings/ft² for the light wire and 30% openings/ft² for the heavy-duty wire. Hardware cloth can be stapled to wood frames built to fit guide slots in ponds or intakes. The heavy-duty screen is normally used for intakes and rotary-drum revolving screens, and the lighter wire is used in pond screening. Heavy-duty 11-gauge cloth costs \$10.39/ft² and lighter 16-gauge cloth costs \$6.67/ft².

Fuse-bonded vinyl-coated galvanized steel mesh (Fig. 37) is being manufactured for the aquaculture industry. It is available up to 72 inches wide with mesh sizes from 1/4-inch square and larger. Gauges are available from 23 to 10. The plastic covering provides a very smooth surface and is non-abrasive to fish.

Figure 37. Types of fuse-bonded vinyl-coated hardware cloth.

Cost:

Screens of 16-gauge hardware cloth galvanized after weaving and stapled to 2-x 1-inch treated lumber costs \$7.67/ft² at the place of manufacture. Life expectancy is seven years. Prices are not available on a ready-to-use screen made of plastic-coated wire, however, a 4-x 150-foot roll (20 gauge) is only \$0.22/ft².

Information Sources:

Western Wire Works (Galvanized cloth)
 C. E. Shepard Co. (Fuse-bonded vinyl wire)
 Nichols Net and Twine Co., Inc. (Fuse-bonded vinyl-coated wire)

4. Aluminum Tube Screens made from aluminum tubing provide an economical method for building station screens (Fig. 38). Construction is as follows: Stiff aluminum tubing, 1/2-inch diameter or larger, is cut to the proper lengths so their ends will fit into a rabbeted groove in the top and bottom inside face of a wood frame. Small aluminum washers can be used as spacers between the bars to obtain the desired opening, or the ends of the tubes can be flattened to provide spacing and attachment. Then hot tar is poured into the bottom groove until filled. After

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cooling, the frame is rotated and the other end is also filled with hot tar. The round tubes produce an ideal hydraulic flow pattern thru this type of screen.

Figure 38. Aluminum tubing screens (IFG).

Advantages:

- Easily passes stringy matter, leaves and needles
- Reduces brushing frequency
- Simple to build
- Inexpensive

Disadvantages:

- Tube spacing if on inlet is critical to prevent fish gilling
- Careless screen handling can bend tubes and alter spacing

cost:

Aluminum tubing screens with treated lumber frames cost \$10.00/ft². Life expectancy is seven years for the frame and 20 years on the tubing.

Information Sources:

Idaho Fish and Game
Washington Department of Game

5. Rotary Drum Screen The rotary drum fish screen is a metal-framed drum covered with heavy-duty 11-gauge hardware cloth. The drum has a stainless steel center shaft and is secured with pillow block type bearings on both ends. The rotating screen is also sealed on both ends and across the bottom to a fish-tight fit with neophrene rubber material bearing lightly on the drum.

The drum is usually installed with about $\frac{2}{3}$ of the screen submerged so that the screen rotation assists in carrying over debris, leaves, needles, etc., and is considered self-cleaning. These screens are usually powered with a one-horsepower electric motor. Other rotary drum screens are rotated with water-powered paddle wheels (Fig. 39) or by internal paddle wheels built to operate inside the drum screen (Fig. 40). Water velocity turns the external paddle wheel and falling water powers the internal paddle wheel. Three or four feet of water drop is required to operate the internal paddle wheel unit.

Figure 39. Rotary drum screen powered by an external paddle wheel.

Rotary drum fish screens are installed on the large pond outlet works to retain fish in the pond. The outlet is usually a permanent concrete structure or a temporary wood structure housing the rotary drum and appurtenances. The cost of rotary screens and the necessary appurtenances may preclude their use at a low-cost facility.

Cost:

Costs vary by size and we suggest contacting one of the sources noted below.

Figure 40. Rotary drum screen powered by internal paddles.

Information Sources:

Idaho Fish and Game Department's Screen Shop, Salmon, ID
Washington Department of Fisheries' Screen Shop, Yakima, WA
Oregon Department of Fish and Wildlife's Screen Shop, John Day, OR

6. Belt Screens Two types of rotating, power-driven belt screens are used at hatcheries, neither of which is considered applicable to low-cost installations. The Link belt (trade name) screen is a series of flat plate screens, usually made of hardware cloth, that travel an **eliptical** path at right angle to the water surface. They are sealed fish tight at the sides and bottom and are usually spray cleaned above the water surface as the screen moves up. Debris is caught in a flume in front of the screen at an elevation above the water surface. This unit can be seen at the WDF Cowlitz Salmon Hatchery and WDG Skamania and Beaver Creek Steelhead hatcheries.

The second type of belt screen, often referred to as the WDF belt screen, uses flexible screening as the belt and functions in a sloping position. Like the drum screen, the debris is moved up and over the screen slope. This unit is in use at the WDF Skykomish, Lewis River, and Humptulips River Salmon hatcheries.

c. PUMPS

The hatchery operator has uses for special types of pumps in performing various station tasks. In addition to the pumps described in Chapter 2 - Water Delivery, a station needs pumps for cleaning, wash down, water transfer, fish handling, irrigation, and fire suppression.

1. Rash Pump The trash pump (Fig. 41) is designed for handling a limited amount of sediments, including up to 1-1/2-inch gravel. This type of pump is used to clean ponds, intakes, fishways, ditches and water boxes after flood debris has settled on the bottom, or after operations have been curtailed and fish moved out of the system. These pumps are usually gasoline powered, self-priming, portable, and mounted on skids.

Figure 41. Trash pump at Tulalip Tribal Hatchery, Washington.

Cost:

A 3- and 4-inch trash pump with accessories costs about \$1,200 and \$3,000, respectively. Life expectancy for both pumps is 15 years of intermittent use.

Information Source:

Pace-Pacific Pump Co.

2. High Pressure Pump High pressure pumps are a self-priming type mounted on a wheeled cart, and include a pressure hose and nozzle, and suction hose with a

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strainer (Fig. 42). The pump can be of large or small diameter with two or more stages to generate the high pressure. The portable unit is moved to the use location and the suction placed in water. After priming by low pump speed or assisted by a separate priming pump or engine vacuum system, the engine can be speeded up to the water pressure desired. Water pressures of 200 to 400 psi can be developed.

Figure 42. High pressure pump at Big Creek Fish Hatchery (OFW).

This pump can be used to flush out ponds after fish release, treatment, or to assist in pond brushing. Clean-up of the spawning area, general cleaning of walks and drives, vehicle and equipment washing, building wash down, and emergency fire protection are some other uses for this system. Caution is required in operation as the high pressures can be destructive to concrete and wood surfaces.

Cost:

Purchase cost of this gas driven pump with accessories is about \$2,000. Life expectancy when used intermittently is about 15 years.

Information Sources:

Pace-Pacific Pump Co.
Landa, Inc.

3. Vacuum Pump Hatchery personnel use this pump to remove dead fish from ponds and for pond cleaning. This pump operates by using an ejector to develop a vacuum which is piped to a wand used by the operator to reach over the pond area.

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The operator maintains his finger over a vacuum breaker hole near the handle which activates the vacuum to the wand end to pick up dead fish or pond debris. He can quickly break the siphon by moving his finger from the hole to avoid live fish should they school near the end of the wand. The operator also uses the vacuum force in the flexible tube to supply water, assist fish flushing, and move fish from one pond to another by having the water level in the pond being supplied lower than the supplying pond.

This pumping system is very similar to a swimming pool cleaning system and is powered by either a gas or electric pump. The equipment is very cumbersome to use unless the flexible tube to the wand is light and floats on top of the water surface, the wand handle is aluminum, and the wand end is designed with wheels similar to an upright carpet vacuum cleaner.

Cost:

Purchase cost is about \$2,000 with accessories. Life expectancy when used intermittently is about 15 years.

Information Sources:

All agencies
Began Equipment

4. Fish Transfer Pump This pump will pass fish through the impeller and case without damage to the fish and is a modification of the pump developed by Pacific Pump Co. to pump whole tomatoes (See Chapter 6). It is now widely used at hatcheries for most fish moving chores, particularly for loading fish from pond to fish planting tanks through a tower that separates the fish and returns the water to the pond (Fig. 6, Chap. 6). At times this pump has been used to lift fish into graders. The speed of the operation must be governed to have the correct numbers of fish passing the grader.

The most practical pump sizes for the fish we propose to culture are 4 to 6 inches; are gasoline engine powered, and usually mounted on a trailer for portability. The pump's priming system should be fully operating before the pump is started and should be run at the lowest speed necessary to lift water and hence minimize damage to fish. The pumping unit should be started, run, and adjusted to lift water to the proper height before the intake screen is opened to move fish. The pump intake usually operates out of a sump which allows pond water levels to be lowered to crowd fish towards the pump suction.

A 4-inch pump is excellent for 1- to 3-inch fish, but we suggest a 5- or 6-inch pump for 3- to 6-inch fish and a B-inch pump for 6- to 12-inch fish.

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Information Sources:

Neilsen Metal Industries (Pump)

Magic Valley Heli-Arc and Manufacturing (Pump)

D. DIP-NETS AND SEINES

All stations require nets to capture or crowd fish. Nets fall into two classes, dip nets and pond seines. Both types are required at a station where fish are handled from the egg to adult stage. Because the units in which fish are reared range from small troughs to large ponds, there can be a multitude of suitable net types; too extensive for individual discussion.

It is recommended that most small nets used for a specific unit be constructed by the culturist. Small dip nets, a pole seine (Fig. 43), or heavy-duty adult dip nets are some examples of nets a culturist can make. Most nets can be purchased from vendors noted in Appendix 2. Heavy-duty dip nets, (Fig. 44) with handles ranging in size from 12-18 inches, cost \$25 each. A heavy-duty, 6-foot deep, knotless, 1/4-inch mesh nylon seine (Fig. 45) costs \$3.00 per linear foot. A 3-inch mesh knotted-nylon adult seine would approximate one-half this cost.

Figure 43. Pole seine for juvenile fish.

In selecting materials for nets and seines of nylon, vinyl or other synthetic plastics, particularly where use will cause exposure to sunlight, we recommend a dark color for longer life. The darker the material the better is its natural protection against the sun's ultra-violet rays. This also applies to all lines and sheeting used around fish facilities.

Figure 44. Standard dip nets for juvenile fish.

Figure 45. Typical pond seine for juvenile fish showing construction details.

E. POND CARE AND CLEANING

Several advantageous concepts in the care and cleaning of ponds are included here. These are not universally practiced and the intent is to identify them for others. No attempt is made to be all inclusive of the more commonly used tools or systems,

1. Pond Brooms A new pond broom has been developed which is relatively new to fish culture and appears to save 25% of the time to brush-clean most ponds. This is the Warren Water Broom (Figs. 46 and 47). The broom is easier to push forward in the water, and on the pull-back stroke current action is minimal. This tends to

Figure 46. Warren Water Broom. Note variety of brush accessories.

Figure 47. Warren Water Broom with handle.

move dislodged pond waste only in a forward direction. Besides saving time, the debris in the pond is less disturbed which results in less stress on the fish. The broom is most adaptable where algae is not a major problem. Any length handle and any size brush can be obtained. Costs are comparable to other pond cleaning brooms. Contact Warren Water Broom (Appendix 2) for more information.

2. Paint As An Algacide Where algae is a problem, and on surfaces where paint can be applied, consideration should be given to the use of a copper-base paint. This is used at the DFO Puntledge River Hatchery on Vancouver Island and OFW McKenzie, Oakridge, and Marion Forks Fish hatcheries. The manager at Puntledge said that it saves labor by eliminating the algae problem and making the pond surface smooth and easier to clean. One gallon of paint will cover 100-200 square feet and last several years. While a newly painted pond (Fig. 48) has a nice appearance, continual painting is required to maintain this look. Paint costs \$3 0/gallon. Any use of paint or chemicals in the water should be approved by a pathologist.

Figure 48. Copper-base paint on pond used to retard algae at the Puntledge River Fish Hatchery (DFO).

3. Herbicides The elimination of unwanted vegetation around ponds can be very effectively and economically controlled with herbicides. Many chemicals are safe to use around fish ponds and cause no harm even when accidentally introduced directly into a pond. Chemicals that are absorbed into the foliage and translocated throughout the entire weed, even below ground, are recommended. Chemicals such as formaldehyde will burn the foliage only to have it shortly reoccur.

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The WDF has an active program in the use of chemicals (Peck, 1979). One manager related "that without the aid of chemicals another person would have been required during the spring and summer months." In addition, your county extension agent can provide a list of suitable chemicals.

4. Chemical Applicators Several agency personnel were observed using hand-held chemical dispensers (Fig. 49) that require 50 percent more labor than the newer type backpack units that are commercially available (Fig. 50). The backpack unit also allows for near perfect spray distribution. The unit illustrated is excellent and can be purchased from most farm stores. (See Appendix 2 for Sprague Sales, Inc.)

Figure 49. Typical hand-held chemical dispenser.

5. Cleaning Large Ponds Few managers attempt to brush or vacuum-clean ponds when they are larger than 1/4 acre, however, in some cases cleaning them should be considered. For example, the WDF Humptulips Salmon Hatchery manager spends 24 to 48 hours vacuum cleaning a 1/2 acre pond about every three months. This time compares to about 9 hours of accumulated time spent during a 3-month period to clean one concrete raceway. However, the numbers of fish reared is 10-15 times greater in the large pond.

Rearing and pond care measures that reduce the possibility of botulism disease are: (1) remove dead fish routinely, (2) do not allow food or fecal matter to accumulate, (3) feed oxytetracycline as prescribed by a pathologist, (4) use quick-lime (CaOH) in empty ponds (contact WDG or Dr. Ecklund, NMFS, Seattle), (5) consider placing scavengers in the ponds such as sturgeon or crayfish, and (6) do not cause excessive mortalities by handling fish improperly.

Figure 50. A modern backpack chemical dispenser.

F. POPULATION ENUMERATION

Two methods are recommended at low-cost facilities for estimating live fish populations. These are the total weight and total volume displacement methods. Both involve random sampling, but unlike estimating the number of eggs, live fish have behavioral patterns that can influence the accuracy of sampling. Some behavioral patterns are:

- (1) larger fish seek out the more favorable situations, generally near the inflow on the more protected areas of a trough or pond
- (2) larger fish move faster and are more difficult to capture
- (3) when crowded, larger fish are usually distributed closer to the bottom
- (4) when captured in a seine or dip net, large fish wriggle their way to the top of the pile

The most common method for obtaining a total population estimate is to weigh all the fish, and by using random samples to determine the number of fish per unit weight, then calculate the total number of fish.

Another common procedure is the displacement method. Fish are placed in a container such as a transport tank, that is first partially filled with water. The increase in Water level as measured on a gauge or mark on the side of the tank determines the volume of fish. During the process, random samples are taken to determine the number of fish per unit volume. This in turn is used to estimate the total population in the tank.

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Electronic fish counters are sometimes used for counting fry as they leave the incubators. These units cost around \$5,000 and are available through Northwest Marine Technology, Inc. The Alaska Department of Fish and Game should be contacted for further information. The WDG has recently tested these units on larger fish. FMC does not recommend them for low-cost facilities as the two other methods described suffice.

When conducting a research program where a random sample of the fish are desired in order to represent the entire population, other methods may be used. The WDF has been using a random sampling machine developed in conjunction with Northwest Marine Technology, Inc., which takes a random sample at pre-set intervals while the fish are being transferred by a fish pump. In the past, agencies have also used the pie-sampler (Worlund et al., 1969).

We recognize that our brief discussion on enumerating techniques over simplifies this complicated subject, and therefore suggest that for more detailed information several hatchery managers be consulted.

G. SIZING DEVICES

Several devices, called fish graders, are used to separate the small fish from the larger fish. This is called sizing, and it allows the culturist to adjust feeding rates to produce a more uniform size of all fish at release time. Sizing is usually necessary for steelhead trout as all hatchery-produced steelhead should be larger than 10 fish per pound. Smaller steelhead have generally not returned well as adults. It is of lesser importance with spring chinook and coho salmon because they have a broader size range as smolts. Fall chinook and other salmon species, because of their short rearing period, are not sorted to size.

A typical grader is shown in Fig. 51. A dip net is used to put fish in the grader. The smaller fish fall through the openings between the aluminum or wood bars and the larger fish are retained. Graders or supplies for grader construction are available from a number of vendors and can be ordered with desired bar spacings. The cost of a grader box 20 x 24 x 10 inches with bars is \$130.

A not her fish grader, used at larger facilities, is the Neilsen fish grader (Fig. 52). This all-aluminum or stainless steel unit is 3.25 x 7.23 x 3.60 feet and weighs 225 pounds. Fish may be delivered to the unit by a dip net or fish pump. The size of the openings in this grader are adjustable for various fish sizes. It is not recommended for use at low-cost facilities.

Figure 51. A typical fish grader.

Figure 52. A Neilsen fish grader.

H. DISCHARGE WATER FACILITIES

A National Pollution Discharge Elimination System (NPDES) Permit may be required if fish production from a facility reaches 20,000 pounds (See Chapter 10). In most cases, the requirement can be satisfied by passing pond cleaning wastes through a settling basin (sedimentation basin). We recommend a review of Piper et al., (1982) to obtain information on hatchery discharge "pollutants". Also, contacts should be made with agency personnel for the latest practices.

Piper (ibid.) states that "generally three types of" pollutants are discharged from hatcheries: (1) pathogenic bacteria and parasites; (2) chemicals and drugs for disease control; (3) metabolic products (ammonia, feces) and waste food".

The discharge of pathogenic bacteria and parasites should have minor concern provided only indigenous stocks are cultured. Generally these pathogens would be found in the watershed. Regarding chemical and drugs for disease control, a concern may occur when the concentration is not significantly reduced through immediate dilution; or when the chemical has an accumulative effect, especially in edible molluscs such as mussels, clams, etc. Domestic water supplies, as noted in Chapter 1, are a major concern of course. The discharge of metabolic waste, dead fish, and settleable inorganic and other organic solids may require a NPDES permit.

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To comply with NPDES permit requirements, we recommend an unlined earthen settling pond similar to that shown in Fig. 53 to settle out settleable solids from pond cleaning operations. The pond should be shallow (less than 4 ft water depth), provide a water retention time of at least one hour (Zook, 1984), and the water velocity should not exceed 0.56 fps (Jensen, 1972). To accomplish proper flow patterns, baffles are also suggested (Piper et al., 1982). The pond should also be drainable and have access for a small tractor for periodic cleaning.

Figure 53. Earthen settling pond at the Chelan Trout Hatchery (WDG and Chelan County PUD).

The size of the settling pond required to comply with the above criteria would therefore depend upon the cleaning system practiced, and the rearing pond's discharge-drain pipings ability to isolate individual rearing pond discharges during cleaning. Vacuum cleaning rearing pond wastes generally moves smaller water quantities to the settling basin than a system employing brush cleaning.

The cost of an earthen settling pond is **\$1.40/ft³** of water volume and does not include the costs for delivering water to and from this pond. A settling basin for 20,000 lbs of fish production will cost between \$3,000 and \$20,000 depending on how the ponds are cleaned and the ability to isolate pond cleaning waters.

NPDES required facilities exist at many Columbia River hatcheries that exceed 1/4 million dollars in capital cost. Most of these are concrete (Fig. 54), have elaborate plumbing systems from the ponds to the basin, and have aeration systems (Fig. 55).

Figure 54. Concrete settling basin at the Big Creek Fish Hatchery (OFW). (A) sludge, (B) ramp.

Figure 55. Floating aerator for pollution abatement settling basin at the Big Creek Fish Hatchery (OFW).

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Aerators are an option for the earthen settling basin to promote aerobic bacterial growth and reduce obnoxious odors.

Large rearing ponds which are cleaned after the fish are removed generally are exempt from permit requirements. Net pens and enclosures would likely have no requirements.

The disposal of sludge from settling basins is described by Piper (ibid.) who suggested it be used as a fertilizer. Eklund (personal communication, NMFS, Seattle, WA), however, warns of the potential dangers from the botulism organism (Clostridium botulinum). Eklund stated: "The sediments of the ponds in which botulism has occurred contain unusually large numbers of C. botulinum type E organisms. These sediments should not be used as fertilizer for home vegetable or flower gardens or for other purposes. Instead the sediments should be buried in the same manner as recommended for dead fish." Common practice at Northwest hatcheries is to utilize sludge as fertilizer, however in light of Dr. Eklund's concern, we recommend managers first contact a pathologist before it is used.

CHAPTER 6

TRANSPORTATION OF SPERM, EGGS, AND LIVE FISH

The methods for transporting sperm, eggs and live fish are discussed in this chapter. In addition, we have attempted to provide a realistic cost estimate for hauling live fish to off-station release sites.

PART I. SPERM AND EGG TRANSPORTATION

Salmon and steelhead trout eggs may be transported prior to fertilization, immediately after fertilization, or as eyed eggs. Sperm is sometimes shipped independently and then used to fertilize eggs. The transportation methods are influenced by transit time, size of shipment, temperature conditions, shipping containers and equipment, and the preference of the fish culturist.

A. GAMETE SHIPMENT

Gamete shipment methods practiced in the Pacific Northwest are similar to the procedures used in Alaska and described in the AFG Fish Culture Manual (1983). This is an excellent reference, and we have used direct quotations here to describe gamete shipment methods.

“When shipping gametes separately, place unfertilized eggs into large plastic jars, buckets with lids, aluminum milkcans, or thick-walled plastic bags (double bagged). Ziploc plastic bags are preferred. Never use copper or galvanized containers. Fill the containers completely with eggs. This prevents sloshing and possible damage to the eggs . . .” It is very common for fish agencies to ship salmon eggs in garbage cans.

To ship sperm, AFG states, “place sperm into plastic whirl-pack bags [plastic bags with patented closure]. During large egg takes, the sperm from 10-15 males may be placed into each bag. Do not fill the bag over one-quarter of capacity, however, because viable sperm require air, maintain a 3:1 air-to-sperm ratio.” Washington and Oregon agencies sometimes use bottles to ship sperm. To transport gametes, AFG recommends that fish culturists place full egg containers and sealed sperm bags in a cooler. “They place the sperm bags so that they lay flat, maximizing the contact of air and sperm. In the Columbia River Basin, the time of shipment likely will be less than 1 or 2 hours, and coolers may not be necessary.

The air temperature is important, and AFG recommends that “if the gamete storage is up to 10 hours, do not exceed 9°C (48°F). If storage exceeds 10 hours, then store the gametes at 2° to 3°C (never 0°C). When ice is used, do not allow water from

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melting ice to touch the egg containers or sperm bags. Transport should not exceed 24 hours or egg fertilization may be less than **80%.**"

Ice should be used with care as it can freeze the eggs if it is much colder than 32F. In such cases, be sure the ice is either warmed in water or that the gametes do not directly touch the ice. Prior to fertilization, most fish culturists warm the chilled gametes for 20-30 minutes so that the temperature is within a few degrees of the incubation water. The shipment of gametes within dead fish is an acceptable procedure if the time of transit is 1 hour or less.

B. EGG SHIPMENT

The common practice is to ship eyed eggs. Newly fertilized eggs can be transported short distances immediately after they are partially or totally water hardened. However, the eggs become more sensitive to handle as time passes and if the procedure must be conducted we suggest all eggs be transported within a **6-hour** period. These eggs should be handled with extreme care, otherwise significant mortalities will occur.

Eyed eggs, on the other hand, are very easy to ship, and standard incubating trays and baskets are commonly used. A good container is a clean, wet burlap bag. As many as 50,000 salmon or steelhead eggs can be shipped per bag on ~~5-to~~ 10-hour trips. Placing the bags two-deep has proved successful, but it is not preferred. If stacking is necessary, air and moisture must be provided for the eggs. In the Columbia River Basin, eyed salmon egg shipments will occur during the colder months, and an insulated box will prevent freezing. A pickup truck is the most common carrier of eggs, and in extremely cold weather, sawdust on the bed floor will help insulate from the cold. A heat source is permissible if it does not emit excessive toxic gases.

Eggs must be kept moist in transit, and a good method is to wrap the eggs in a water-absorbent material such as cotton diapers, or burlap. If the eggs are in transit longer than 3 to 4 hours, ice should be allowed to slowly melt to replace lost moisture, or water added if necessary. The time in shipment is not critical, since eggs can incubate out of water for more than a week, but the eggs must be kept cool and damp.

It is unlikely that air freight containers will be **required** for stations in the Columbia River Basin; however, they are available at Skretting and Heath Techna Corp (Appendix 2).

PART II. LIVE FISH TRANSPORTATION

Live fish transportation is necessary and common at most fish cultural stations, both during on-station rearing and offstation planting. Numerous techniques are available for transporting adult and juvenile salmon and steelhead, but extreme care must be exercised to minimize stress and mortality. Onstation transfers may require only transfer pipes or minor equipment, while off-station transportation systems can include units of any size up to 3,500 gallon tankers and trailers. One of the most dangerous activities for the fish culturist occurs during trucking fish off-station. Driver training and experience are highly recommended regardless of tank size.

A. BIOLOGICAL REQUIREMENTS

The major concern when transporting live fish is to assure that good quality water is maintained, especially the oxygen level. This is true regardless of the method used, and on long hauls water temperature and levels of ammonia, carbon dioxide, and foreign matter are extremely important.

A USFWS publication, "**Fish Hatchery Management**" by Piper et al., (1982) is a good source of information on water quality for fish transportation. They recommend maintaining oxygen levels in excess of 7 ppm (but accept 6 ppm), noting that a failure to do so may contribute to delayed fish mortality. They further state that the ammonia level in distribution tanks can reach 10 ppm; however, exposure to 11 to 12 ppm total ammonia for 6 hours adversely affects trout. They expressed concern if the CO₂ levels increase rapidly and state that fish become distressed if levels approach 25 ppm.

The importance of temperature cannot be over-emphasized. Piper (ibid.) states "**for** each one degree rise in temperature above **52°F**, the fish load should be decreased by 5.6%; conversely, for each one degree F decrease in temperature, the load can be increased by 5.6 %."

A number of Northwest agencies add sodium chloride to the water and report success in reducing fish mortality during transportation. Piper (ibid.) recommends raising the level of soft water to a total hardness of 50 ppm by adding 0.1 - 0.3% sodium chloride and enough calcium chloride to reach the desired **level**.

Anesthetics as an aid to fish transportation in the Northwest is limited mainly to the use of the drug tricaine methane sulfonate (MS-222); but we found few cases where this was used. The benefits of anesthetics, according to Piper (ibid.), are that payloads two to three times larger may be achieved with less stress and possibly less injury to the fish. He states that 0.1 gram per **gallon** appears to be useful in transporting fish. In water with a temperature in the mid **40F's** or higher, 0.2 gram per gallon is the standard concentration for "completely" immobilizing salmonids for clipping their fins; however, lower temperatures require greater concentrations for the same effects. The main disadvantage to the use of **MS-222** is that the Federal Food and Drug Administration prohibits its use on fish that may be consumed by any form of life within several weeks after exposure to the drug. The cost of **MS-222** is **\$30/100** grams, which is the amount needed for a 1,000-gallon tank truck.

There are a number of biologically oriented operational procedures that are important to consider when transporting salmon and steelhead. These are:

- (1) Fish should be starved at least 24 hours prior to handling to reduce the amount of fecal matter and vomiting.
- (2) Clean oxygenated water must be used.
- (3) It is advantageous to flush the tank as it is being loaded, since the greatest deterioration of the transport water occurs during loading and shortly thereafter.

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- (4) On a long haul, flushing the tank with fresh and cooler water after 6 hours is beneficial.
- (5) Water in unrefrigerated fish tanks can often be cooled by filling the tank when air temperatures are reduced, such as during night hours.
- (6) Ice can be added to cool tank water.

The payload that can be hauled in a transportation unit depends on so many variables that it is impossible to formulate a figure for all situations. Hatcherymen generalize, however, that you can safely transport 1 pound of 5-to 6-inch salmonids per gallon of water in a tank with an overhead spray system. With increased efficiency in the aeration system, the number of fish safely hauled can increase. If transported fish are smaller, you should haul less poundage, and the reverse is true if they are larger. Chinook do not haul as well as coho or steelhead, and the smolts of all species are more difficult to haul than presmolts.

By understanding the biological requirements of salmonids, the payloads for transportation can be optimized. The proper use of equipment is the other important consideration, and a discussion follows.

B. ON-STATION FISH TRANSPORTATION EQUIPMENT

On-station fish transportation equipment includes pipes and tubes, flumes, pumps, brails and lifts, crowders, and small containers. The choice for a particular operation often depends on the personal preference of the manager, but all the items described here are useful. Further, some of the items serve a dual use and can be used for off-station fish transfers.

1. Pipes and Tubes The most universal method of on-station fish transfer is through pipes and tubes. All age groups of fish can be transferred in this manner. Common pipe or tube materials are plastics and aluminum. Pipe is sometimes desirable for adult transfer because it is portable, and fish cannot flop out as sometimes happens in flumes.

Aluminum irrigation pipe is most commonly used for the transfer of fish on-station; 10-inch diameter for adults (Fig. 1) and 4-inch for juveniles (Fig. 2). This pipe is light weight, readily available, and stores easily. Its one disadvantage is that it dents easily. The cost of 4-inch aluminum pipe is **\$1.50/ft**, and 10-inch pipe costs \$5.79, both with connectors.

Plastic pipe (PVC) can also be used, but, it is not generally used for juveniles unless permanently installed. A disadvantage of PVC pipe is that it is brittle when cold. Four-inch pipe will cost **\$0.70/ft** with connectors, while 10-inch pipe costs **\$6.00/ft** with connectors. Transferring fish with pipes that are permanently installed is referred to as a tube transfer. Generally this is seen at large stations, and PVC is usually used. Figs. 3 and 4 show, respectively, a number of tubes and a single plastic pipe used in transporting adults.

Figure 1. Stored sections of 10-inch aluminum pipe used for fish transfers.

Figure 2. Four-inch aluminum pipe being used to transfer juvenile salmon at the Washougal Salmon Hatchery (WDF).

Figure 3. Tube transfers used at the Chehalis River Hatchery in British Columbia, Canada (DFO).

Figure 4. PVC pipe used to transfer adult salmon at Priest Rapids Salmon Hatchery (WDF).

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2. Flumes Flumes are used to transport fish between ponds or between transport tanks and ponds. Their use is common when fish are too large to pass through the discharge hose of a transport tank, or when small fish are being moved between ponds in large volume. In this latter case a portable flume is used and the fish are poured directly into it, thus eliminating the hopper required by pipes.

A flume can be as simple as a steep bank lined with plastic or as illustrated in Fig. 5. A short adapter is usually required between the transport unit and the flume. Foam rubber is used for cushioning wherever required. Any material is satisfactory as long as the surface is smooth and, when lubricated with water, provides a slippery, non-abrasive surface. Plastic film liners are very effective. The side walls on flumes should be high enough to prevent fish from flipping overboard.

Figure 5. Flume used to transfer salmon and steelhead trout at the Rapid River Hatchery (IFG).

3. Pumps, Brails and Lifts A common method for moving fish is a unit called the "Fish Pump" (Fig. 6). It was developed for use in the agricultural fields, but it is a useful tool in fisheries work. Fish can pass through the "open-style" impellor without harm, provided proper procedures are employed. The 6-inch pump, generally preferred, is powered with a gasoline motor. It can be mounted on a truck or trailer, or as a permanent installation.

The fish pump will handle the smallest fry to fish over 12 inches long. It can be used to deliver fish and water to transfer pipes, to grader boxes, and to dryers on transport tanks. In addition, it is useful in cleaning and transferring plastic substrates, or acting as a 750-gpm pump for an emergency water supply. The unit

Figure 7. Brail used in an adult salmon and steelhead transfer system at Priest Rapids Salmon Hatchery (WDF); (A) transfer brail, (B) tank on truck.

Power-driven crowders are commonly seen where large numbers of adults are handled for spawning. The one illustrated in Fig. 8 would cost in excess of \$50,000. Mechanical crowders are not recommended when the number of adults handled is less than 10,000.

For more information on small low-cost hand crowders, contact any fisheries agency. For crowder screen materials, see Appendix 2.

3. Small Containers Every hatchery uses small containers to transfer fish. Plastic j-gallon buckets and garbage cans are very common. Fifty-gallon drums can be used, but they are very heavy and awkward to handle. A simple larger unit is the bed of a pickup truck lined with heavy reinforced plastic sheet. The truck's bed, once filled with water and fish, can be emptied by dropping the tailgate.

C. OFF-STATION FISH TRANSPORTATION EQUIPMENT

Transportation of fish to and from the fish cultural station or collection sites is conducted by a variety of means. Methods discussed include portable fish tanks, tank trucks and trailers, floating live boxes, adult tube transfers, collapsible roll poly, and hand-carried containers. Aircraft and barges are recognized as viable but costly methods, and are not discussed.

Figure 8. Mechanical fish crowder at the Hoodspout Salmon Hatchery (WDF); (A) crowder, (B) bars on crowder.

As we have emphasized earlier, the two most important factors regulating the efficiency of any transport unit are oxygen and temperature. Aeration systems employ several techniques, including the splash, air scoop, overhead spray, direct insertion of air or oxygen into the circulating water, or air or oxygen passed through air stones. To address temperature concerns, insulated and/or refrigerated tanks can be designed or are available from commercial outlets.

1. Portable Tanks Portable tanks are best suited for low-cost operations. The choice of size ranges from 75 (Fig. 9) to 1,000 gallons or more. They are usually hauled on a truck (Fig. 10) or by truck and trailer, and then removed when the project is completed.

Common materials used in construction include aluminum, steel, and fiberglass. Options in aeration systems include all those previously mentioned, and the choice depends on the program. A low-cost aeration method is a system that adds pure oxygen or air to the water. Provision should also be made in designing the plumbing to allow adaptation of a waterspray system. These usually are powered by a 12-volt DC battery or gasoline motor. A typical portable fish-transport tank is shown in Figure 11 with its water circulation system (Fig. 12) and air/oxygen system (Fig. 13).

Figure 9. One-hundred gallon portable fish transport tank (DFO).

Figure 10. Three 300-gallon fish transport tanks mounted on a flatbed truck (Tulalip Tribal Hatchery).

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Figure 11. Typical portable fish-transport tank with overhead spray and oxygen injection.

A refrigeration system is not recommended on portable units; however, polyurethane foam sandwiched between fiberglass or metal shells can effectively insulate the unit so that, with the use of ice, water temperature can be properly regulated.

The combination of a trailer and portable tank is a viable option for use at a low-cost facility. A heavy-duty pickup truck, for example, can pull a 4,000 lb unit while the load itself would be too heavy for the truck alone. Trailers can be custom-built for approximately \$1,000 to accommodate a 400- to 500-gallon payload. A portable tank is recommended because it can be removed and the trailer used for other purposes. Aquaforms (Appendix 2) has a heavy-duty fifth-wheel trailer for about \$4,000 that can be ordered complete with tank for approximately \$8,000.

A major advantage of the portable tank is its mobility, which allows it to be used to traverse back roads and bridges with load limits to reach areas inaccessible to large units. Its greatest disadvantage is inefficiency when handling large numbers of fish over long distances.

Approximate cost of fiberglass tanks (tank only) are: 1,000-gallon, four compartments (\$7,000); 500-gallon, three compartments (\$4,500); 100-gallon, two compartments (\$2,000); and 100-gallon, one compartment (\$1,500).

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Figure 12. Sketch of a water circulation system for the portable fish-transport tank in Fig. 11.

Information on portable fish tanks is available at most tribal, state and federal hatcheries, and recently the Canada Department of Fisheries and Oceans conducted experiments with low-cost transportation methods. Publication is pending (Bérézay, 1984)

Appendix 2 lists several manufacturers or vendors of portable fish tanks.

2. Tank Trucks and Tank Trailers Tank trucks and tank trailers (Fig. 14) are units used exclusively for hauling **fish**. Because of their size and cost they are not practical to purchase for use at small or mediumsize stations. The capital cost of a **3,000-gallon** unit with the necessary refrigeration and aeration equipment is approximately \$100,000.

If the occasion arises where it would be advantageous to use large equipment, it may be possible to rent or lease from one of the fish agencies or a private grower. Also, contract hauling is available from LTI, Inc. (Appendix 2), which has two **3,500-gallon** transfer tanks that can be used singly or in tandem.

a. Loading capacities for tank units Fig. 15 illustrates approximate tank loading capacities for hauling juvenile salmon and steelhead trout. We are assuming the

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water temperature is maintained at 48F and the tank has an overhead spray and oxygen aeration system. Data were obtained from WDF, IFG, and WDG **personnel**. Since information on sockeye salmon was not available, we arbitrarily treated them similar to fall chinook salmon.

Figure 13. Sketch of an air/oxygen circulation system for the portable fish-transport tank in Fig. 11.

Tank capacities for adult salmon and steelhead trout were often very site specific and lacked adequate temperature data. However, for adults we feel it would be safe to use the upper density limits shown in Fig. 15 for the largest juveniles.

b. Cost of transporting fish Table 1 illustrates the labor and equipment costs per mile of travel for three sizes of fish transport units. Table 2 illustrates the cost per pound of fish transported on a typical 50-mile haul (100 mile round trip) for each of these units. Our estimates have included average equipment operator cost for loading, unloading, and travel (driver only). Operation and maintenance costs include all anticipated repairs and fuel usage over the life of the equipment. The investment cost only included the original purchase price with a 30% value left after 150,000 miles and 200,000 miles on the gasoline and diesel trucks, respectively. **Investment** credits were not included, and it was assumed all equipment was located on station.

Transportation of Sperm, Eggs, and Live Fish

Table 1. Estimated cost per mile of fish transport equipment.

<u>Tank & truck size</u>	<u>Tank & truck cost</u>	<u>Driver cost</u> ⁽³⁾	<u>Operation & maintenance</u> ⁽⁴⁾	<u>Amortized cost</u> ⁽⁵⁾	Total cost
<u>200 gal</u> 1 ton	\$13,000 ⁽¹⁾	\$0.48	\$0.17	\$0.07	\$0.75
<u>1,000 gal</u> <u>34,000 GVW</u>	35,000 ⁽¹⁾	0.51	0.30	0.17	0.98
<u>3,000 gal</u> <u>Diesel tanker</u>	100,000 ⁽²⁾	0.60	0.53	0.35	1.48

(1) Estimated 30% value at 150,000 miles.

(2) Estimated 30% value at 200,000 miles.

(3) Includes average equipment-operator salary: \$13.34 per hour for larger tanker and \$12.09 for one ton or smaller.

(4) Includes all maintenance and fuel at January 1984 prices. Fuel consumption based on 9, 5.25, and 4.5 mpg for small, medium, and large tankers, respectively. Maintenance was estimated at \$0.06, \$0.10, and \$0.26 per mile for small, medium, and large tankers, respectively.

(5) These values are based on total unit costs shown in footnotes 1 and 2 and include no added cost for investment. Truck life expectancy in miles and trade-in values are considered.

Table 2. Estimated costs of a 50-mile fish haul (100-mile round-trip) expressed in cost per pound of fish per gallon of tank water for three tank sizes.

<u>Tank size</u> <u>(Gallons)</u>	<u>Pounds of fish per gallon of water</u>			
	<u>0.25</u>	<u>0.50</u>	<u>1.00</u>	1.50
200	\$1.50	\$0.75	\$0.37	\$0.25
1,000	0.39	0.20	0.10	0.07
3,000	0.20	0.10	0.05	0.03

Source: Calculations based on data shown in Figure 15 and Table 1. Cost amounts are rounded to nearest one cent.

Figure 14. Tank truck and tank trailer fish transport system (IFG).

3. Floating Live Box Transporting fish short distances by water can be done using floating live boxes. The situation dictates the size and shape of the box. The capture of adult steelhead or salmon from streams may require that they be moved downstream to a collection point for subsequent transport to a hatchery. One method is to construct a floating box as illustrated in Fig. 16. In a unit 4 x 5 feet in surface area and 3-feet deep, 40 or more lo-pound fish can be transported for several miles. The advantage of this box is that it can be transported over the shallowest of riffles. This method has been used by WDF.

Set pens are also a method of transporting fish short distances across deep water areas such as lakes (see net pens in Chapter 5).

4. Tube Transfers A tube transfer system can be used for loading or releasing adult fish when they must be transferred several hundred feet between the truck and stream. Using this method, one or more adults are placed in a tube (Fig. 17) with water and then hand carried. Materials used are aluminum or PVC. For information contact Canada Department of Fisheries and Oceans.

Figure 15. Approximate loading rates of fish-transport tanks in pounds of fish per gallon and by fish size, species, and racial group (with water temperature at constant 48F).

5. Collapsible Roll Poly In British Columbia, an inexpensive technique for transferring juvenile fish involves the use of a collapsible, transparent, 6-mil poly tube. The plastic is purchased in lengths of up to 1,000 feet and cut to any desired length. One end is attached to the discharge hose of the transport tank and the balance unrolled over the inaccessible area to the stream. When the valve on the tank is opened, the water and fish expand the collapsed tubing to form a 6-inch transparent, flexible release pipe. Upon completion of the release, the poly is collapsed and rolled up for easy storage. The advantage of this system is that it allows access to many release points not otherwise possible without considerable cost. The cost of the tubing is about \$0.19/linear foot. For information on this

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method, contact Canada Department of Fisheries and Oceans. For vendor see Western Concord Mfg. Ltd. in Appendix 2.

Figure 16. Floating live-box transport system.

6. Cans, Buckets, and Backpacks Many small containers can be used to hand transport fish for short distances. Five-gallon buckets are the most commonly used, especially when randomly distributing fish along a stream. This is referred to as bucket planting. Most managers fill the buckets with $\frac{2}{3}$ water and $\frac{1}{3}$ fish and keep the maximum time in transit to the stream from 1 to 2 minutes.

Transportation of Sperm, Eggs, and Live Fish

Backpacking anadromous salmonids is rarely done, but volunteer groups may wish to use this procedure for planting fish in isolated areas. Up to 1,000 salmon or 1,500 steelhead can be carried by a single person in a **4-gallon** pack for 1 to 2 hours. The water is aerated by the splashing in the container.

Figure 17. Tube transport system.

CHAPTER 7

PRODUCTION SUPPORT FACILITIES AND EQUIPMENT

PART I. BUILDINGS

Hatchery building styles (Figs. 1 and 2) and construction materials may vary to suit program goals and budgets without detrimental impact on fish production. However, traditional hatchery facility construction has gone to the most permanent type of construction that budgets will allow. As construction costs increase from metal to wood to masonry, so do the creature comfort parts of the structure, such as locker rooms, crew showers, kitchen facilities, offices, libraries, and display areas. In considering low-cost facility development, it is important that this trend be carefully considered.

Figure 1. Vancouver Trout Hatchery with majestic multi-purpose wood building (WDG).

The three common construction materials are metal, wood, and masonry and their advantages and disadvantages are shown in Table 1 and costs in Table 2. Pre-built buildings offer construction savings compared to on-site construction. Industrial type containers, such as cargo containers and used truck or trailer vans, are suitable for storage or personnel buildings, and offer cost saving options. New or used mobile homes for station personnel housing, and insulated vans or cargo units for adaptation to cold

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Table 1. A comparison of metal, wood, and masonry buildings.

	<u>Advantages</u>	<u>Disadvantages</u>
<u>Metal</u>	<p>Low cost</p> <p>Erects rapidly</p> <p>Requires minimal fire protection</p> <p>Disassembly for relocation less difficult than wood or masonry</p> <p>Can be insulated</p> <p>Pre-painted panels available</p> <p>30-year life</p>	<p>Mastic seal required on all joints</p> <p>Condensation inside affects insulation and causes rusting of steel parts</p> <p>Regular maintenance: painting every 8-10 years, roof coating every 5 years.</p>
<u>Wood (Pre-fabricated)</u>	<p>Lower cost than masonry</p> <p>Full use of newest materials and construction methods</p> <p>40-year life</p>	<p>Size limited to highway restrictions or 14 feet maximum for either full or half-width units</p> <p>Requires heavy equipment to transport and set-up</p> <p>Regular maintenance: painting every 8-10 years, roof replacement every 20 years.</p> <p>Energy efficiency limited to factory designs</p> <p>Relocation impractical</p>
<u>Wood (Site-built)</u>	<p>Can be sized for intended use</p> <p>Roof style and materials can be selected for local weather conditions and longer life</p> <p>Energy efficiency can be designed with minimal extra cost</p> <p>50-year life</p>	<p>Custom construction at remote sites is costly</p> <p>Relocation impractical</p> <p>Alteration may be limited</p> <p>Regular maintenance: painting every 10 years, roof replacement every 20 years.</p>
<u>Masonry</u>	<p>Most durable construction</p> <p>Size and shape can meet initial operational needs</p> <p>Requires minimal fire protection</p> <p>100-year life</p>	<p>Initial construction costly</p> <p>Regular maintenance: cement and brick require resealing every 20-30 years and surface protection every 5 years.</p> <p>Replace composition roof every 20 years. Tile roof same life as building.</p> <p>Alteration limited to nonsupporting areas</p> <p>Relocation impractical</p>

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Table 2. Building costs by material and building types.

<u>Building type</u>	<u>Metal</u>	<u>Construction material</u>		<u>Masonry</u>
		<u>Wood</u> (In \$/ft ²)		
1. Hatchery With some interiors(1) As presently being built ⁽²⁾ Typical size: 20 x 30 feet; includes foundation, concrete drain troughs, and 4-inch concrete floor.	\$54.00 \$54.00	\$59.00 \$96.00	\$75.00 \$126.00	
2. Storage Typical size: 30 x 40 feet; includes foundation and 4-inch concrete floor.	\$20.00	\$25.75	NA	
3. Housing a. <u>Mobile</u> Typical size: 26 x 50 (1300 ft ²) on support blocks and with skirting.	\$23.50 ⁽³⁾	\$32.00	NA	
b. <u>Permanent</u> Typical size: 26 x 50 (1300 ft ²) on 6-inch foundation 2 ft high.	NA	\$50.00	\$77.00	
4. Cold storage Typical size: 12 x 24 feet; on 6-inch foundation 3 ft high.	\$90.00	\$97.00	\$125.00	

- (1) Represents the same interior with shell cost reflecting the difference.
- (2) Building costs reflect “as built” by agencies when materials listed are used.
- (3) All metal mobile homes were limited to single width (14 ft) units of various lengths. The unit priced was 14 x 56 or 765 ft². Price includes transportation, installation on concrete blocks, and skirting.

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storage needs are other cost saving options for low-cost facilities. Travel trailers are useful and cost effective for temporary or seasonal housing. Regardless of the unit chosen, we recommend that consideration be given to the use of existing agency, tribal, or rental storage space.

Figure 2. Rocky Reach Hatchery with multi-purpose metal building (Chelan County PUD and WDF). This building has 960 ft² and the construction cost in 1983 was \$29,100.00. If we assume construction cost at 75% of total cost, this building costs 38,800 or \$40.42/ft² (Steve Hays personal communication).

The space requirement and capital cost for a small food storage facility is shown below for a station that produces 20,000 pounds of fish and has an annual moist pellet food requirement of 30,000 pounds. Delivery is assumed to be made three times per year. Thus we recommend a 12,000 pound freezer capacity allowing up to 2,000 pounds carry-over at fill-up time.

The capital cost of the building is estimated at \$28,000 based on 144 ft² for the freezer area, and 144 ft² for non-refrigerated storage. The area required was estimated as follows:

- (1) For 12,000 pounds of food, storage for 240 50-pound bags will be required. The volume per 50 pound bag = 2 ft³ when loose stacked on a 4- x 1-foot pallet.
- (2) Using two pallets per stack, each pallet is layered with 16 bags or a total height of

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about 5 feet for 32 bags. A total of eight pallets is required; four on the floor and four at mid-height. A total of 64 ft² of floor space is needed.

- (3) The space for the aisleway is 48 ft², and for the evaporator and minor miscellaneous storage, 32 ft².
- (4) For machinery, electrical, and food thawing, a 12- x 12-foot area is planned.

Contacts in 1984 with local cold storage rental outlets provided an annual cost of \$2,000 to provide storage for the program as described. Rental of freezer storage is discussed under Food Storage.

PART II. FOOD STORAGE

Proper facilities for the storage of fish food is a vital part of any fish production unit. The fact that Oregon moist pellet (OMP) requires refrigeration, and dry feed does not, dictates the type of storage facilities required. Heat and moisture are the two most significant factors causing oxidation and spoilage of the vital elements in fish feeds. For the moist OMP, it is essential that the storage temperature be maintained at 0°F or below.

Dry feeds, on the other hand, require storage that is dry, well ventilated, and cool. Dry feeds should not be stored in a closed-up or damp building without humidity control. Any sound building with a good roof and plenty of air circulation is satisfactory. In warm locations, metal buildings with open doors and windows are adequate. Always stack dry feed on pallets to avoid moisture penetration from the floor and provide an air space between the stacks. OMP should be stacked in the freezer in a similar fashion to provide adequate circulation of cold air, and to prevent any build-up of heat from oxidation or spoilage. Under proper storage, both OMP and dry feeds will have a 90-day shelf life without significant deterioration.

Freezer units for the storage of OMP come in a variety of forms, shapes, and sizes; ranging from home freezers to giant commercial units capable of storing millions of pounds. Even a household refrigerator can be used on a temporary basis for short-term storage. Most hatchery freezers are commercially built walk-in, drive-in units that are fabricated separately or as part of the hatchery buildings (Fig. 3). Modern construction, insulation, and refrigeration units keep these types highly cost-effective and trouble-free. A 50,000-pound capacity freezer costs approximately \$75,000 and has a life expectancy of 30 years.

For small installations and for temporary storage, used refrigerator-trailer units (Fig. 4), usually powered by small diesel motors, are sometimes available at used truck-trailer dealers. They can hold up to 45,000 lbs. While the cost is relatively low, reliability, especially in the diesel powered unit is sometimes questionable and they require careful maintenance. In Alaska it is common to find refrigerated container units parked at various locations, often having the advantage of dual power units, either electric or diesel. The disadvantages of either semi-trailer or container units are difficult accessibility to the contents, and lack of space for orderly storage.

Figure 3. Fifty-thousand pound capacity fabricated freezer at the Puyallup Salmon Hatchery (WDF).

Figure 4. A refrigerated trailer being used for fish food storage at the private Clear Springs Fish Hatchery, Idaho.

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Types of refrigeration units vary from the older, open ammonia units which are found in large commercial freezers, to modern freon units that are virtually trouble free. Failure in freon systems is most apt to be in the power unit. Fortunately, if a unit fails, the critical temperature of 32°F, or below, can be maintained for a considerable length of time provided the unit is not opened, and if normal operating temperature is at -10°F, or below. The -10°F operating temperature is a measure of safety that is well to consider.

The rental of freezer space will often be the most economical for low-cost facilities or short-term programs, in which case, a small unit with a three- or four-day supply capacity may also be required at the site. Earlier in this Chapter under Buildings, the capital cost is estimated at \$28,000 for a food storage facility for a station that produces 20,000 pounds of fish and has an annual OMP requirement of 30,000 pounds. In our contacts with cold storage rental outlets, the estimated cost was \$2,000 per year to handle food storage for the program as described. Rental of freezer space and dual use of nearby agency cold storage facilities are viable options that should be considered.

PART III. ROADS

Roads are essential to provide access from a public road to, and around the station grounds. Road types include concrete, asphalt, and prepared gravel. The width of a road is dependent on useage, and usual station access and onstation road widths are as follows:

<u>Type of road</u>	<u>Width</u> (in feet)
Two lane access roads	20 - 24
Single lane roads ⁽¹⁾	16 - 18
Operation road around ponds and station	12
Minimum access width	10

(1) For low-cost developments, a 16-foot single lane road is recommended with turnouts at 500-foot intervals.

Successful roads, regardless of final topping, should have good drainage and a compacted gravelly base. A good base consists of 8 inches of compacted 2-to 5-inch pit run rock. Recommended surfacing consists of 5 inches of 2-inch minus crushed rock. This can be oiled or surfaced with cement or asphalt. In low and swampy areas, side ditches should be a minimum of 1 foot below the prepared base and sloped or culverted so water can be drained completely away.

If ground water exists, a plastic fabric mat should be laid down prior to installation of the road base to prevent mud from penetrating the base and damaging the road surface. The advantages and disadvantages of each type of road surfacing are shown in Table 3, and road construction and maintenance costs for 12-and 20-foot road widths by surface type are illustrated in Table 4.

Table 3. The advantages and disadvantages of various road surfaces.

<u>Surface</u>	<u>Advantages</u>	<u>Disadvantages</u>
<u>Gravel</u>	<p>Lowest cost</p> <p>Least damaged by freezing</p> <p>Minimum cost to reshape</p> <p>Long life if maintained</p> <p>Safest surface during adverse weather</p>	<p>Surface gravel shifts requiring regular grading</p> <p>Develops chuck holes</p> <p>Dusty in dry weather</p> <p>Must limit load during a thaw to protect base.</p>
<u>Black top</u>	<p>Medium cost</p> <p>20-year life if protected during thaws</p> <p>Can be spray resealed</p> <p>A smooth surface</p>	<p>Porus surface requires expert installation and maintenance personnel</p> <p>Slick surface in adverse weather</p> <p>Must limit loads during a thaw to protect base.</p>
<u>Concrete</u>	<p>Longest life</p> <p>Smooth surface</p> <p>Minimal hydraulicing</p>	<p>Highest cost</p> <p>Develops slick surface during icing and winter storm</p> <p>Must limit load during thaw to protect base</p> <p>Develops joint bumps</p>

PART IV. SECURITY AND ALARM SYSTEMS

The value of the fish resource and the cost of fish production absolutely necessitates the installation of alarm systems and security measures at every fish rearing facility. The failure of mechanical equipment that stops or interrupts the water supply can be devastating because an entire year's production can be lost in a single incident. Protection from vandalism, including theft and poaching by humans, to predation by birds and mammals, must be designed into any fish facility. Security measures and devices are

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described in this section under the general headings of water alarms, adult fish security, and juvenile fish security. Security for the buildings is also required and must be planned for, but we have discussed this very briefly because many good systems are available and choice will depend mainly upon budget restraints. The local law enforcement agency is a primary source of information. All fish alarms are subject to failure, so it is important that all systems protecting a facility be inspected and tested on a regular basis to insure maximum reliability.

Table 4. Estimated road construction and annual maintenance costs by surface type and width for 100 feet of roadway, including 2-foot shoulders.

<u>Surface material</u>	<u>Road cost per 100 feet</u>		<u>Annual maintenance costs per 100 feet</u>	
	<u>Road width in feet</u> <u>20</u>	<u>12</u>	<u>Road width in feet</u> <u>20</u>	<u>12</u>
<u>Gravel</u> ⁽¹⁾ 8-inch base 6-inch topping	\$1,250	\$875	\$150	\$100
<u>Oiled gravel</u> MC-250 oil	\$1,800	\$1,225	\$300 ⁽²⁾	\$190 ⁽²⁾
<u>Blacktop</u> 8-inch base 2-inch blacktop	\$2,400	\$1,575	\$200 ⁽²⁾	\$120 ⁽²⁾
<u>Concrete</u> 8-inch base 6-inch concrete	\$7,950	\$4,900	\$50	\$50
<u>Culvert CMP ea.</u> ⁽³⁾ 1 8-inch diameter x 16 gauge	\$375	\$275	\$15	\$15

(1) For low-cost developments, pit-run base rock is initially recommended followed by a 6-inch surfacing several years later as necessary.

(2) Cost based on re-oil or oil sealing every three-year interval, or oiling 1/3 of roadway each year.

(3) Corrugated metal pipe. Included here since culverts are an integral part of road construction costs regardless of surface type. Costs include installation.

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A. WATER ALARMS

Table 5 shows four types of alarm switch devices that can be used directly or through relay switches to operate audible alarms. The chart shows where these activating switches are used. Where more than one type is shown for the same location, the site conditions such as pipeline pressure and velocity, and/or individual preference, should determine the selection.

Table 5. Four types of audible water alarm switches and where they are used in a hatchery facility.

<u>Type of switch</u> (described below)				<u>Action</u>	<u>Where switch is used</u>
<u>(1)</u>	<u>(2)</u>	<u>(3)</u>	<u>(4)</u>		
X	X		X	SA	Gravity intake - still well
	X		X		Surface water supply pumps
	X		X		Well supply pumps
	X		X		Pipelines supply and distribution
X				DA	Distribution tower
X				SA	Incubation supply trough
X				SA	Shallow trays
X				SA	Deep troughs and tanks
		X	X		Ponds - single spout drop
X			X	SA	Ponds - manifold supply
X				DA	Ponds - flume supply
X				DA	Ponds - water levels
X		X		DA	Holding pond supply and levels
X			X	SA	Fishway supply level and auxiliary
	X		X		Recirculating pumps

- (1) Float operated mercury bulb switch wired into alarm system. Single acting at one level (SA); double acting at high and low levels (DA).
- (2) Pressure operated mercury bulb switch or micro switch.
- (3) Water flow operated by depressing an exposed hinged paddle with mercury bulb switch.
- (4) Velocity operated paddle set into a pipeline to operate micro-switches.

Water alarms should have an independent power supply, such as a 12-volt heavy-duty deep-cycle battery. If the alarms are on public power and the power fails, the alarm system is de-activated. The battery should be placed near a public power outlet and kept fully charged. Do not use the facility's auxiliary power generator battery for the alarm system. If something is defective with the alarm system it will discharge the generator's battery and two systems are then inoperative.

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1. Water Intakes A float-activated mercury switch at the intake to the hatchery water supply and connected by buried wire to the hatchery building, will activate an alarm when the intake level supplying the pipeline drops to a preset critical level. Since most water flow shut-downs are not instantaneous, the alarm will sound but some flow will continue to keep the pipeline partially full. Immediate response to the alarm will usually prevent any fish loss resulting from water shortage and delays in refilling the pipeline.

On high-head pipelines, a pressure-operated switch located at the hatchery and connected to the alarm system is used. The alarm is activated when the water level in the pipeline drops below the intake operating level.

For intake pipes that run full of water, an internal paddle switch connected to an alarm system at the hatchery is a reliable system. A flow reduction reduces the pressure on the paddle which activates the switch and the alarm. Dual contact units are available that detect a slight decrease in flow as well as a critical shut down.

Alarm costs vary depending on the number of signaling units; wire lengths; type of signal such as a horn, lights, or telephone calls to duty personnel; and if control and indicator boards are required. A simple system could cost \$3,000-\$4,000, while deluxe control systems range from \$30,000-\$40,000.

2. Incubation Units A constant adequate flow of water to the incubation facilities is a top priority when fish are in the alevin stage. Most station water systems are designed to provide incubation facilities first choice of any water in the supply line. The alarm control should be installed at a location in the system that is first affected by any decrease in water flow. Since most operators run the incubation units with a small waste line to the drain at the end of the supply trough or pipe system, the water level at this location is first affected by a flow decrease and is the best location for the float switch that sounds the alarm. For deep and shallow troughs, the end of the supply branch or an end section of the first affected trough can be used as the alarm location.

Individual vertical incubators and the pipes and valves to shallow and deep troughs can become plugged with debris, but an alarm at each of these locations would be cost prohibitive. These sites and the main outlet screens should be inspected and cleaned regularly. If organic debris is present in the incubator water supply, a fine mesh screen can be installed to collect the material at the supply to the overhead trough to prevent individual stacks from plugging. The flow valve to individual units should be kept wide open and the main valve should be adjusted to the flow needed. Then only minor valve adjustments are required to balance the system.

3. Rearing Ponds An alarm system to monitor flows to the rearing ponds can be the internal paddle type located after the valve, if the flow quantity is sufficient to activate the switch, or the external-paddle switch for small flows, which is attached to the discharge end of the supply pipe. The latter unit is designed so the water discharge hits and depresses the paddle. If the flow decreases, the paddle moves, activating a switch which in turn activates an alarm.

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If the pond flow is adequate, but the pond stand pipe or stop logs are not tight and the pond level could accidentally fall, a pond water-level alarm is used to warn of this condition. This unit is a float operated mercury switch set in a stilling tube at the drain end of the pond behind the screens. Here it warns of a water loss caused by low flow, plugged intake screens, or a defective drain control.

Information Sources:

All Northwest fishery agencies.
Phipps Water Alarm Co.

B. ADULT FISH SECURITY

Whenever adult salmon and steelhead trout are accumulated and held for ripening and spawning, they must be protected since they represent the brood stock for subsequent production. Not only must a hatchery be properly equipped with alarms to signal water supply failures, it must also provide protection from poachers. Various protective techniques are described.

1. Fences Chain-link fences 6 to 8 feet high with locked gates and barbed wire tops are often used to prevent entry to holding ponds. Poachers sometimes use bolt cutters to effect entry, so additional alarm systems are needed. An alarm wire circuit located in the fence with audible signals, and human proximity alarms are available to deter fence cutters.

A finer mesh fence fastened to the chain-link, or a separate fence at the pond edge and completely encircling the holding area is used to keep out predatory animals.

An 1 1-gauge chain-link security fence 1200 feet long and 8 feet high, with a one-arm threestrand barbed wire top, 8-inch corner posts, 4-inch gate posts, 2-inch intermediate posts, a 1 1/2-inch top rail, and one 16-foot double gate would cost \$6900, or \$5.75 per foot. This price assumes that the station is within a 100-mile round trip of the supplier.

2. Buildings If fencing is not practical or is cost prohibitive, then a security system for each building may be required. A variety of systems are available with different methods of operation and alarm signals. A system that will send a signal from each building and from any window or door that is opened to a master control in the main building is available from retail catalog such as J. C. Penney or Sears Roebuck Co. A two-building installation system for use on a 20x30-foot incubation building and a 30x40-foot storage building costs approximately \$1500-\$2000 installed. This system can be adapted to turn on yard lights and/or sound a horn alarm. Another device can be added to the above alarm system that starts a recording system that initiates telephone calls in sequence to three employees that live off station, or calls a local law enforcement agency.

Several alarm systems are available that are activated by noise or the proximity of persons or animals, and these activate signal systems such as lights, sirens, horns, or a phone. The costs vary but generally depend on the sophistication of the system.

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3. Lights Yard lights are an additional deterrent to protect the station property equipment and adult fish. Mercury vapor yard lights set with daylight-dark controls, or with a timer, provide adequate night visibility. Additional mercury vapor lights, or spot lights activated by the alarm systems mentioned earlier, can be a further deterrent to prowlers. The local power company can provide costs for these units.

4. Guards Watchman can be used in place of security and alarm devices, particularly to protect brood stock, but they require special equipment such as spot lights, a look-out shed, phones, proximity alarms, and sometimes dogs. A good guard dog, particularly within a fenced station, can be an effective deterrent to intruders.

C. JUVENILE FISH SECURITY

The concentration of fish in hatchery ponds is a natural attraction for both birds and mammals. Those birds most damaging to juvenile fish include the mergansers, gulls, terns, and herons. Other birds likely to cause damage are diving ducks, kingfishers, grebes, and cormorants. Damage from loons, water ouzels, ospreys and others is less common. Fish-eating birds can consume fish at a daily rate of 50% of their body weight. It is not uncommon to lose over 30% of the fish population from a large rearing pond during the winter months. Alexander, (1977) estimated that American mergansers eat 1.03 pounds daily when feeding in natural streams. At that rate ten mergansers would have the ability to devour 3,600 2-inch fish at 350/lb per day or 108,000 fish per month. Mink normally avoid hatcheries, but land otter can be a problem. The average consumption rate for an adult male otter is 3 lb/day (Missett and Parker, 1983).

Permits are not required to scare or mechanically deter predatory birds and mammals. With few exceptions, a permit to kill birds must be issued by the USFWS. Permits are issued only after one can demonstrate a potential for serious damage. Regulations in eastern Washington and Idaho prohibit otter trapping; however, licensed trappers have a season in western Washington and most of Oregon.

Control measures for bird and mammal predators include canopies and covers, fencing, overhead lines, scare and kill devices, or some combination of these. The measures selected will depend upon predator species, type of facility, and the work practices of station employees.

1. Canopies and Covers A complete enclosure, including a fence and overhead canopy, eliminates all predator problems. This may only be practical, however, for small ponds. Enclosing a 100 ft² rearing area costs approximately \$10-15,000. Generally, an enclosure or canopy should allow access to the rearing area for routine maintenance, and must also be sufficiently sturdy to withstand an accumulation of leaves, or snow and ice. The canopy top is made of 2- or 3-inch wire mesh. For less permanent installations, bird netting can be used (Fig. 5). To support the more permanent cover, strong support posts must be provided.

A pond-level cover installed 1 to 4 feet above the water is an effective control and costs much less. Although direct access to the fish is more difficult than with elevated canopies, fewer problems with ground maintenance and snow and ice are

encountered. The configuration of the pond determines the design of the pond-level canopy. A pond which is 80 x 270 feet (1/2 acre) requires a 1/4-inch stainless steel cable anchored and stretched lengthwise along the centerline of the pond 3 to 5 feet above the water. This cable may require intermediate post supports in several places along its length. A small boat-winch is used to maintain tension on the center line to provide a taut ridge or to lower it into the water in case of snow.

Figure 5. Permanent canopy using netting for predatory bird control at the Dworshak National Fish Hatchery (USFWS).

Steel posts 3-to 4-feet long are driven into the ground around the pond at 10-foot intervals. These should be located 1 foot above the water level but lower than the center line. Braided polyline is attached to each post and stretched across the pond and over the center line to form support for the net. S-shaped hooks are used for connectors (Hager, 1981). Strips of netting are placed across the pond and then fastened with the "S" hooks to the cross lines. Managers often leave one section loosely attached so employees can work under the netting. Fig. 6 shows a pond-level canopy on a narrow pond without the centerline wire.

The estimated total material cost in 1984 for covering a 1-acre pond is \$2,500, and a 1/2-acre pond cover costs about \$1,500. The life of the netting and string is approximately four years. The netting cost for a 1-acre pond is estimated at \$700 and the braided polyline at \$900 (Atkins and Kramer, 1979). Managers frequently cover concrete ponds by laying netting across the top of the pond walls. This is effective and the only cost involved is for the netting; about \$0.02/ft².

Figure 6. A pond-level canopy without the centerline wire support at the Elokom Salmon Hatchery (WDF).

The mesh size of bird netting varies from 1/16 to 5 inches, however, a mesh size of 5/8- to 3/4-inch is generally preferred. This size comes in 14- and 17-foot widths and can be ordered in 100-foot lengths or rolls 100- to 5,000-feet long at a cost of approximately \$0.015/ft². Some birds have been observed to land on 5-inch square netting and wriggle through. One of the biggest advantages of the smaller mesh is that herons find it very difficult to sit on the net and pick fish through the small openings.

Information Sources:

All Northwest fishery agencies have experience in the use of netting
Internet, Inc.
Memphis Net and Twine Co.
Glitsch, Inc.
Wildlife Control Technology

2. Fencing Various kinds of fences are effective and commonly used to discourage small mammals and wading birds. A perimeter electric fence is very effective for otter, and under certain conditions, wading birds. A 5-acre pond has been fenced at the WDG Cowlitz Trout Hatchery and is reported to work well in controlling the Great Blue Heron. OFW has also controlled heron with electric fences. A single-wire electric fence is often sufficient, but managers usually install two or three wires, one of which serves as a ground (Fig. 7). The cost of an electric fence for a 1-acre pond, including labor, will approximate \$500 as based on a fence installed at the Tulalip Tribal Hatchery.

A 30-inch high chicken-wire or **plastic-mesh** fence is also effective for wading birds when set inside the perimeter of the pond at a water depth of about 1 foot or more (Fig. 8). This combination prevents the wading birds from fishing in the pond.

3. Stringers Stringers or lines set at 2- to 4-foot intervals across a pond either overhead or at pond level, are commonly used. An overhead line system at the IFG **Hagerman** Fish Hatchery uses wire stringers and requires heavy metal poles and braces for support (Fig. 9). Note the springs (Fig. 10) used to keep the wires taut.

Pond-level lines of synthetic materials are most common. Clear nylon monofilament fishing line is very inexpensive and used at some hatcheries. Because it deteriorates rapidly in sunlight it has only a **one-** or two-year life expectancy.

Dark-colored materials have a longer life (Fig. 11). Red colored braided polyline is used at the WDF Elokomin Salmon Hatchery (Fig. 12) and is expected to last five or six years. Here the lines are attached to short steel posts and elevated upward from the side of the pond to form a canopy. The cost to cover a **1/2-acre** pond using this material would approximate \$1000.

Figure 7. A three-wire electric fence at the Shelton Trout Hatchery (WDG).

A stringer system will deter American mergansers, gulls, and terns, but is not effective with hooded merganser, kingfishers, diving and dabbling ducks, crows, or other miscellaneous small birds.

4. Scare Devices The best scare device is a fish worker; however, for small installations the workers continual presence may not be economically feasible. Therefore, mechanical scare devices are sometimes used. For any scare device to be effective, the predator population should be harassed before they become accustomed to pond feeding. It has not been demonstrated that mechanical scare devices, without the presence of a person, will consistently keep predation under satisfactory control. But these devices, on occasion, may do an adequate job.

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Fig. 13 illustrates a flashing colored-light system used at the OF W Big Creek Fish Hatchery. Although various intensities of lights were tried, night-feeding birds become accustomed to their long-term use.

Fig. 14 shows an automatic exploder. This device, recently tested at the Dworkshak NFH, and in the 1960's at fish farms operated by WDF, was described as temporarily beneficial by the users. The automatic exploder is controlled by a timer and uses propane or acetylene to power the loud shotgun-like explosion. Used in combination with other techniques, it can be partially effective and would be recommended for intermittent use on large rearing ponds.

Shells that are propelled into the air and explode with a loud noise are also effective for short durations. Cracker shells are available for shotguns; however, if the shells go off in the water, fish can be killed. They can also be potentially dangerous to the culturist if the wad remains in the barrel. Noise-bombs and whistle bombs are available for flare pistols of several sizes. The noise from a shotgun blast can also be helpful.

It should be recognized that loud noise devices can become an irritant to nearby neighbors, particularly if used during night or early morning hours. Water sprays, high frequency sound, bird distress calls, scare crows, bird kites, and balloons are other lesser important devices that have a temporary beneficial effect.

5. Kill Devices Firearms, particularly the shotgun, are the most effective devices for destroying predators; however, their use has serious safety and regulatory considerations. Few birds need to be killed if feeding habits in hatchery ponds, as noted previously, are not allowed to get started; immediate harrassment is most important. Traps are used for wading birds, kingfishers, and otter. No. 0 and No. 1 singlespring traps are excellent for small and large sitting or wading birds,

Figure 8. Wire-mesh fence to prevent predation by wading birds at the Washougal Salmon Hatchery (WDF).

respectively. A No. 3 or No. 4 doublespring trap is generally used for otter. However, trapping should be done only by experienced individuals, and before any traps are used, permits must be obtained from the appropriate regulatory agency.

Figure 9. An overhead stringer system for bird control at the Hagerman Fish Hatchery (IFG).

6. Combination A combination of control practices is usually best. For example, the WDF Humptulips Salmon Hatchery manager uses overhead lines on his 1 1/2-acre pond to deter American merganser. Bird netting is secured to these lines at the pond's edge and stretched over the water 5 or 6 feet to control predation by blue heron. Cracker shells are used to scare the occasional diving duck.

Figure 10. A view from below of the overhead wire stringers in Fig. 7 showing the springs used to keep wires taut.

Figure 11. Pond-level stringers to prevent American merganser predation at Klaskanine Fish Hatchery (OFW).

Figure 12. Stringers of red polyline form a canopy to discourage fish predation at the Elokomin Salmon Hatchery (WDF).

Figure 13. The flashing colored-light setup used to scare fish-eating birds at the Big Creek Fish Hatchery (OFW).

Figure 14. An automatic propane exploder used to scare predatory birds at the Big Creek Fish Hatchery (OFW).

PART V. EQUIPMENT **LIST**

A necessary part of the fish cultural facility planning process and operation is the equipment. Planners and managers, regardless of the size, cost, or complexity of the station, should not overlook the need for tools and adequate equipment. Most fisheries agencies have developed standard equipment lists for hatcheries (Appendix 4). Although this list includes many items that may not be applicable in a “low-cost facility”, it illustrates the type and variety of equipment used in fish cultural operations. Further, the list will serve as a useful shopping guide for developing total project costs. Information sources for many of the **smaller** items are listed in (Appendix 2).

CHAPTER 8

PROJECT SELECTION AND EVALUATION

In the preceding chapters we have dealt primarily with the technical components that make up a low-cost fish facility such as water requirements of the fish, water delivery systems, adult collection, incubation, and rearing systems, transportation of fish, and production support equipment. In this chapter we deal with some key elements that are necessary to consider in the selection of sites and program alternatives. These include a checklist of mainly site specific factors to be considered, the costs of producing salmonids, personnel skills and salaries, and the use of an economics analysis to evaluate hypothetical hatchery operations and alternatives.

PART I. SITE CONSIDERATIONS

Table 1 is presented mainly as a checklist to remind the reader of the numerous additional items that should be considered when facility planning begins. Although not listed, we recognize that public relations and political considerations are also real, but comment no further.

Table 1. Considerations in facility site selection.

NATURAL ELEMENTS

Weather	Wind, snow, rain, temperature
Flooding	Risk factors
Watershed	Stability, planning program
Offstation considerations	Migratory obstacles, pollution, predation, diversions

PHYSICAL SITE

Construction considerations	Soil, access, power, remoteness, communications , topography
Land	Ownership, cost, availability, size, future expansion

SUPPORT SERVICES

Vendors	Access to supplies and materials
	Space, rentals, freezers, contract fish rearing.
Tax supported entities	For labor and equipment exchange, egg and fish transfers, freezer space, security, road repair, etc.

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AVAILABILITY OF PERSONNEL

Skill required	Availability
Temporary help	Availability
Volunteer help	Availability
Housing	Rental, mobile, on-station, permanent
Personnel benefit	Schools, hospitals, shopping centers, T.V., safety, etc.

LEGAL REQUIREMENTS	Mitigative, treaty obligations, governmental permit requirements
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MANAGEMENT GOALS	Are they addressed?
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PART II **COST OF SALMONID PRODUCTION**

The cost of producing salmonids is commonly expressed in terms of dollars spent to produce one pound of fish annually. This figure may include (1) the capital cost of the facility, (2) the annual operating cost, or (3) a combination of operating and capital costs. We are presenting the cost of **salmonid** production using these three categories, and have broken each into its components.

A. CAPITALEXPENDITURES

The components that make up capital outlays are illustrated in Fig. 1. Construction (75%) is the largest item, with other costs **totalling** 25%. Land aquisition coats are not included in the components, but are discussed in detail in Part IV of this chapter. The total capital coat **of** a hatchery is often expressed in terms of dollars spent to produce a pound of juvenile fish. For example, a \$2 million hatchery with a 100,000 pound annual production, results in a coat of \$20 of capital monies for each pound of fish produced annually.

Salmonid stations designed for approximately 100,000 pounds have been constructed for **\$20/lb** while others with similar production programs cost three to four times this amount (1984 dollars). These differences are usually caused by a combination of factors starting with site selection, production unit selection, equipment, the type of program, construction materials, and other considerations such as better facilities for the employees and visitors. In order to assign a portion of the capital cost to the annual production cost we refer you to Part IV of this chapter. Using a simplistic analysis, however, the capital cost of a \$2 million station pro-rated on an annual basis and producing 100,000 **lbs** of fish would be \$2.80 per pound of fish produced, if we used a straight line depreciation of 4% (25-year life) and assumed an interest rate of 10% on borrowed monies. O & M costs are additional.

Figure 1. Components of capital expenditures in hatchery construction.

B. OPERATING EXPENDITURES

When the production at a station is expressed in terms of operating costs, the same measure (fish per pound) is used, and the broad categories are labor, fish food, electrical energy, and miscellaneous supplies.

OFW recently developed an operating budget for fiscal 1984 and 1985 which we believe will be representative of actual costs as conducted at their hatcheries. To illustrate this, we choose hatchery "A" with 50 percent pumped water requiring approximately 200 feet of lift (Fig. 2), Hatchery "B" with 100 percent pumped water and requiring 20 feet of lift (Fig. 3); and hatchery "C" is the average of eight hatcheries with gravity flow.

From these illustrations, one can compute the labor and food costs, and readily relate to the added operational outlays if pumps are required to deliver water.

A **cost** of **\$2.52/lb** was projected for 1984 for WDF state-funded salmon station& This figure included agency main office overhead (Flieg, personal communication). During 1983 the cost was \$2.16 (Table 2) without this overhead included.

Hatchery "A"

Total annual cost	\$901,629.00
Pounds of fish	270,833
(50:50 F. chinook, coho)	
Cost (fish per pound)	\$3.33

Figure 2. Composition of the annual operating costs for hatchery "A" (OFW) with 50% pumped water and 200 ft of lift (average of fiscal 1984 and 1985 budget projections).

Hatchery "B"

Total annual cost	\$280,000.00
Pounds of fish	112,500
(100 % spring chinook)	
Cost (fish per pound)	\$2.49

Figure 3. Composition of the annual operating costs for hatchery "B" (OFW) with 100% pumped water and 20 ft of lift (average of fiscal 1984 and 1985 budget projections).

Hatchery "C"

Total annual cost	\$2,195,098.00
Pounds of fish (combination of fall & spring chinook, coho , steelhead, and cutthroat trout)	1,071,535
Cost (fish per pound)	\$2.05

Figure 4. Composition Of the annual operating costs for hatchery "C" (eight OFW hatcheries) with gravity flow (average of fiscal 1984 and 1985 budget projections).

Table 2. Estimated total cost/lb of producing juvenile salmon at WDF hatcheries in 1983. (From Washington State Senate Natural Resources Committee).(1)

Cost incurred by fish production	\$2.16/lb.
For hatchery staff and operations	69%
Maintenance for station repair	13%
Pathology and nutrition	4%
Hatchery supervision and research	14%
	<u>100%</u>

(1) Does not include overhead costs of the main office, such as payroll, purchasing, legal support, etc.

While the electrical cost, food cost, and miscellaneous supplies illustrated in Figs. 2, 3, and 4 appear to be self-explanatory, we believe a further analysis of labor costs will aid in facility design and programming. To accomplish this, we selected a study conducted at the WDF Klickitat Salmon Hatchery (Clayton, 1968). During the time of the study, this gravity-supplied, spring-fed station produced 113,701 lbs of salmonids composed of 647,719 spring chinook, **3,716,473** fall chinook, and **1,673,220 coho**. Fig. 5 shows the time in hours assigned for (1) paid leave, (2) maintenance, and (3) fish culture; while Table 3 further allots the time spent on maintenance and fish culture (labor). Table 3 also illustrates the typical work tasks conducted, and the hours spent on each.

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We recognize that there can be great variances in work effort, however we believe the level of effort spend at the Klickitat Salmon Hatchery is indicative of many Northwest hatcheries.

Figure 5. Annual man hours of fish culture, maintenance, and leave by month at the WDF Klickitat Salmon Hatchery. From Clayton, (1968).

The Klickitat Hatchery program did not require security guards for adults nor were all eggs taken at the hatchery. Also, the time employees stand by after working-hours in case of emergency was not included.

In addition to the information in Table 3 we attempted to obtain estimates of time spent on similar specific tasks during our visits to numerous facilities (Appendix 3). We found the answers to be highly variable because of the diversity of the programs and facilities. For example, the normal expected spawning efficiency, or the average numbers of eggs taken by one person in an **8-hour** day, ranged from 300,000 - 600,000 for chinook, 200,000 - 400,000 for **coho** and 150,000 - 300,000 for steelhead trout.

During the incubation process, managers generally agreed that egg picking (see Chapter 4) required about half the time spent for egg care. One man could hand-remove in 8 hours

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"all" the dead eggs from a 250,000 shocked egg lot of any species if the losses were in the 5-8 percent range. Heavy egg **loss** could easily double the time required.

Except for maintenance tasks, the greatest diversity of answers was the hours used per man for the rearing program, and was related to fish size and facility type. We believe that 8 hours of direct daily **labor** is sufficient to handle 2 million **400/lb** fall chinook in ten raceways. **These** same fish at **10/lb** may require 100 raceways and 24 hours of direct attention per day, or one man for 30 raceways. **The** use of larger rearing units such as **1/2-acre** ponds, or large net enclosures would reduce the hours indicated to about one-third.

The average production of juvenile fish per man year of effort at Northwest stations approximates 25,000 lbs (Zook, 1984). While we will tend to use this figure as a guide, most of the prototypes we illustrate are smaller than 25,000 pounds. Also, in our theoretical prototype designs of **50,000-lb** stations (Chapter 9), we will emphasis smaller but more numerous lots to illustrate a management program to maintain genetic integrity.

Table 3. Annual man hours for fish culture and maintenance activities by the hatchery culturists at the WDF Klickitat Salmon Hatchery. From Clayton, (1968).

<u>Fish culture</u>	<u>Hours</u>	<u>Maintenance</u>	<u>Hours</u>
Feed fish	1325	Pickup supplies	772
Transfer/plant fish	559	Clerical	741
Clean/disinfect ponds	447	Equipment building	537
Pick eggs	407	Equipment repair	462
Pick fish	379	Miscellaneous	334
Clerical	371	Clean/maintain grounds	317
Miscellaneous	263	Training school	236
Sample fish	200	Snow removal	175
Spawn fish	174	Service equipment	153
Size fish	148	Lawn mowing and care	134
Clean troughs/trays	125	Repair screens	93
Treat fish	100	Road maintenance	81
Pick fry	100	Clean buildings	75
Fish trap	60	Public relations	70
Unload feed	43	Painting	43
Check intakes	31	Repair buildings	42
Mark fish	25	Repair ponds	36
Treat eggs	<u>20</u>	Haul garbage	27
		Clean equipment	<u>25</u>
<u>Total</u>	4777	<u>Total</u>	4353

c. CAPITAL AND OPERATING EXPENDITURES

Based on the most current information available from agency projected budgets and recent budget experiences, we believe that the total combined average cost of both capital and operating expenditures to produce a pound of juvenile fish at Northwest

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hatcheries will range between \$4.50 and \$6. We recognize that this cost will vary with the program, the assignment of interest and depreciation rates on the structure, the efficiency of personnel, the station's electrical energy requirement and numerous other variables.

In the private sector, we find slightly lower cost quoted to **FMC** by the management of Swecker Salmon Farm (personal communication). Mr. Swecker quoted a price of **\$3.00/lb** for **10/lb** fish and **\$4.00/lb** for **80/lb** fish, such as fall chinook. All prices were based on eyed eggs being provided free, and included compensation for property and business taxes not required of agencies.

The price quotation by Mr. Swecker shows that for a given species, to purchase a pound of small fish costs considerably more than a pound of large fish. A similar price-size contrast shows in the quotations presented to **FMC** by Mr. **Russ McLeary** of Troutlodge, Tacoma, WA for relatively small lots (5,000 fish). His prices were \$42, \$6.67, and \$2.15 per pound for rainbow trout at the respective sizes of 400, 30, and 5.5 fish/lb. The above price quotations demonstrate that the cost of buying a pound of fish from a private grower is less for large fish than smaller sizes. It is important to understand this difference when evaluating production and capital cost for tribal and agency hatcheries.

PART III. PERSONNEL SKILLS AND SALARIES

Work in salmon and steelhead trout hatcheries has been standardized over the years so that the work performed is similar wherever the hatchery is located. As a result, job descriptions used by the Northwest fishery agencies listing typical responsibilities' and the knowledge and abilities required are very similar. Therefore, we have included copies of IFG job descriptions for the Culturist and Superintendents I and II in Appendix 5.

The major differences we noticed in the agencies' minimum qualifications were in the amount of education required and the length of time "in grade". The USFWS was the most demanding in its minimum education requirement. Idaho Fish and Game, with a very practical stance, required only that the individual demonstrate competence for the assigned task. Competence being based on any combination of education, training, experience, and ability to manage, if required. No level for educational achievement is specified, but they recognize it as an asset (Dick, personal communication). Probationary periods range from 6 to 12 months. As to differences in the "in grade" requirement, IFG does not require a minimum length of time at a particular level before advancing to a higher grade. However, OFW, WDG, and WDF all require a specific "time in grade" before becoming eligible for promotion to the next level.

We believe that the minimum requirement for the superintendent level position at hatcheries with production ranging between 10,000 to 50,000 pounds, should be one full year Of experience as a culturist, or first level superintendent, at a "comparable" station. The "comparable" station to include similar species spawned, incubated, and reared; comparable types of production units and equipment; similar water delivery systems; and comparable production levels.

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The knowledge and skills required for the superintendent's assistant at stations with production from 10,000 to 50,000 pounds is described under a Culturist or Superintendent I in the job descriptions in Appendix 5. Again, we feel that these adequately describe the skills and knowledge required, and the minimum qualifications are satisfactory. For laborers, part-time assistants, and volunteer workers, Northwest agencies do not require fish culture experience.

The accompanying table is an example of approximate 1984 monthly salary levels for hatchery personnel who would be required for the low-cost facilities recommended by this report. Although these data are from WDF, they are reasonably typical of salaries and benefits paid by Northwest regulatory agencies. The column showing the total monthly salary (salary plus benefits) will serve as a guide for estimating labor costs. Other factors to be allowed for are: starting pay, overtime, and paid leave. According to Clayton, (1968), annual leave time at the WDF Klickitat Salmon Hatchery amounted to 13 percent of the workers yearly salary. Standby pay policies vary between agencies and is granted workers for being available on station in case an emergency situation develops. This duty is usually divided up among the employees living on station so that the station is attended 24 hours each day when fish are on the station. To cover this cost, we have arbitrarily used 10% of monthly salary of the manager (including benefits) **wherever** we have applied it.

Table 4. Salaries for various hatchery classes. All figures shown have been rounded to some extent. Source: Washington State Department of Fisheries.

<u>Job class</u>	<u>Duty</u>	<u>Monthly salary range</u>	<u>Average monthly salary</u>	<u>Benefits(1)</u>	<u>Total monthly salary with benefits</u>
Superintendent 2	Manages 20-50,000 lb. capacity station	\$1400-1800	\$1600	\$ 368	\$2000
Superintendent 1	Manages 10-20,000 lb. capacity station	\$1300-1650	\$1475	\$339	\$1800
Culturist	Assistant to Superintendents 1 and 2	\$1000-1450	\$1225	\$283	\$1500
Laborer	Labor duties and security	\$1200-1350	\$1275	\$293	\$1550
Volunteer(2)	As directed	0	0	0	0

(1) Benefits calculated at 23% of monthly salary. Includes life and health insurance, retirement and **OASI**. For part-time workers, the benefits are 14%. Also a benefit, but not included is standby pay which, when it is required, is added at the rate of 10 % monthly salary including benefits.

(2) Volunteer helpers receive no salary, but agency pays for Industrial Insurance to protect worker in case of injury at rate of **\$0.056/hr.**

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Salmon and steelhead trout rearing programs, staffed with volunteer help, have a long and generally successful record in the Pacific Northwest. Many of these programs are extremely helpful in educating the public to the importance of habitat for **fish**, and they can reduce the cost of production. Volunteer projects have been formalized in Oregon and British Columbia, while a less formal arrangement exists in Washington State.

The volunteer programs are not without problems, but most negative results, especially in public relations, can be avoided by a carefully planned operation. In talking with agency personnel, we concluded that volunteer projects should be:

- (1) of a duration not to tire the volunteer; generally a short program with a clear beginning and ending.
- (2) educational to the volunteer.
- (3)** a relatively pleasant task.
- (4)** meaningful to the enhancement of fish.
- (5)** one that allows participation by many members of an organization, not just one or two.
- (6)** a project with well-defined lines of communications that are maintained.

If the above guides are followed, the program will likely bring satisfaction to all parties involved.

To summarize the personnel requirements for stations where adults are captured **and** spawned, eggs and alevins incubated, and fish reared and released, we recommend the following:

For a station under **20,000-pound** production:

Superintendent 1	(full-time or as required)
Culturist as required	(part-time)

For a station of **20- 50,000-pound** production:

Superintendent 2	(full-time)
1 Culturist	(full-time or as required)
Culturist or Laborer as required	(part-time)

PART IV. HATCHERY EVALUATION AND SELECTION

For decades, the value of salmon and steelhead trout hatcheries has been debated and millions of dollars in research funds spent in efforts to provide a proper evaluation. Often this work has been done after the facility was built, when there was no turning back. We

believe, that given the state of the art of fish culture and fishery management, and the array of modern equipment available, we can start an evaluation of a facility before hard commitments are made; this will allow us to select the best alternatives possible based on a cost-benefit analysis.

The following material was prepared under contract with FMC by Stephen B. Mathews, **PhD.**, University of Washington, Seattle, WA. Dr. Mathews discusses the economists long established Present Value Theory and proceeds to apply this to evaluate potential hatchery subcomponents, such as incubation and rearing systems. He also covers the estimation of expected values of production given some set of components, and where two projects have similar efficiency ratios, provides a sunk cost analysis to assist in a final selection. Finally, Dr. Mathews evaluates six hypothetical hatchery operations with varying production goals, and dollar costs that range broadly from high to low.

A. PRESENT VALUE THEORY AND EXAMPLES

Present Value Theory has been developed by economists to evaluate and choose among alternative potential strategies for achieving common goals for both private business and government funded projects. So far, such theory has not been utilized for evaluating potential hatchery projects that might be built. There are many ways to achieve similar ends with hatchery projects. Several alternative projects with similar production potentials (quantities of smolts that can be raised) may differ vastly in terms of capital cost, project life, or yearly operating costs. To put several projects in terms of a common denominator, Present Value Theory provides a logical and time tested framework.

The fundamental concept behind this theory is that a unit of cost incurred at some time, n , in the future can be related to the present by a discounting factor, $\$1/(1+r)^n$. The term r is the discounting rate, or what economists sometimes call the marginal time preference rate. This rate measures the indifference of an individual to incurring a unit of cost a year from now versus some cost at present, or to receiving a unit of benefit a year from now versus some benefit at present. Commonly, the discount rate, r , is considered to be the prevailing rate of interest for lending and borrowing since, if an individual chooses to wait a year before making a unit cost purchase, he would need to invest (not spend) only $1/(1+r)$ today, and that amount would be worth 1 unit in a year at r rate of interest; if he chooses to wait 2 years to make a unit cost purchase, he could invest $1/(1+r)^2$ today which would grow to a unit value in 2 years. Thus, generally, a unit cost n years in the future has a present value of $1/(1+r)^n$.

The same logic applies to future income benefits received. An individual would be indifferent to receiving a unit value n years in the future as receiving $1/(1+r)^n$ today, since he could invest the latter amount today and it would grow to 1 unit in n years.

The term,

$$V_{n,r} = \frac{1}{(1+r)^n}$$

is the discount factor to apply to any amount of cost or revenue accruing from a project n years in the future in order to place a present value on such an expenditure or benefit.

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Thus, if an annual operating cost of C were to be incurred for a hatchery n years in the future, the present value of this cost (**P.V.**) would be

$$P.V. = \frac{C}{(1+r)^n}$$

Similarly, the present value of some future amount of revenue, B , to be received in n years would be

$$P.V. = \frac{B}{(1+r)^n}$$

If there is to be a continuing stream over n years of some constant cost (or benefit) resulting from a project, the present value of this sum of costs (or benefits) for years 1, 2, 3,—, n would be:

$$\begin{aligned} P.V. &= \frac{C}{(1+r)} + \frac{C}{(1+r)^2} + \dots + \frac{C}{(1+r)^n} \\ &= C \left[\sum_{i=1}^n \frac{1}{(1+r)^i} \right] \end{aligned}$$

where C is the annual cost (or benefit) amount.

Economists call the term in brackets in the above expression the annuity factor, $A_{n,r}$. Tables are available in many economics, engineering or financial reference books for both $V_{n,r}$ and $A_{n,r}$.

One other concept, a hybrid of the above concepts, needs to be explained. Consider a stream of benefits = B , that will not start for m years in the future, but that once started, continues for years, where n is the number of years from now that the project will end. The present value of such a stream would be:

$$P.V. = BA_{n,r}V_{m,r}$$

With these concepts, we have a framework for hatchery evaluation and planning, given capital cost, annual operating and maintenance costs, project life, yearly production in terms of quantity of **smolts** or value of adults contributed, and final site value, which includes final land and depreciated facilities value. Although it would be desirable, we do not need to know precisely the value of the fish contributed for purposes of comparing particular projects, as long as we can assume it is proportional to quantity of **smolts** reared. Evaluating contribution involves knotty problems of estimating contribution rates, estimating unit recreational values, describing which of several choices or values best applies to commercially-caught fish (ex-vessel, wholesale or retail), whether to apply regional income multipliers, how to evaluate fish caught outside of the particular political region of the agency building the hatchery, etc. Thus, for the present purposes, value will be assumed proportional to quantity of smolts reared ($S = KP$), where S = annual dollar value of adults contributed, P = pounds of smolts produced annually, and K = an unknown proportionality constant.

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If S were predictable, then to evaluate a particular project, one would take the difference between the discounted stream of fishery values and the discounted stream of costs over the estimated project life; this would be the present net value of the project. Even with insufficient knowledge to estimate K , the following ratio is a useful statistic for evaluating alternative projects:

$$\text{Hatchery Efficiency Ratio (H.E.R.)} = \frac{PA_{n,r} V_{m,r}}{\text{P.V. of total project costs over project life}} = \frac{N \text{ (numerator)}}{D \text{ (denominator)}}$$

where, P = the annual pounds of smolts produced

m = average cycle length of the species reared, in years.

Note several things:

1. The term m lets value contributed be lagged appropriately behind production (however production would also continue m years beyond any time the project were ceased). For chinook and coho hatcheries, an appropriate value for m would be 3 years.
2. H.E.R. has the dimensions of pounds of production per dollar of cost. Its denominator is the total fixed and operating costs, net final site and facilities value, with each element of cost over project life discounted to the present **according** to the time such a cost would be incurred. **The** numerator is proportional to the present value of the stream of fishery benefits created by the project, i.e., for **any** year, $S = KP$, and

$$PA_{n,r} V_{m,r} = \frac{S}{K} A_{n,r} V_{m,r} .$$

Therefore,

$$(\text{H.E.R.})(K) = \frac{\text{Present value of total project benefits}}{\text{Present value of total project costs}}$$

In other words, H.E.R. is proportional to the ratio of discounted benefits to discounted costs.

3. For purposes of comparing projects with different lives, H.E.R. is independent of project life. **This** will be shown below with an example.
4. Computation of H.E.R. could include an inflation factor but, for project comparison and choice among alternatives, such is not needed.

For a simple example of H.E.R. computation, consider a hatchery with the following structure (all values and poundages in **000's**):

1. Land acquisition cost = \$200.
2. Land value appreciates at r per year.
3. Design and construction cost for facilities = \$800.

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4. Yearly O + M costs = \$100.
5. Project life = 20 years.
6. **Annual** production = 50 **lbs.**
7. Cycle (**m**) = 3 years.
8. Depreciated (recovery) value of facilities over 20 years = 100.
9. **r** = .1

On the numerator side:

$$P = 50$$

$$A_{n,r} = A_{20,.1} = 8.51356$$

$$V_{m,r} = V_{3,.1} = .75131.$$

$$\text{Thus, } N = PA_{n,r}V_{m,r} = (50) (8.51350) (.75131) = 319.82.$$

On the denominator side:

D = land cost + facilities cost + discounted stream of O + M costs - final land value discounted to present - recovery value of facilities discounted to present.

$$\begin{aligned}
 &= 200 + 800 + 100 A_{20,.1} \frac{-(200)V_{20,.1} - 100V_{20,.1}}{V_{20,.1}} \\
 &= 200 + 800 + (100) (8.51356) - 200 - 100 (.14864) \\
 &= 1636.492.
 \end{aligned}$$

(Note that the discounted final land value equaled the initial cost under the assumption that land appreciated at the rate **r**). Finally,

$$\text{H.E.R.} = \frac{N}{D} = \frac{319.82}{1636.49} = .1954 \text{ lb}/\$$$

or, reciprocally, the production from this hatchery would cost \$5.12 per lb.

Let's continue with this example to show that H.E.R. **"works"** for comparing projects with dissimilar lives. This can be done by comparing two hypothetical hatcheries, one with a 20-year life as above with 50,000 lb production capacity, and the second a 40-year life hatchery costing twice as much to build (land \$400,000, construction **\$1,600,000**), but with the same operating costs and production capacity. Conceptually one might desire to compare the two over the same time period, i.e., 40 years, considering that the 20-year hatchery would be replaced precisely at year 20. I will show that H.E.R. for the 20-year hatchery over a 20-year time period is the same as for a **20-year** hatchery, with replacement at year 20 and continuance for another 20 years. This is shown in the following computations:

Project Selection and Evaluation

D = 200 (land)	+ 800 (original facilities cost)	+ $100 A_{40,r}$ (O+M for 40 years)	+ $800 V_{20,r}$ (facilities replacement cost)
- $100 V_{20,r}$ (recovery value of first set of facilities)	- $100 V_{40,r}$ (recovery value of second set of facilities)		- $\frac{200 V_{40,r}}{V_{40,r}}$ (final land value discounted to present)

$$D = 200 + 800 + (100)(9.77905) + (800)(.1874) - (100)(.14874) - (100)(.02289) - 200$$

= 1879.734, which represents the discounted costs for a **40-year** time period of a 20-year hatchery replaced after 20 years.

Benefits for these two back-to-back **20-year** projects would total

$$N = 50 A_{40,r} V_{3,r} = (50)(9.77905)(.76131) = 367.3549.$$

$$\text{H.E.R.} = \frac{N}{D} = \frac{367.3549}{1879.734} = .1954 \text{ lb/\$}$$

This is precisely the same as the H.E.R. for the project over a 20-year life, as shown earlier.

To continue with this example and further demonstrate the power of present value analysis, let us compute H.E.R. for the **40-year** project costing originally twice as much as the 20-year project. Which would be preferable, the cheaper hatchery with the shorter life or the more expensive one with the longer life?

For the 40-year hatchery:

$$N = 50 A_{40,r} V_{3,r} = 367.3549.$$

D = 400 (land)	+ 1600 (facilities)	+ $100 A_{40,r}$ (O+M)	- $\frac{400 V_{40,r}}{V_{40,r}}$ (final land)	- $200 V_{40,r}$ (recovery of facilities)
= 2573.483				

$$\text{H.E.R.} = \frac{N}{D} = \frac{367.3549}{2573.483} = .1428 \text{ lb/\$}$$

or reciprocally **\$7.00/lb. compared to \$5.12/lb.** for the 20-year alternative.

The 40-year project is therefore 27% less efficient according to the present terms of analysis.

$$\frac{.1954 - .1428}{.1428} = .27$$

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The advantage of the cheaper, shorter-lived hatchery is that, comparatively speaking, it required only half the initial capital of the 40-year hatchery for the first 20-year time period. The present value of the additional 1 million required after 20 years is a lot less than the 1 million additional cost required at present for the 40-year project. Put another way, the extra 1 million could be invested for 20 years at r interest before it was spent; the interest on this would be additional revenue not available from the **40-year** alternative.

This illustrates a basic principle for consideration in hatchery design: all else being equal, cheap, replaceable facilities may be a sensible alternative to expensive long-lived facilities. Clearly there is some practical limit to shortness of life and cost reduction. One could show mathematically, as above, that there would be theoretical increases in efficiency with shorter and shorter-lived hatcheries with construction costs inversely proportional to life. However, practically speaking, this process at some point would lead to a system that would not have the same expected annual production; i.e., in simple terms, would break down too often.

B. COST AND PRODUCTION ESTIMATION

In applying the foregoing theoretical framework of analysis to any particular project or set of projects, one needs estimates or projections of capital and operating costs, production capabilities, and expected life of each project and/or the separate lives of the components of each project. I will outline a worksheet for organizing such data inputs and illustrate with examples.

First, consider briefly what are the major, necessary items of costs for a hatchery. On the capital cost side, a hatchery requires a physical site which must include a sufficient amount of land of suitable characteristics in terms of space, topography, and substrate, and a sufficient water supply. The latter can come from any one or some combination of surface wells, artesian wells, surface springs, **fluvial** waters, or lacustrine waters. Fresh water is required for early life stages, but saltwater can work well for later rearing. **The** major items in hatchery construction are for (1) design and site development, (2) water supply systems, (3) adult collection and holding, (4) incubation, (5) rearing, (6) transportation of reared fish, and (7) production support (shop, food freezers, feeders, stand-by generators, etc.).

The major operating cost items are manpower, fish-food and power. Manpower and power costs are highly dependent upon facilities selected, but fish-food costs tend to be proportional to pounds reared over a broad range of facilities.

The above categories of costs include over 90% of the capital and operating costs of hatcheries at the present level of technology. Therefore, a simple, straightforward, and meaningful hatchery efficiency analysis of a proposed project can be conducted considering only the above defined costs. If future technology stimulated the need for additional significant cost items (e.g., computers, fish-foodmaking machinery, pathology labs, etc.), these could be incorporated into the present planning and evaluation framework.

Table 5 illustrates the matrix of input requirements for the denominator of H.E.R. Probably the time period selected for evaluating any particular project would be the estimated length of life for the item with the longest life, perhaps the rearing facilities. Components with shorter lives could be considered replaced as their respective lives were used up within the overall timeframe of the hatchery, and their costs and recovery values would be appropriately treated via present value accounting methodology.

c. FACILITIES RISK

Risk considerations of this nature can be treated in the development of the H.E.R. numerator. Each hatchery is designed for a certain maximum planned poundage, but the likelihood of achieving this each year depends upon the probabilities of success of each of the separate components. An objective evaluation procedure for planned enhancement projects should involve some procedure for assessing or predicting the expected or average annual production, which would be some fraction of the planned production and depend upon the probabilities of success of each of the major hatchery components. These probabilities depend totally or partially on the type of facilities selected and their costs. For example, the probability of success of a pumped water delivery system would be greater with a back-up power generator system than without. A set of vertical tray incubators to hatch 5 million eggs costs more than a stack of pond trays or gravel boxes with the same capacity, but the probability of partial or total egg or fry loss may be less with the vertical tray system. Dirt rearing ponds are cheaper per unit volume than concrete raceways, but the dirt ponds could have a higher risk of disease than concrete ponds, especially if density levels were the same.

Therefore, item by item, each component should be assessed as to its **relative** risk in relation to the overall hatchery planned production. Albeit such **assessments** may have subjective elements. They could be little more than educated guesses or they could be made from extensive analysis of historical data gleaned from **past** experience at other hatcheries.

Table 6 illustrates one simple scoring system that could be used to estimate expected value of production given some set of components. A more **elaborate** or sophisticated system based on probability assignment could be developed, but such complexity may be unwarranted. Some people might even regard the proposed scheme **as** unrealistic or requiring too much guesswork.

This proposed system involves the separate rating of each of the major components on a 1 to 10 scale, with 1 being assigned if there is virtually no chance of producing at any significant level of the component capacity in any year, and 10 being assigned **if** there is a virtual 100% chance of reaching the capacity goal in all years of component life.

After assigning such scores, each of the 5 major components in Table 6 would be assigned a weighting factor. These would depend upon the evaluator's determination of the importance of that particular component to the attainment of the entire project's planned capacity output. For example, the adult facilities might fail totally in one year, yet the hatchery could get eggs or **fry** from elsewhere. On the other hand, if the rearing system failed totally, there might **be** relatively little that could be done to regain production that

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year. Consequently adult facilities might be given a lesser weighting score than rearing facilities.

Table 5. An example of worksheet for compiling data inputs for an H.E.R. analysis of a planned salmon enhancement project.

Item	Production capacity (flow, eggs, fry, pounds, etc.)	Capital cost \$	Estimated life yr.	Recovery value at end of life \$	Annual manpower for operation, maintenance & supervision yr. \$/yr. \$			Annual water use requirement acre-ft.		Annual power use kw \$/kw \$			Annual fish food lb. \$/lb. \$		
Land		\$		\$	-	-	-	-	-	-	-	-	-	-	-
Site Development	-	\$	yr.	\$	yr.	\$	\$	-	-	-	-	-	-	-	-
Water systems	cfs	\$	yr.	\$	yr.	\$	\$	-	-	-	-	-	-	-	-
Adult collection	eggs	\$	yr.	\$	yr.	\$	\$	acre-ft.	kw	\$	\$	-	-	-	-
Incubator	fry	\$	yr.	\$	yr.	\$	\$	acre-ft.	k w	\$	\$	-	-	-	-
Rearing	lbs.	\$	yr.	\$	yr.	\$	\$	acre-ft.	kw	\$	\$	lb.	\$	\$	\$
Transportation	lb.-mi.	\$	yr.	\$	yr.	\$	\$	-	---			---			-
support		\$	yr.	\$	yr.	\$	\$	-	kw	\$	\$	-	-	-	-

As an example, the weighting factors might be from 1 to 10, with **1** being assigned if attainment of the particular component's capacity had no effect on the overall output of the hatchery and **10** being assigned if that component were absolutely crucial.

The final score for the hatchery would be a weighted average of the scores for the individual components. This divided by 10 would be a factor for reducing N, the numerator in H.E.R.

The process of scoring and weighting depends on many site specific, stock specific, species specific, and agency specific considerations. However, since it is intended to evaluate and compare possible expenditures from some common fund source on some set of two or more potential enhancement projects designed to meet similar fishery goals in some common geographical and a politically defined region, it should improve the rationality of decision making, compared to the present mode of making such choices.

D. SITE RISK AND SUNK COST

There is sufficient history with hatchery production and evaluation to demonstrate that even though a hatchery may be producing its goals in terms of poundage of apparently **good** quality smolts each year, such fish may not be surviving and contributing significantly to fisheries.

Table 6. Example of a scoring system for hatchery components.

Component systems	Score	assign 1-10
Water system	Score 1-10, where 1 is <u>sure to fail totally</u> in providing any of the water needs and 10 is <u>sure to succeed</u> in providing all the water needs.	
Adult trapping	Score 1-10, where 1 is sure to be <u>totally inadequate for egg requirement needs</u> and 10 is <u>sure to provide egg needs</u> .	
Incubation	Score 1-10, where 1 is <u>sure to provide no viable fry</u> and 10 is <u>sure to provide all fry needed of high quality</u> .	
Rearing	Score 1-10, where 1 is <u>sure to provide no reared fish of any quality</u> and 10 is <u>sure to release 100% of planned capacity of high quality individuals</u> .	
Transportation	Score 1-10, where 1 is <u>sure to inadequately release any of the fish reared</u> and 10 is <u>sure to release 100% of the reared capacity in excellent condition</u> .	

Considering such a hatchery as a private business, it should probably be closed down if and when it is determined to be producing less in value per year than its annual operating costs. Even if its yearly contribution exceeded in value its yearly operating costs, it would be a good business decision, other things being equal, to close it at the time that the present value of the future stream of discounted differences between value of contribution and costs to the end of the project was less than the recovery value of the project at that time.

Presumably such a hatchery would only have been built in the first place had its projected net present value at time of construction been positive. However, living in an uncertain world, actual and projected values may differ. Given such uncertainty, how should a planner regard choices between two opposing cost strategies, one of which may involve high initial capital investment offset by relatively low operating costs, and the other involving a low initial outlay for capital but high operating costs? If a substantial portion of the capital outlay is sunk cost, in the sense that it cannot be recovered either totally or partially by sale of the items constructed or purchased, or by transfer of such items to another site, it may make sense to choose the alternative of low capital outlay but high operating cost.

Consider a simple extreme example: there are two potential programs of enhancement for a stream, each of which is projected to yield the same annual fishery contribution. Alternative 1 consists of a 10-year life capital project costing \$100,000 having no recoverable portion of the costs, and requiring no operating costs per year (an artificial spawning channel, for instance). Alternative 2 requires no capital costs, but has yearly

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operating costs (a program of spawning, hatching and planting eyed-eggs from low-cost **"throw away"** gravel boxes, for instance). Assume the two programs have equal projected net present values. Then the yearly operating costs of alternative 2, C, must be such that

$$\frac{C}{(1+r)^1} + \dots + \frac{C}{(1+r)^{10}} = \$100,000$$

or $CA_{10,r} = 100,000$

or $C = \frac{100,000}{A_{10,r}} = \$16,274$

(Note: Total expenditures over the 10 years would equal 162,740 > 100,000. But of the two alternatives, both would end up costing the same after 10 years. The fixed cost alternative would leave you 100,000 $(1+.1)^{10} = \$259,000$ poorer than if you did not do it. The operating cost alternatives would cost you the same over ten years, $C(1+.1)^9 + C(1+.1)^8 + \dots + C(1+.1)^0 = \$259,000$.)

Assume, however, that unknown to us, the entire smolt production from either alternative goes through a non-removable pollution block and dies, a fact we determine sometime during the 10 year period. With alternative 2 we can cancel the project once we learn of the pollution problem, thus saving the operating costs from the additional years. The present value of the costs of alternative 1 is \$100,000 no matter what may be found out about the pollution block and the fishery contribution during the 10 years. The present value of the stream of costs from alternative 2 would always be less than \$100,000 unless the project was continued for 10 years, in which case costs would be equal. Thus, given some risk of project failure and consequent cessation of the project, the expected value of the net return would be less with the capital intensive alternative. In simple terms, if there are two courses of action which, on the surface, seem to cost the same and potentially seem capable of yielding the same benefits, it makes common sense to choose the strategy that allows greater **flexibility**—the one that allows disinvestment if the initial projections prove to be faulty.

The above logic would seem to have wide application in hatchery planning where levels of uncertainty are so high. Expensive "labor saving" equipment or facilities may make no sense at all; to the contrary, it may be better to build cheap structures even though they may require lots of labor to maintain and operate. low-cost, short-lived (**"throw away"**) facilities may make sense if they perform the biological functions required as well as high-cost, longer-lived facilities. As a further example, even though the energy conservation implied in a gravity-fed water system compared to one of **pumping** from a river may be appealing, a high-cost head works and plumbing system to deliver gravity-fed water may not make as much sense as an alternative pumping system even though the latter may have high power costs. Power costs are operating costs which can be stopped given project failure, and pumps can be sold or transferred, unlike most components of a particular **in-stream** head-works.

Therefore, in addition to calculating H.E.R. for alternative hatchery projects, it may be useful to do a sunk cost analysis of each alternative. Then, of two or more projects with

similar H.E.R., the additional criteria of minimizing that portion of present value of total costs representing sunk costs may be useful in final project selection.

Such an analysis would be straightforward. Each of the major items of planned capital purchase or construction would be evaluated with the following question: of the total cost at the time of purchase or construction, what portion could be recovered relatively quickly by resale or reassignment to an alternative use or site if an immediate decision were made to close or discontinue the project in question? The remaining values would be summed for all capital items to give total project sunk cost. If expressed as a portion of present value of total cost, including operating costs, this could be a very useful measure for final decision-making among alternatives.

An example of such computations for a hypothetical hatchery follows in Tables 7a and 7b. In this example, assume that yearly O+M costs are 100, interest rate is **.1**, and project life is 40 years. From Table **7a**, total sunk costs are 675; from Table **7b**, total discounted operating and capital costs over project life are 1989. Therefore, the sunk cost ratio for this particular project would be **$675/1989 = .339$** , which could be compared with that of some alternative project.

E. INCUBATION SYSTEM ANALYSIS

Present value analysis can be used to evaluate various potential subcomponents of a hatchery system in exactly the same manner as evaluating a total hatchery. If each of several systems is evaluated in terms of discounted future physical production per dollar of total capital plus discounted operating costs, the resulting efficiency ratio provides a bottom line for comparison.

Such an analysis is presented in Table 8. I assumed that the only benefits of each system would be in alevins produced. Some systems, in addition to producing alevins, can produce some additional quantity of eyed eggs for sale or out-planting, which would represent some additional benefits. Some systems can be used for alternative hatchery operations, such as rearing, adult holding, or marking. I have excluded such additional benefits.

In Chapter 4, Table 4, capital and operating costs for various incubation systems were developed per 100,000 alevins. I assumed that all rearing, from fertilized egg to alevin, would be done in the identified system; however, certain systems may be used in combination, one to eye the eggs and the other to produce final alevins. Cost and floor space requirements are from Chapter 4, Table 4. I assumed that all units except pond trays would have a building, with construction costs equal to \$50 per square foot. Actually, any of the systems could be placed outside with suitable light covering; however, for working comfort and security reasons most permanent hatchery **facilities** would have a building of some sort. Plumbing costs were assigned as follows: complex plumbing, **\$205/1 00,000 alevins**; semi-complex plumbing **\$50/1 00,000 alevins**; simple plumbing **\$24/100,000 alevins** (Table 8). These values were computed by construction specialist Melvin Ebey for vertical incubators (complex plumbing), deep trough (semi-complex) and deepmatrix box (simple).

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Table 7a. An example of sunk cost computation for hypothetical hatchery.

Item of cost	Cost %	Percentage immediately recoverable by sale or other use %	sunk cost	Life yr.	Recovery value at end of life \$
Land	100	100	0	40	100
Site development (and design)	100	0	100	40	0
Water system	100	0	100	20	0
Adult collection facility	100	10	90	40	0
Incubation facilities	150	50	75	20	15
Rearing ponds	300	10	270	40	0
Transportation	50	80	20	10	10
Support facilities	100	80	20	10	20
Totals	1000		675		

Table 7b. Present value of total costs for hypothetical hatchery in sunk cost example.

0 & M	$100 A_{40,r}$	=	977.905
Land	$100 - \frac{100 V_{40,r}}{V_{40,r}}$	=	0
Site Development		=	100
Water system	$100 + 100 V_{20,r}$	=	114.874
Adult collection		=	100
Incubation	$150 + 150 V_{20,r} - 15 V_{20,r} - 15 V_{40,r}$	=	169.749
Rearing		=	300
Transportation	$50 + 50 V_{10,r} + 50 V_{20,r} + 50 V_{30,r} - 10 V_{10,r} - 10 V_{20,r} - 10 V_{30,r} - 10 V_{40,r}$	=	73.443
support facilities	$100 + 100 V_{10,r} + 100 V_{20,r} + 100 V_{30,r} - 10 V_{10,r} - 10 V_{20,r} - 10 V_{30,r} - 10 V_{40,r}$	=	153.022
Total		=	1988.993

Table 8. Computation of efficiency ratios for alternative fry incubation systems.

System	Capital cost/ 100,000 alevins \$				n system life-yr.	Annual water use/ 100,000 alevins \$/ 100,000 alevins			Annual manpower/ 100,000 alevins man \$/man years year \$			A _{n,r} r=1	Efficiency Ratio alevins/ total \$
	incu- bators	plumb- ing	floor- space	total		000 ft ³	000 ft ³	000 ft ³	man years	\$/man year	\$		
1. Vertical cabinet (8-tray)	1750	205	714	2669	20	189	.10	19	.015	25,000	375	8.51	141
2. NO PAD (single tray)	500	205	161	866	25	162	.10	16	.010	25,000	250	9.08	277
3. Deep trough (10-compartment)	460	50	385	895	20	73	.10	7	.005	25,000	125	8.51	422
4. Shallow trough (7-compartment)	4300	50	1667	6017	25	486	.10	49	.015	25,000	375	9.08	92
5. Wooden pond tray (2'x 5' x 4')	100	24	0	124	8	216	.10	22	.010	25,000	250	5.33	339
8. Metal pond tray (2'x5'x4')	400	24	0	424	15	216	.10	22	.010	25,000	250	7.63	305
7. Deep matrix box (4' x 8' x 4')	300	50	385	735	9	324	.10	32	.010	25,000	250	5.75	244
8. Deep matrix box (2' x 8' x 1.25')	500	50	1250	1800	9	324	.10	32	.015	25,000	375	5.75	139
9. Shallow matrix box (2' x 8' x 1.25')	663	50	2000	2713	9	1080	.10	108	.015	25,000	375	5.75	105
10. Montana box	267	50	132	449	10	130	.10	13	.010	25,000	250	6.14	297
11. Free style box (single)	400	24	238	662	20	288	.10	29	.005	25,000	125	8.51	431
12. Cylinder (modified jar)	500	205	500	1205	25	378	.10	38	.010	25,000	250	9.08	238
13. Cylinder (1 gallon jug)	167	205	1000	1372	15	864	.10	86	.015	25,000	375	7.63	156
14. Cylinder (5-gallon bucket)	67	205	278	550	20	360	.10	56	.010	25,000	250	8.51	285
15. Cylinder (55-gallon drum)	125	24	385	534	15	270	.10	27	.005	25,000	125	7.63	450
18. Cylinder (R-48 barrel)	248	24	178	450	20	119	.10	12	.005	25,000	125	8.51	527

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Annual manpower costs were estimated on the basis that one man-year is required for incubation of 10 million eggs and alevins at an average large hatchery. Thus, 100,000 eggs would require **.010** man-years, for a system of average labor intensity. The factor was arbitrarily scaled upwards to **.015** man years for 100,000 alevins with a high-intensity system and to **.005** man years per 100,000 alevins with a low-intensity system. One man year, including overhead and administration, was estimated to cost \$25,000. Table 8 indicates the required relative labor intensity per system.

Other operating costs would be required, and these were considered proportional to water use requirements. Obviously power costs would be included here for a pumped water system but, even for a gravity system, there would be costs for water line maintenance and monitoring, filtering, de-nitrifying, etc. I calculated an average water cost figure of **\$.10/1000** cubic feet as follows. The approximate cost of power for pumping at three types of facilities was:

Bonneville hatchery which pumps half of its water requirements from 200' wells (60- cfs available water)	\$.14/1000 ft³
Clackamas hatchery which pumps all water (river) from a 20' head (23 cfs available water)	\$.07/1000 ft³
Gravity system	\$.00/1000 ft³

Clackamas might represent an average condition between a heavy pumping facility versus one with no pumping, for comparative use throughout my analysis I arbitrarily added approximately 50% to the Clackamas hatchery power costs for additional non-power water costs to arrive at the value of **\$.10/1 000 ft³**.

The efficiency ratios in Table 4 were calculated as follows:

$$\text{Efficiency ratio} = \frac{100,000 A_{n,r}}{\text{capital cost} + \text{water cost} + \text{labor cost} A_{n,r}}$$

$A_{n,r}$ is the sum of the annuity factors as previously defined, with $r = .1$ and n the system life.

The numerator, as previously discussed for an entire hatchery, represents the discounted sum of the physical benefits (alevins) over the life of the system. The denominator is the sum of the initial capital cost plus the discounted stream of operating costs over the life of the system.

The efficiency ratio is a good measure for comparing systems with variable life, as can be shown by the following example:

Consider the Montana box system, with a **10-year** life. Its efficiency ratio is **297 alevins/dollar**. Is this a reasonable value for comparison with, say, the freestyle box with a **20-year** life and an efficiency ratio of **431 alevins/dollar**? That the answer is yes is best illustrated by considering the efficiency ratio from a Montana box system for **20** years, assuming full replacement after 10 years, the estimated life:

$$\text{Efficiency ratio of Montana box system for 20 years} = \frac{100,000 A_{20,.1}}{449 + 449V_{10,.1} + 263 A_{20,.1}} = 297$$

Thus the efficiency ratio as defined is independent of the number of lifetimes over which we might wish to evaluate a system.

The last column of Table 8 indicates that, although there has been some **arbitrary** cost assignment in the analysis, there is, nonetheless, a very wide range of efficiency ratios for the alternative means of doing the same job. **The** range is in the order of 5 - 1. The most efficient systems are the deep trough, the freestyle box, and the two barrel type incubators. All four are similarly efficient and substantially better than the remaining systems. The least efficient systems are the shallow trough and the shallow matrix box.

F. REARING SYSTEM ANALYSIS

A number of rearing systems were evaluated and compared with present value methodology. An efficiency ratio was defined as follows:

$$\text{Efficiency ratio} = \frac{\text{sum of the discounted reared poundages produced over the estimated life of the project}}{\text{sum of the discounted capital and operating costs over the life of the project}}$$

As previously, this is a good measure for comparing systems with different lengths of life.

Table 9 indicates the 18 separate systems that were evaluated-small pond systems (raceways and circulars), large pond systems, and net pens or enclosures.

Capital costs for the rearing spaces were estimated from the per cubic foot values in Chapter 5, Table 3. Additionally, we made the following assumptions as to pounds of reared salmonids (chinook, **coho** or **steelhead**) that **can** be produced per cubic foot of rearing space:

small ponds - 1 lb per **ft³**
 large ponds - **.5** lb per **ft³**
 net pens or enclosures - **.3** lb per **ft³**

These differences represent what is generally found in actual rearing **usage**. They reflect perhaps a better flow (circulation) regime progressing from net pens to raceways, but perhaps, additionally, a tendency or desire towards less dense rearing allowable by cheaper construction modes.

Loading densities vary by species, size, and temperature; but these values were assumed reasonable for illustration.

The plumbing costs in Table 9 reflect estimates for total water delivery systems-intakes, pumps, main lines, feeder lines, valves, and outlets. **These** are based on average plumbing costs per cfs of rearing water for recently constructed hatcheries. I assumed a full

Table 9. Computations of efficiency ratios for alternative rearing systems.

System		Capital cost/ 50,000 lbs (10 cfs flow)		pond life	plumbing life	Annual water use/50,000 lbs			Annual manpower 50,000 lbs			Food at .60/lb		Efficiency ratio	
		\$	\$			000	\$/50,000	man-	\$/man	\$	\$	lb/\$	\$/lb		
		ponds	plumbing			ft ³	\$/000	--	.1ba	years	year				
1.	Concrete raceway	322,660	300,000	50	25	315,360	.1	31,536	1.67	25,000	41,750	30,000	.277	3.61	
2.	Earthen raceway	165,000	300,000	50	25	315,360	.1	31,536	1.67	25,000	41,750	30,000	.327	3.06	
3.	Wooden raceway	210,000	300,000	10	25	315,360	.1	31,536	1.67	25,600	41,750	30,000	.250	4.00	
4.	Metal raceway	300,000	300,000	20	25	315,360	.1	31,536	1.67	25,000	41,750	30,000	.291	3.43	
5.	Concrete raceway	470,000	300,000	50	25	315,360	.1	31,536	1.67	25,000	41,750	30,000	.272	3.67	
6.	Earthen circular	180,000	300,000	50	25	315,360	.1	31,536	1.67	25,000	41,750	30,000	.323	3.09	
7.	Fiberglass circular	200,000	300,000	25	25	315,360	.1	31,536	1.67	25,000	41,750	30,000	.316	3.17	
8.	Plastic sheet	156,000	300,000	10	25	315,360	.1	31,536	1.67	25,000	41,750	30,000	.271	3.67	
9.	Wooden circular	600,000	300,000	40	25	315,360	.1	31,536	1.67	25,000	41,750	30,000	.252	3.96	
10.	Sheet-steel circular	314,000	300,000	15	25	315,360	.1	31,536	1.67	25,000	41,750	30,000	.281	3.55	
11.	Dirt large pond	140,000	150,000	50	25	315,360	.1	31,536	.83	25,000	20,750	30,000	.443	2.25	
12.	Gravel large pond	150,000	150,000	50	25	315,360	.1	31,536	.83	25,000	20,750	30,000	.438	2.26	
13.	Asphalt large pond	195,000	150,000	15	25	315,360	.1	31,536	.83	25,000	20,750	30,000	.402	2.49	
14.	Concrete large pond	250,000	150,000	50	25	315,360	.1	31,536	.83	25,000	20,750	30,000	.403	2.46	
15.	Shot-crete large pond	225,000	150,000	50	25	315,360	.1	31,536	.83	25,000	20,750	30,000	.412	2.43	
16.	Plastic sheet large pond	200,000	150,000	45	25	315,360	.1	31,536	.83	25,000	20,750	30,000	.420	2.38	
17.	Net pen	95,000	0	10		0		0	.83	25,000	20,750	30,000	.512	1.95	
18.	Net enclosure	16,667	0	10		0		0	.83	25,000	20,750	30,000	.588	1.70	

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plumbing cost value of \$300,000 per 10 cfs (50,000 lba of reared fish at 10 **lb/gal/min**) in a small pond system, \$150,000 for a large pond system and \$0 for a net pen or enclosure system.

Pond life estimates were from Chapter 5, Table 3. A 25-year life was assumed for all plumbing systems.

The major operating or variable costs include costs proportional to water use, labor, and feed. Water costs for small and large pond systems were estimated on the basis of **\$.10** per 1000 **ft³**, previously derived for incubation system water. Two values **for labor costs** were used; one for small ponds in which approximately half of the labor is for pond cleaning, and **another** for large ponds and net systems for which routine cleaning is a substantially lessor chore. The small pond value was based on an estimate that one man year is required to rear 30,000 lbs., a figure approximating recent experience at public hatcheries. For large ponds or pens it was estimated that one man year could rear 60,000 **lbs.**

Food costs were based on a **1.5:1** food to fish conversion rate and a food cost per pound of **\$.40**.

The efficiency ratios were all calculated assuming 50,000 lbs of reared fish **per** year over a 50-year period. As previously discussed, the comparisons are independent of the time period used, as long as one adheres strictly to the present value **model**. An example of such computations is given below for a system utilizing wooden circular ponds, according to the data of Table 9. **The** interest rate, **r**, was **.1**.

Efficiency ratio =

50,000A_{50,r}

$$\frac{600,000 + 600,000V_{40,r} - 450,000V_{50,r} + 300,000 + 300,000V_{25,r} + 103,286A_{50,r}}{\begin{array}{l} \text{initial} \\ \text{pond} \\ \text{cost} \end{array} \quad \begin{array}{l} \text{replacement} \\ \text{pond cost} \end{array} \quad \begin{array}{l} \text{unused pond} \\ \text{value at} \\ \text{50 years} \end{array} \quad \begin{array}{l} \text{initial} \\ \text{plumbing} \\ \text{cost} \end{array} \quad \begin{array}{l} \text{replacement} \\ \text{plumbing} \\ \text{cost} \end{array} \quad \begin{array}{l} \text{variable} \\ \text{rearing} \\ \text{costs} \end{array}}$$

= **.253 pounds** per \$ or \$3.96 per pound

These ratios ranged from a highest efficiency value of **.588** pounds per \$ for a net enclosure to **.250** pounds per \$ for a **wooden** raceway system.

G. FULL HATCHERY ANALYSIS

To demonstrate the use of hatchery efficiency ratio for **evaluating** projected hatchery designs or comparing several alternative production modes, we **"designed"** six hypothetical hatchery operations, each producing only **coho** salmon. The first three combinations **were** hatcheries producing 50,000 lbs. of fully reared (**20/lb coho**) and 500 lbs of eyed eggs for out-planting (approximately 500,000 eggs). These three combinations were a high cost alternative typical of recent agency projects, a medium cost alternative designed with

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cost-consciousness, and a low cost alternative. **The** other three combinations were three small hatcheries, each capable of 10,000 **lbs** of fully reared **coho** and 500 lbs of eyed eggs. Within this production range, we again hypothesized high, medium and low cost alternatives. Brief discussions of each alternative are given below.

50,500 lb. high cost. Coats are summarized in Table 10. This example had a 10 cfs flow, 10 concrete raceways, a vertical stack of incubators, housing for three people, and a permanent wier or **ladder** for adult collection. Incubation needs were calculated on the basis of 2 million alevins, sufficient for a 500,000 eyed egg plant, **1,000,000** fully reared **smolts** and the expected egg to alevin mortality losses. Rearing pond needs were

Table 10. A 50,500 pound-2 million egg hatchery with high costs.

Capital Costs		
<u>Item and Description</u>	<u>Cost \$</u>	<u>Life (yr)</u>
Pollution pond - 5,000 cu. ft. dirt pond dc water system	15,000	50
Roadways - 1/2 mi. 20' wide oiled gravel	46,800	50
3 houses - 1300 sq. ft. each	123,900	50
Food freezer	75,000	25
Tool shed and office - 1200 sq. ft.	50,000	50
Diesel generator	20,000	15
Concrete raceway rearing ponds - 10 20' x 80'	300,000	50
Water delivery system and plumbing	300,000	25
Incubator system - 8-tray vertical stacks and plumbing	39,100	20
Incubator shed - 360 sq. ft.	18,000	50
Land clearing and grading - 10 acres	25,000	50
Adult trapping and holding - permanent wier or ladder	120,000	50
Landscaping	25,000	50
Pick-up truck	10,000	10
Tools and miscellaneous equipment	15,000	10
Total excluding land	1,182,800	
Estimated land cost	300,000	
Total including estimated land cost	1,482,800	

Annual Operating Costs		
<u>Item</u>	<u>Description</u>	<u>Cost \$</u>
Manpower	3 man years	75,000
Water	3.1536 x 10⁸ cu. ft.	31,536
Food	75,000 lbs.	30,000
Misc. supplies	Drugs, telephone, fuel	
	office supplies, parts, etc.	8,000
Misc. maint.	Equipment repair, roadway & building maintenance	
		8,000
Total		152,536

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conservatively calculated on the basis of a holding density of 1 lb/ft³. Variable water costs were estimated on the basis of \$.10/1000 ft³, a coefficient that has been previously **discussed**. Other costs were estimated from data given elsewhere in this report. Normally such costs have included add-on factors to cover both design and contingency. The total capital cost for this hypothetical unit was about 1.2 million (\$24/pound of production) and operating costs approximated \$150,000/year.

50,500 lb, medium Cost. Costs are illustrated in Table 11. This alternative had the same production capacity as the previous example, but its means of production differed in

Table 11. A 50,500 pound-2 million egg hatchery with medium costs.

Capital Costs		
Item and Description	Cost \$	Life (yr)
Pollution pond - 5,000 cu. ft. dirt pond & water system	15,000	50
Roadways - 1/2 mi. 12' wide gravel	22,750	25
2 houses - 1100 sq. ft. each	69,900	50
Tool shed and office - 1200 sq. ft.	50,000	50
Diesel generator	20,000	15
Concrete raceway - 4 20' x 80'	120,000	50
Dirt rearing pond - 34,600 cu. ft.	48,400	50
Water delivery system and plumbing	150,000	25
Incubator system - 10 comp. deep trough & plumbing	10,200	20
Incubator shed - 192 sq. ft.	9,600	50
Land clearing and grading - 10 acres	25,000	50
Adult trapping - temporary rack	10,000	10
Adult hauling - flat bed truck and tank	20,000	10
Adult holding - dirt pond modifications	10,000	50
Landscaping	15,000	50
Tools and miscellaneous equipment	15,000	10
Total excluding land	610,850	
Estimated land cost	300,000	
Total including estimated land cost	910,850	

Annual Operating Costs		
Item	Description	Cost \$
Manpower	2 man years	50,000
Water	3.1536 x 10 ⁸ cu. ft.	31,536
Food	75,000 lbs.	30,000
Misc. supplies	Drugs, telephone, fuel office supplies, parts, etc.	8,000
Misc. maint.	Equipment repair, roadway & building maintenance	6,000
Freezer rental		1,200
Total		126,736

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several regards. It had 4 raceways and a large dirt pond to take up the bulk of the production. With less raceway cleaning, it could be operated with two men. The incubation system was the cheaper deep trough type. Adult trapping was with a temporary wier; adult holding was in the large dirt pond, suitably modified. Other costs not strictly related to production were scaled down, such as roadways, landscaping and freezer space. **The** latter function was considered to be accomplished by rental of freezer space. Plumbing costs were less than the high-cost alternative since there were less ponds overall. **The** capital cost was about **.6** million or one-half those of the first example. Operating **costs were** less because of the elimination of the one man-year.

50,500 lb., low cost. Costs are summarized in Table 12. This alternative represents the approximate bottom level for which 50,000 lbs. of reared **coho** and 500,000 eyed eggs for

Table 12. A 50,500 pound-2 million egg hatchery with low costs.

Capital Costs		
<u>Item and Description</u>	<u>Cost \$</u>	<u>Life (yr)</u>
Roadways - 1/2 mi. 12' wide gravel	22,750	25
2 houses - 1160 sq. ft. each	69,900	50
Tool shed and office - 600 sq. ft.	25,000	50
Incubator system - R-48 barrels and plumbing	5,400	20
Water system - intake and lines	6,000	20
Net pen rearing system - netting, floats, lines	100,000	10
Land clearing and grading - 4 acres	10,000	50
Landscaping	5,000	50
Pick-up truck	10,000	10
Outboard skiff and motor	3,000	10
Tools and miscellaneous equipment	10,000	10
Total excluding land	267,050	
Estimated land cost	120,000	
Total including estimated land cost	387,050	

Annual Operating Costs		
<u>Item</u>	<u>Description</u>	<u>Cost \$</u>
Manpower	2 man years	50,000
Water	Incubation only	-240
Food	75,000 lbs.	30,000
Misc. supplies	Drugs, telephone, fuel office supplies, parts, etc.	5,000
Misc. maint.	Equipment repair, roadway & building maintenance	5,000
Eyed egg purchase	2 x 10 ⁶ at \$8/1000	16,000
Freezer rental		1,200
Total		107,440

planting could be sensibly and safely produced. It utilized outdoor, barrel-type Incubators and net pens for rearing, both of which have been proven. It assumes, of course, the **availability** of a suitable body of laucustrine water. No adult collection facilities were included. This hatchery would rely upon fertilized eggs from other sources. A cost of **\$8/1000** for fertilized eggs was assumed, which would represent an annual operating cost. Operating costs did not include the water proportional costs of the previous two examples since there would be no pumping or line service **costs** with floating pens. This low cost system costs less than half the previous one but, of course, the pens and floats would have to be replaced regularly, unlike ponds,

10,500 lbs: high, medium and low cost. Similar production and cost-scaling assumptions were made as for the previous three examples. All three examples assumed a **coho** production of 10,000 **lbs.** of fully **reared** fish and 500,000 eyed eggs for planting. Incubators were costed on the basis of **1,000,000** alevins. **The** high-cost unit had two concrete raceways, a dirt rearing-adult pond, a vertical tray incubator system, and a wooden ladder for fish collection. The medium-cost unit had one large dirt rearing pond, a deep trough incubator system, and a wooden ladder. Roth units were assumed operable by one man. **The** low cost unit had barrel incubators, floating pens, and no adult collection facilities. It was assumed operable with **.75** man years. Costs for three of these units are summarized in Tables 13, 14 and 15 respectively.

An example of hatchery efficiency ratio (H.E.R.) computations for the 50,500 lb, high-cost unit is given in Table 16. The ratios for all units are given in Table 17. They vary from a low of \$3.17 per pound of production for a 50,500 lb low-cost unit to \$18.10 for a 10,500 lbs, high-cost unit. In all cases an interest rate of **r = .1** was assumed.

Although these examples are hypothetical, they illustrate that there is a substantial range of efficiencies of operation within the bounds of standard hatchery designs and production modes. These examples also indicate potential efficiencies of scale may exist with size. Efficiencies tended to be greater for producing the larger poundage values than the smaller ones. Further analysis would be needed to more fully define the production values at which efficiencies are greatest.

In the previous examples, land costs were added to each table only for completeness and as a reminder that these are important up-front cost considerations. However, since land tends to appreciate in value roughly in proportion to the going interest rate, land may not be a true cost at **all**. This point was previously discussed in the section on present value theory.

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Table 13. A 10,500 pound-1 million egg hatchery with high costs.

Capital Costs		
Item and Description	Cost \$	Life (yr)
Roadways - $1\frac{1}{2}$ mi. 12' wide gravel	22,750	25
House --1300 sq. ft.	41,300	50
Tool shed and office - portable 400 sq. ft.	12,000	25
Concrete raceways - 2 20' x 80'	60,000	50
Dirt rearing-adult holding pond - 5000 cu. ft.	15,000	50
Water delivery system and plumbing	75,000	25
Incubator system - 8-tray vertical and plumbing	19,550	20
Incubation shed - 200 sq. ft.	10,000	50
Land clearing and grading - 4 acres	10,000	50
Adult trapping and holding - wooden ladder and pond modification	28,000	25
Landscaping	12,000	50
Pick-up truck	10,000	10
Tools and miscellaneous equipment	7,500	10
Total excluding land	323,100	
Estimated land cost	120,000	
Total including estimated land cost	443,100	

Annual Operating Costs		
Item	Description	Cost \$
Manpower	1 man year	25,000
Water	6.307 x 10^7 cu. ft.	6,307
Food	20,250 lbs.	8,100
Misc. supplies	Drugs, telephone, fuel office supplies, parts, etc.	2,000
Misc. maint.	Equipment repair, roadway & building maintenance	4,000
Freezer rental		1,200
Total		46,607

Table 14. A 10,500 pound-l million egg hatchery with medium costs.

Capital Coats		
<u>Item and Description</u>	<u>Cost \$</u>	<u>Life (yr)</u>
Roadways - 1/2 mi. 12' wide gravel	22,750	25
House - 1100 sq. ft.	34,950	50
Tool shed and office - portable 400 sq. ft.	12,000	25
Dirt rearing pond - 13,000 cu. ft.	18,900	50
Water delivery system and plumbing	30,000	25
Incubator system - IO comp. deep trough and plumbing	5,100	20
Incubation shed - 150 sq. ft.	7,500	50
Land clearing and grading - 4 acres	10,000	50
Adult trapping and holding - wooden ladder and pond modification	28,000	25
Landscaping	4,000	50
Pick-up truck	10,000	10
Tools and miscellaneous equipment	<u>6,000</u>	10
Total excluding land	189,200	
Estimated land cost	<u>120,000</u>	
Total including estimated land cost	<u>309,200</u>	

Annual Operating Costs		
<u>Item</u>	<u>Description</u>	<u>Cost \$</u>
Manpow er	1 man year	25,000
Water	6.307 x 10⁷ cu. ft.	6,307
Food	20,250 lbs.	8,100
M isc. supplies	Drugs, telephone, fuel office supplies, parts, etc.	2,000
Misc. maint.	Equipment repair, roadway & building maintenance	4,000
Freezer rental		<u>1,200</u>
Total		46,607

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Table 15. A 10,500 pound-1 million egg hatchery with low costs.

Capital Costs		
<u>Item and Description</u>	<u>Cost \$</u>	<u>Life (yr)</u>
House - 1100 sq. ft.	34,950	50
Tool shed - portable 200 sq. ft.	6,000	25
Incubator system R-48 barrels and plumbing	2,700	20
Water system - intake and lines	6,000	20
Net pen rearing system - net and floats	23,750	10
Land clearing and grading - 2 acres	5,000	50
Landscaping	2,000	50
Pick-up truck	10,000	10
Tools and miscellaneous equipment	5,000	10
Total excluding land	95,400	
Estimated land cost	120,000	
Total including estimated land cost	215,400	

Annual Operating Costs		
<u>Item</u>	<u>Description</u>	<u>Cost \$</u>
Manpower	.75 man years	18,750
Water	Incubation only	120
Misc. supplies	Drugs, telephone, fuel office supplies, parts, etc.	2,000
Food	20,250 lbs.	8,000
Misc. maint.	Equipment repair, roadway & building maintenance	2,000
Egg purchase	1 x 10 ⁶ at \$8/1000	8,000
Freezer rental		1,200
Total		40,070

Table 16. An example of computations of hatchery efficiency ratio for a 50,500 lb. high cost unit.

$$\text{H.E.R.} = \frac{50,500 A_{50,r}}{\text{Total discounted costs over hatchery life of 50 years}}$$

The separate elements of the denominator are as follows:

<u>Item</u>	<u>Explanation</u>
1. 723,700	cost of 50-year items
2. 375,500 (1+V _{25,r})	cost of 25-year items
3. 20,000 (1+V _{15,r} +V _{30,r} +V _{45,r})	cost of 15-year items
4. - 69667 V _{50,r}	salvage value of 15-year items
5. 39,100 (1+V _{20,r} +V _{40,r})	cost of 20-year items
6. -19,550 V _{50,r}	salvage value of 20-year items
7. 25,000 (1+V _{10,r} +V _{20,r} +V _{30,r} +V _{40,r})	cost of 10-year items
8. 152,536 A _{50,r}	operating costs

For simplicity, no recovery values are assumed for any items at end of their lives. The salvage values above represent the fractional values for certain replacement items at the 50-year point.

Table 17. Hatchery efficiency ratios for six hypothetical production combinations.

50,500 lbs-2 million eggs	<u>lb/\$</u>	<u>\$/lb</u>
high cost	.178	5.61
medium cost	.252	3.96
low cost	.316	3.17
10,500 lbs-1 million eggs		
high cost	.123	8.10
medium cost	.150	6.67
low cost	.181	5.52

CHAPTER 9

THEORETICAL HATCHERIES

Within this Chapter, 20 theoretical low-cost hatcheries have been conceived that produce 10,000 lbs, 20,000 lbs, or 50,000 lbs of juvenile salmon and steelhead trout annually. They have the capability of adult capture and spawning, egg and **alevin** incubation, and rearing and releasing. Prototype designs have been developed for each along with the estimated operational and capital costs. Special consideration has been given to both physical and biological conditions that are likely to be encountered in areas east of the Cascade range.

PART I. METHODS USED IN DEVELOPING 20 THEORETICAL HATCHERIES

The steps we took for the theoretical physical development of each hatchery were:

- (1) Clearly define the goal of juvenile fish production.
- (2) Develop the biological criteria for the life phase of each species needed to meet these goals.
- (3) Identify operational considerations.
- (4) Develop theoretical site conditions.
- (5) Design the physical components of the facility with consideration for alternatives.
- (6) Compute the capital operating and maintenance costs, and define the manpower required to manage each facility.

Each of these steps listed is further explained as it applies in general to all 20 hatcheries. A discussion will be included with each conceptional plan.

A. DEVELOPMENT OF GOALS

The ultimate goal of a hatchery is to economically produce adults by releasing juvenile fish. In this report, the goal is to produce given numbers and sizes of certain species of juvenile fish in low-cost life facilities with components designed to last 10 years or longer; however, because all hatcheries are theoretical and the intent is to compare developmental options, we will forgo any analysis of adult production.

We were provided specific hatchery goals for 12 stations where all production occurs at a single site. The other eight facilities include off-station production (Table 1). For the latter eight facilities, more specific goals were developed with emphasis on aiding natural

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production and local fishery harvest. Specific programs are presented with each facility concept later in this chapter.

Table 1. Broad production goals for 20 theoretical hatcheries.

Species	With on-station production			With on and offstation	
		<u>only (pounds)</u>		<u>production (pounds)⁽¹⁾</u>	
Fall chinook	10,000	20,000	50,000	20,000	50,000
Spring chinook	10,000	20,000	50,000	20,000	50,000
Fall chinook and coho	10,000	20,000	50,000	0	0
Coho	0	0	0	20,000	50,000
Steelhead	10,000	20,000	50,000	20,000	50,000

(1) Offstation production includes adult holding, incubation, and/or rearing as satellites to the main station.

B. BIOLOGICAL CRITERIA

The biological criteria used to develop the physical concept for each facility was previously presented in this report and is primarily documented in:

Chapter 3, Table 2 "Space and flow criteria for long-term holding of adult salmon and steelhead trout . . .";

Chapter 4, Table 1 through 3 for incubation temperature requirements, incubation water requirements, and incubation density by unit types, respectively;

Chapter 5, Table 1, 2 and 4 on water flow, rearing space, and food requirements, respectively; and

Chapter 6, Table 2 on transportation densities.

While these tables assisted our design team in developing the physical hatchery concept, further criteria were developed from which we based the production program. This mainly relates to adult timing and the survival rates for each life phase (Table 2). This table was developed after conferring with agency personnel. It will be used as a standard for all 20 hatcheries; recognizing, however, that managers and existing facilities can experience different results.

Table 3 was developed from Table 2 to provide a standard system in which to obtain the required numbers of adults, eggs, and fish for a 10,000-lb smolt program. The needs of a larger smolt program is a direct multiple of these figures (i.e., a 50,000-lb smolt station requires a multiple of 5).

The temperature and feeding levels are the two most common factors affecting growth, and are used exclusively in this report. Using 50-52F rearing water, our observation was that it takes salmon about 120 days to reach 80 fish per pound, and this is the general rate of growth we will use. If we begin with fish at 1 100/lb (1.41 inches) and they grow to 80/lb (3.45 inches), the gain in inches per month is slightly slower than steelhead.

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Table 2. General biological criteria used to program theoretical **salmonid** hatcheries in the **Columbia River Basin**.

<u>Species</u>		<u>Chinook</u>			<u>Coho</u>	<u>Steelhead</u>	
<u>Life Phase</u>		<u>Early Fall</u>	<u>Spring/ Summer</u>	<u>Late Fall</u>		<u>Spring/ Summer</u>	<u>Winter</u>
<u>Adult</u>							
Arrival time:	From:	9/1	4/1	10/1	9/15	5/1	12/1
(month/day)	To:	10/15	8/15	12/10	12/1	3/15	4/1
M/F return ratio ⁽¹⁾		1.5-1	1.5-1	1.5-1	1:1	1:1	1:1
M/F holding ratio		1:1	1.5:1	1:1	1:2	1:1	1:2
Average weight		15	15	18	8	8	8
% pre-spawn survival		95	80	so	95	so	95
% F suitable for spawning		100	100	100	so	so	so
% F return used for spawning		95	80	so	85.5	81	85.5
% of run held at one time		60	100	70	70	100	60
<u>Spawning</u>							
Max. no. F's spawned per M		3	3	3	3	3	3
Spawning period:	From:		S-1 5	8-20	11-1	10-1	12/1
12/15	To:		10-20	10-1	12-15	12-15	4/1
(month/day)							
5/1							
Average no. eggs/F		4,500	5,000	5,000	2,400	4,500	3,500
Average no. eggs/lb (eyed)		1,300	1,600	1,300	1,600	4,000	3,300
<u>Incubation</u> (Survival rates in %)							
From fertilization to eyed stage		92	92	92	92	92	92
From fertilization to first feeding		so	so	so	so	so	so
<u>Development rate</u>							
Days to 1st feeding @ 52F		83	83	83	70	32	32
Days to 1st feeding @ 48F		104	104	104	88	36	36
<u>Rearing</u> (Survival rates in %)							
First 30 days of feeding		97	97	97	97	97	97
First 100 days of feeding		93	93	93	93	93	93
First feeding until smolt		93	72	93	83	72	72
<u>Growth</u> (see following narration)							
<u>Release</u>							
Time of smolt release	From:	5/1	4/1	5/1	5-1	4/15	4/15
	To:	6/15	5/1	6/15	6-1	5/15	5/15
Size at release as smolts (fish/lb)		50-100	10-15	50-100	18-22	6-8	6-8
% survival from fertilization to release		84	65	84	75	65	65

(1) M = Male; F = Female

Table 3. Numbers of adults, eggs, and juveniles needed for a 10,000-lb smolt release.

<u>Species</u>	<u>Chinook</u>		<u>Coho</u>		<u>Steelhead</u>	
<u>Life Phase</u>	<u>Early</u> <u>Fall</u>	<u>Spring/</u> <u>Summer</u>	<u>Late</u> <u>Fall</u>		<u>Spring/</u> <u>Summer</u>	<u>Winter</u>
Adult (numbers)						
Total F return	223	46	211	130	30	36
Spawned F	212	37	191	111	24	31
Return total M & F	552	70	528	260	60	78
Ratio of M to F holding	1:1	1.5:1	1:1	1:2	1:1	1:2
No. M & F held at one time	26	115	297	137	60	36
<u>Incubation (numbers)</u>						
New fertilized eggs	952,000	185,000	952,000	267,000	108,000	108,000
Eyed eggs	876,000	179,000	876,000	245,000	99,000	99,000
<u>Rearing (numbers)</u>						
Fry ponded	857,000	166,000	857,000	240,000	97,000	97,000
At 30 days	831,000	161,000	831,000	233,000	94,000	94,000
At 100 days	797,000	155,000	797,000	223,000	90,000	90,000
At smolt stage	800,000	120,000	800,000	200,000	70,000	70,000

Gearheard (personal communication) related that steelhead trout grow at the approximate rate of 0.5 inches per month in rearing water with a temperature of **47-53F**, and this is the basis for our programming growth rates for steelhead trout. Starting with a one-inch trout at **2857/lb**, we calculate that at the end of 13 months the fish will reach 7.5 inches, or about 7 fish/lb. We suggest you refer to Piper et al., (1982) for tables converting fish in inches to fish per pound.

As previously mentioned, the survival of steelhead trout from juveniles to adults appears to be enhanced if they are reared in water cooler than **50F** during the winter and early spring period prior to release. We have programmed this as a biological requirement. In addition, we used the option of accelerating maturation and incubation to provide more rearing for a steelhead trout rearing program (see Chapters 3 & 4).

We have developed Table 4 to show the approximate anticipated size of juvenile fall chinook and steelhead trout by month that a culturist could expect in a rearing program given the above situation.

Most often the growth rates for spring chinook and **coho** salmon juveniles either should be slowed and/or the number of days for rearing reduced. Generally, the times of the year that space and water are usually in greatest need for spring chinook and **coho** is at the time of smolt release, during low warm summer flows, and during the fall of the year when low flows persist and adults are being held. In Chapter 4 we documented that fish size can be regulated by using cool incubation water, cool winter rearing water, reduced feeding rates, or a combination of these. These options will be used to give the culturist considerable latitude to manipulate fish size. All these options will result in a more suitable hatchery environment for the juveniles and adults.

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Table 4. Anticipated growth for fall chinook salmon and steelhead trout in water temperatures approximating SOP.

<u>Days of rearing</u>	<u>Fall chinook</u>		<u>Steelhead trout</u>	
	<u>Fish/lb</u>	<u>Length (Inches)</u>	<u>Fish/lb</u>	<u>Length (Inches)</u>
0	1100	1.4	2857	1.0
30	500	1.9	862	1.5
60	250	2.4	352	2.0
so	125	3.0	185	2.5
120	80	3.4	102	3.0
150			67	3.5
180			44	4.0
210			31	4.5
240			23	5.0
270			17	5.5
300			13	6.0
330			10	6.5
360			8	7.0
390			7	7.5
420			5	8.0

With the theoretical spring chinook and **coho** stations that follow, the fish sizes that we feel are achievable by time are shown in Table 5.

Table 5. Programmed growth rates for juvenile spring chinook and **coho** salmon by time for theoretical hatcheries.

<u>Date</u>	<u>Spring chinook</u>		<u>Coho</u>	
	<u>Fish/lb</u>	<u>Grams/fish</u>	<u>Fish/lb</u>	<u>Grams/fish</u>
April 15	100-150	<4.5	250-300	<1.5
June 1	65-70	<7.0	1 SO-200	<3.0
October 1				
For fall release	15	30.0	not conducted	
Held for spring release	25-30	<18.0	35-40	<13.0
As smolts				
(April 15 - May 1)	12	38.0	20	23.0

Water sources used in the theoretical hatcheries have a temperature profile arbitrarily chosen, but they are based on recorded temperatures of typical Columbia River **Basin** streams and ground water sources east of the Cascade range. Fig. 1 (upper) is the surface water temperature curve used to rear fall chinook salmon and steelhead trout, while Fig. 1 (lower) is the surface water temperature curve we will use at the spring chinook and **coho** salmon hatcheries.

The ground water temperatures programmed are 53F for fall chinook, 48F for spring chinook and **coho**, and **50F** for steelhead trout.

Figure 1. Surface water temperature curves for rearing fall chinook salmon and steelhead trout (upper), and spring chinook and coho salmon (lower), at theoretical hatcheries. Source: S-year average at Wells Salmon Hatchery, WDF (upper), and two years of records at Entiat NFH, USFWS (lower).

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c. OPERATIONAL CONSIDERATIONS

The facilities and personnel needed to handle the adult holding and spawning, incubation and rearing is based on information from previous chapters. To briefly review, we present the following:

1. General Consideration First and foremost, quality fish are predictable; the cost of the facility **is** comparatively low; portability is a consideration; rapid installation is an advantage; and single life-phase use of any unit is avoided if feasible, etc.
3. Adult Holding and Spawning Small groups will require similar security costs as large groups; spawning of adults, as steelhead, over long periods of time will tie up space so individual holding will be used for efficiency; for small programs, such as **10,000–20,000** pounds production of steelhead, **coho**, or spring chinook, a spawn shed will not be necessary; etc.
3. Incubation Provisions will be required to isolate the steelhead trout eggs because of disease considerations; large and small egg lots will be **considered**; units with multi-purpose use will be preferred, such as ones which can conveniently eye eggs, incubate alevins, rear fry, hold adults, or be used for miscellaneous programs, such as marking fish.
4. Rearing Small units will be used where many small lots of fish begin feeding over a long period of time; ponds that can be readily sectioned to **accomodate** this concern, or for segregation for other reasons, will be preferred. Large ponds are less costly per **ft³** of space and more manpower efficient than smaller ponds and will be used where possible. Net enclosures and net pens will be used where possible because they require no costly inlet or outlet structure, are portable, low cost, and provide rapid installation; rearing ponds will be designed to handle adults; etc.
5. Personnel and Other Considerations In the theoretical hatcheries that follow, we have assumed the operations of each facility is located east of the Cascade range, where most natural elements are extreme. Other assumptions are (see Chapter 8, Table 1): support services are within 20 miles; skilled personnel is available; temporary and volunteer helpers exist; no support is available from nearby tax supported entities; some housing onstation is **required**; the schools, hospitals, and shopping centers are available; work assignments other than at the fish culture station can be made for any employee; and once given the hatchery production goal, it is assumed that the legal requirements and management goals are properly addressed.

D. THEORETICAL SITE SELECTION

Most quality hatchery sites for developing large **salmonid** hatcheries (100,000 lbs or more annual production) in the Columbia River **Basin** have been developed. We believe, however, that good numbers of potential sites are still available for developing smaller hatcheries producing smaller quantities of fish. Most of our low-capital propagation facilities and techniques illustrated in this chapter have been successfully utilized or are

being utilized in salmon and steelhead trout programs. These facilities are particularly efficient and cost effective for smaller hatchery installations where rearing programs are designed to operate for a given length of time.

It is recognized that no two hatchery sites are identical, however, we have chosen to use an onstation production hatchery site that is similar to all 20 stations. The site has about 5 acres of relatively flat ground and is supplied with gravity flow surface water and ground water obtained from a single source or a combination of springs, wells, or infiltration galleries. It is also recognized that ground water is not essential provided that surface water flows and quality adequately meet the criteria for all phases of fish life involved in hatchery operations.

E. DESIGN

The following engineering guidelines were established by the Department of Energy's (BPA) work statement for "Prototype **Designs**".

- 0 Flexibility in design to allow **accomodation** to various sites and to permit future modification at relatively low cost;
- 0 Water supplied, ideally, by gravity from a spring source, although flexibility in design to **accomodate** other water sources is require⁴
- 0 Low capital cost;
- 0 Construction will minimize the use of concrete or other permanent structural material in favor of wood, fiberglass, preformed components, or other relatively low-cost construction;
- 0 Design must be applicable to environmental conditions in the Columbia River Basin; and
- 0 Operation and maintenance (**O & M**) costs should be minimized.

To develop the "Prototype Designs", the following criteria were established to meet the above guidelines, and to provide for general cost comparisons for the various low-cost salmon production systems previously identified in this publication.

Site Preparation

- (1) Average clearing and grubbing work effort.
- (2) Minimal cut and fill for site development.
- (3) Site drainage utilizing culverts and ditches.
- (4) Roads - surfacing, widths and lengths all standardized.

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- (5) Electrical and phone service transmission lines to site are not included in Project costs.

Water Supply & Drains

- (1) Stream width at surface water intake and **fishway** location standardized.
- (2) Stream and spring intakes - Concrete construction for stability against washouts. Stream intake sized to permit future expansion and provide a safety factor against water shutdowns caused by icing, debris, or stream sedimentation.
- (3) Surface and spring water supplies are gravity flow.
- (4) Pipelines, water supply canals, and drains are all standardized for materials and lengths. Pipes are sized not to exceed 2 feet of head loss per 1,000 feet of pipe length for gravity flow, and drainpipes are sized to provide increased drainage capacity to allow for rapid lowering of pond waterlevels without diminishing incoming water supplies.
- (5) Groundwater aerated with packed column aerators.
- (6) Well pumps are submersible types for security against vandalism.
- (7) Multi-well systems are each located at least 1,000 feet apart to minimize interference.
- (8) Diesel generators are provided for back-up power during power outages to supply electricity to wells and/or infiltration gallery ground-water pumps.
- (9) All outside pipelines and valves are buried for protection against vandalism and extreme air temperatures.
- (10) After once being used, no reconditioning of the water is considered. Used water will have the option to gravitate to downstream ponds or new pond development, 'space permitting, or be pumped back upstream where space is available for pond development. The general criteria for re-use of water is that rearing densities should be reduced by one-third with each re-use, provided dissolved oxygen is maintained near optimum in the rearing-pond water.

Fish Production Systems

- (1) Egg incubation systems utilize aerated ground water. Incubation equipment is housed in the hatchery building's tank room for light control, protection from vandalism and extreme climatic conditions. Double stack incubation equipment is used to minimize floor space and reduce piping needs.

Theoretical Hatcheries

- (2) Ground water surplus to the incubation systems is piped to rearing and adult holding facilities for tempering surface water supplies, as necessary, and to imprint **smolts** for adult return to hatchery waters
- (3) Use of dirt ponds is optimized because of lowest unit cost and ease of future expansion.
- (4) **Fishways** require a 6-foot fish lift, and dimensions are standardized to utilize full 4- x 8-foot sheets of plywood.
- (5) Pollution control pond is sized for 1 hour detention time. Pond cleaning by vacuum system on facilities producing over 20,000 lb of fish annually.
- (6) Net covering is provided over rearing ponds for protection against fish-eating birds.
- (7) Electrified fencing around large rearing ponds is provided for protection against wading birds and swimming fish-eating mammals
- (8) Low-water alarms are provided for incubation and pond water supplies. Mobile **phone-call** systems are provided for low-water alarms on remote large ponds with no **on-site** operator.

Buildings

- (1) All buildings, except for the storage building, utilize concrete foundations.
- (2) All large buildings utilize a 12- or 24-foot wide modular dimension for ease of procurement, erection, and future expansion.
- (3) All buildings maintain a **40-foot** clear distance between buildings to minimize fire damages.
- (4) Housing - Provide one quality three-bedroom prefabricated wood frame residence of 1,100 **ft²** with attached garage for the manager.
- (5) Hatchery - Metal frame, siding, and roof: heated, and insulated: partitioned for tank, crew lockers, office, mechanical, and rest rooms.
- (6) Storage Building - Pole supported, metal siding and roof, with minimal lighting and gravel floor. Cabinets and storage bins to be installed later by owner.
- (7) Cold Storage Building - Freon system capable of -10F OMP holding temperature. Small capacity units (to 16,000 lb/OMP storage), use 66 **lb/ft²** for sizing the building. Over 16,000 lb capacity units use 83 **lb/ft²** for building size. Provide additional work space for thawing and handling feed.

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F. CAPITAL AND OPERATIONS AND MAINTENANCE

The capital and operations (O & M) costs, including O & M manpower effort and experience required, are listed in the write-up of each prototype facility later in this report. The general approach used is included below.

Capital Costs: Capital costs are all costs associated with facility developments. The capital cost estimates for constructing the "Prototype Designs" are in 1983 dollars and are summarized in Table No. 70 at the end of this Chapter. This table also provides individual estimates for the following hatchery elements for each "Prototype Design".

- Site development
- Water supply and drains
- Fish production facilities
- Buildings
- Equipment, furnishings, and supplies

These estimates include costs for site-specific planning, design, contract administration, construction, construction contingencies, and facility start-up instructions. Because of highly variable costs that could require substantial funding, the above estimates do not include property (land and water rights) acquisition, environmental documents (assessments, statements, permits, and archaeologic investigations), and permanent electrical or telephone services into the site.

Operations and Maintenance (O & M) Costs: O & M costs, as the name implies, are those associated with operating and maintaining the facility to meet management production goals. In the operation of the theoretical hatcheries presented in this chapter, we assume approximately 90% of the total O & M cost is spent for fish food, labor, and electricity (see Chapter 8, p 241-243). Of the **90%**, labor cost approximates 50 % (Fig. 5, p 244). In a breakdown of labor costs, we assume 45%-50 % will be **alloted** for such maintenance items as equipment and building repair, road and ground maintenance, screen and pond repair, painting, et **al**. or as documented in Chapter 8, Table 3 (**p** 245). The remaining 10% of the O & M expenditures is programmed to be utilized for routine expenses, supplies, vehicle operations, specialized facility and equipment maintenance, rental equipment, and contract services. For a 50,000 lb production station, the dollars programmed **will** approximate \$9,000 to \$10,000. Utilities on housing will be paid by the tenant and dollars accumulated from rental charges will not be considered. As the facilities and equipment age, the dollar amount may require an increase. Major repairs or rehabilitation work, and major equipment replacements should also be programmed well in advance of need, to minimize emergencies that could severely impact the O & M funds

A few of the specific operating cost items used in our O & M estimates are as follows:

OMP feed @ **\$.45/lb** for small fingerlings

OMP feed @ **\$.40/lb** for larger fingerlings to smolt-sized fish

Electrical costs for hatcheries without water pumps @ 3% of O & M budget and pumping electrical costs @ **\$23/HP** month (equivalent to 1 HP for 30 days).

PART II. CONCEPTS OF 20 THEORETICAL HATCHERIES

Following the methods described in Part I., we have summarized for all 20 hatcheries the space (ft³) requirements for adult holding (Table 6), the recommended type and numbers of incubation units (Table 7), the recommended rearing space and numbers of units (Table 8), and the recommended water supply (Table 9).

Following these tables the 20 hatcheries are individually described and include:

Identification

Goals

Biological requirements

Facilities and equipment

Operational strategies

costs

The hatcheries are grouped by species in the same order as shown in Table 1., then followed with a general discussion.

Table 6. Minimum recommended space (ft³) for adult holding by station capacity.

Species	Onstation production (pounds)			On- and off-station production (pounds)	
	10,000	20,000	50,000	20,000	50,000
Fall chinook	1876	3752	9380	4252	12,000
Spring chinook	920	1840	4600	3960	4952
Fall chinook/coho	1022	2044	5110		
Coho				4324	10,800
Steelhead	85	170	425	545	500

Table 7. Recommended number and type of incubation units by station capacity. (Deeps and shallow refer to trough incubators, see Chapter 4.)

Species	Onstation production (pounds)			On- and off-station production (pounds)	
	10,000	20,000	50,000	20,000	50,000
Fall chinook	5 deeps 1 shallow	9 deeps 1 shallow	22 deeps 1 shallow	9 deeps 1 shallow	22 deeps 1 shallow
Spring chinook	1 deep 1 shallow	2 deeps 1 shallow	5 deeps 1 shallow	4 deeps 1 shallow	6 deeps 1 shallow
Fall chinook/ coho	4 deeps 1 shallow	4 deeps 1 shallow 3 barrels	10 deeps 1 shallow 8 barrels		
Coho				7 deeps 1 shallow	16 deeps 1 shallow
Steelhead	27, 1-gal jugs 1 shallow 14, 5-gal jugs	27, 5-gal jugs 1 shallow	77, 5-gal jugs 1 shallow	47, 5-gal jugs 1 shallow	85, 5-gal incb. 1 shallow

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Table 8. Minimum recommended rearing space (**ft³**) by rearing unit size by station capacity.

Species	On-station production (pounds)			On- and off-station production (pounds)			
	10,000	20,000	50,000	20,000		50,000	
				On	Off	On	Off
Fall chinook	2 @ 2,000 1 @ 6,200	4 @ 2,000 1 @ 13,270	6 @ 2,000 2 @ 23,650	2 @ 2,000 1 @ 6,200	1 @ 10,500	6 @ 2,000	1 @ 77,000
Spring chinook	2 @ 2,000 1 @ 3,500	4 @ 2,000 1 @ 6,200	4 @ 2,000 2 @ 15,800	3 @ 2,000 1 @ 4,000	1 @ 3,360	6 @ 2,000 1 @ 8,000	6 @ 15x18x6 ⁽¹⁾ 1 @ 11,000
Fall chinook/ coho	4 @ 1,000 1 @ 3,069	4 @ 2,000 1 @ 6,200	6 @ 2,000 1 @ 17,400 1 @ 14,920				
Coho				4 @ 2,000	1 @ 4,776	7 @ 2,000 1 @ 10,880	1 @ 13,140
Steelhead	2 @ 1,000 1 @ 5,000 3 @ 50 ⁽²⁾	2 @ 2,000 1 @ 10,000 6 @ 50 ⁽²⁾	4 @ 2,000 1 @ 24,500 2 @ 50 ⁽²⁾	4 @ 2,000 8 @ 50 ⁽²⁾	2 @ 15'x ⁽¹⁾ 18'x6' 3 @ 15'x ⁽¹⁾ 15'x10' Enclosure 100'x50'x4'	8 @ 2,000 8 @ 50 ⁽²⁾	3 @ 15'x18'x6' ⁽¹⁾ x6' 1 @ 8920 2 @ 15'x18'x ⁽¹⁾ x8'

(1) Net pens

(2) The small 50 **ft³** units shown for steelhead rearing are primarily used for adult holding and initial rearing except at the 50,000 lb station with on-station production where they are primarily used for rearing.

Table 9. Minimum recommended water flows (gpm) by water type and station capacity.

Species	On-station production (pounds)			On- and off-station production ⁽¹⁾ (pounds)		
	10,000	20,000	50,000	20,000	50,000	
	Ground River	Ground River	Ground River	Ground River	Ground River	Ground River
Fall chinook	343 1740	686 3480	1715 8700	343 1760	1715	787
Spring chinook	216 1095	432 2190	1080 5475	432 1119	1080	2445
Fall chinook/coho	17 1 946	342 1891	855 4727			
Coho				90 770	225	1924
Steelhead	214 934	428 1868	1070 4670	428 1422	1070	2070

(1) Only includes water used for on-station production.

A. THEORETICAL FALL CHINOOK SALMON HATCHERIES

The conceptual plans, operations, and costs of five theoretical hatcheries follow,

1. Fall Chinook Salmon Hatchery No. 1Goals:

Produce 800,000 fall chinook smolts at 80 fish/lb (10,000 lbs) from an early spawning adult stock for annual on-station releases in stream "A" between May 15 and June 10.

Summary of Biological Requirements:

Smolt production (no./size)	800,000 @ 80/lb
Fertilized eggs (no. spawned)	952,000
Females to spawn (no.)	212
Adults held at one time (no.)	268
Recommended minimum water (gpm)	
ground and or spring	343 @ 53F
surface	1,740 @ (see Fig. 1)
Recommended minimum pond space	10,000 ft ³
or equivalent	

Facilities Development:

Table 10 lists the facilities and the associated requirements of Fall Chinook Salmon Hatchery No. 1 and Fig. 2 illustrates the physical plan for the hatchery.

Operational Strategies:

The water and space as related to the percentage of the total biological requirements are shown by time in Figs. 3 and 4, respectively. Comments follow on the operational strategies for each life phase of husbandry.

(1) Adults All adult fall chinook salmon will be captured at the head of the fishway and held until mature in the adult/rearing pond in a water temperature of 53F or colder. (see Fig. 2)

(2) Incubation All newly fertilized eggs will be incubated in one (or more) lo-compartment deep trough(s) until the eggs are well eyed. Dead egg removal (egg picking) will then be conducted, and the live eggs (approximately 875,000) placed on trays with plastic substrates in five deep troughs. In all cases, the first eggs to hatch will be placed in the lower sections of each trough. Incubation water will be 53F.

(3) Rearing For rearing, the fish will be transferred from the incubation units to the two 2,000 ft³ raceways. The raceways will be sectioned and the five deep troughs used as required during the early feeding phases. A total of 480,000 smolts will be programmed for release from the 6,200 ft³ pond. and 160,000 from each of the raceways.

Figure 2. Schematic of Fall Chinook Salmon Hatchery No. 1.

Theoretical Hatcheries

Water-use strategies will be to start all fish on the spring and well water; then use the surface water as required. The water from the raceways will be passed through the 6,200 **ft³** pond; however, no value for added production will be assigned. A warming effect will occur, however, providing a more rapid growth.

(4) Release All fall chinook smolts will be released through the outlet drain. As the approach 90 /lb the screens will be pulled to allow a volitional emigration. Feeding will continue for several weeks, at which time the ponds will be drained, forcing the remaining fish into stream **"A"**.

Costs:

Table 11 shows the estimated capital cost for Fall Chinook Salmon Hatchery No. 1, and Table 12 shows the estimated annual operational costs and manpower requirements.

Table 10. Facility development for Fall Chinook Salmon Hatchery No. 1 (10,000 lbs, on-station release.)

Facilities	No.	Size	Description
Site Development			
Clearing & Grubbing	4	Acres	Clearing & grubbing of hatchery site, entrance road & pipeline R/W.
Entrance Road	1/2	Mile	16' wiae, 8" pit run base over ave. 2' fill ht. Turnouts @ 500' intervals.
On Site Road & Drives	3,600	yd ²	8" base & 2" crushed rock topping.
Water Supply & Drains			
Stream Intake	1	10' x 4	Coarse & fine screen reinforced concrete with rock check
Supply Lines			12" diameter & larger - CMP, under 12" - PVC
Drain Lines			12" diameter & larger - CMP, under 12" - PVC
Production Well	1	150 gpm	8" diameter x 200' deep with 10 HP submersible pump
Domestic Well	1	5 gpm	6" diameter x 120' deep with 1/2 HP submersible pump. Pressure tank with wood frame house - PVC underground piping to buildings & spawning shed.
Spring Intake	1	16' long	Concrete cut-off wall x 5' high with 2' x 4' concrete screened intake box - 200 gpm.
Aeration Head Box	1	4'x4'	Plywood construction/compartments for spring and well water aeration through two 2 packed column aerator units.
Stream Rock Check	1	20 yd ³	Heavy rock rip rap (30'x6'x3')

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Facilities	No.	Size	Description
Fish Production Facilities			
Raceways	2	83'x8'	2,000 ft³ water each - Prefab steel/plastic sh. lining.
Pond	1	80'x36'	Combination rearing & adult holding 6,000 ft³ water, dirt sides & bottom/3:1 bank slopes. Pen fencing utilized for adult holding separation.
Hatching Tanks	5	16'x18"	5 deep tanks for egg incubation & 1 shallow tank for egg picking.
Adult Fish Rack	1	40 lin ft	Wood constr - annual installation
Fishway	1	6' lift	Plywood constr/4'W x 4'H x 48'L/six 8' pools with cyclone fencing on top of fishway for fish containment.
Buildings			
Hatchery	1	18'x24'	Metal building with tank, office, crew locker, mechanical' and rest rooms.
Storage	1	36'x24'	Metal building with gravel floor, three 12' bays for equipment and supply storage and diesel generator housing.
Cold Storage Fish Feed	1	16'x12'	Prefab 10'x12' freon cold storage unit/8,000 lb capacity with a 12'x6' add on for food handling and thawing OMP feed delivery 2 x per year.
Residence	1	46'x24'	3 BR. wood frame prefab unit/attached garage (residence would be marketable if facility closed).
Spawning Shed	1	10'x10'	Open sides & ends with roof for spawning at head end of holding pond.
Equipment			
General List			1 pick-up, nets, pumps' misc. tools & cleaning equip. (\$24,000)

Table 11. Facility development costs for Fall Chinook Salmon Hatchery No. 1.

<u>Facility</u>	<u>Estimated cost</u>
Site development	\$ 85,800.00
Water supply and drains	148,200.00
Fish production facilities	63,400.00
Buildings	135,800.00
Equipment	24,000.00
Total	\$457,200.00

Theoretical Hatcheries

Table 12. Estimated annual operational costs and labor requirements for Fall Chinook Salmon Hatchery No. 1.

<u>Item</u>		<u>Estimated cost</u>
Food		
@ \$0.45/lb		\$ 6,750
conversion 1.5: 1		
Manpower (O & M)		
Superintendent 1	10 man months	18,000
Culturist	3 man months	4,500
standby	9 man months	1,620
	Subtotal	30,870
Misc. (10% all other costs - O & M)		3,087
	Subtotal	33,957
Electrical power		
general use		1,000
water delivery (10 HP, 7 months)		1,610
Total		\$36,572

Figure 3. Water-use strategies for Fall Chinook Salmon Hatchery No. 1.

Figure 4. Space-use requirements for Fall Chinook Salmon Hatchery No. 1.

2. Fall Chinook Salmon Hatchery No. 2

Goals:

Produce **1,600,000** fall chinook smolts at 80 fish/lb (20,000 lbs) from an early spawning adult stock for annual on-station releases in stream "A" between May 15 and June 10.

Summary of Biological Requirements:

Smolt production (no./size)	1,600,000 @ 80/lb
Fertilized eggs (no. spawned)	1,905,000
Females to spawn (no.)	424
Adults held at one time (no.)	536
Recommended minimum water (gpm)	
ground and or spring	686 @ 53F
surface	3,480 @ (see Fig. 1)
Recommended minimum pond space	20,000 ft ³
or equivalent.	

Facilities Development:

Table 13 lists the facilities and the associated requirements of Fall Chinook Salmon Hatchery No. 2, and Fig. 5 illustrates the physical plan for the hatchery.

Operational Strategies:

The water and space as related to the percentage of the total biological requirements are shown by time in Figs. 3 and 4, for Fall Chinook Salmon Hatchery No. 1 and are typical for this station. The husbandry for each life phase is identical to Fall Chinook Salmon Hatchery No. 1, including that we

Figure 5. Schematic of Fall Chinook Salmon Hatchery No. 2.

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have chosen to provide a **fishway** to capture the adults. All adults will be held in the large rearing/holding pond shown in Fig. 5.

Costs:

Table 14 shows the estimated capital cost for Fall Chinook Salmon Hatchery No. 2, and Table 15 shows the estimated annual operational costs and manpower requirements.

Table 13. Facility development for Fall Chinook Salmon Hatchery No. 2 (20,000 lbs, onstation release.)

Facilities	No.	Size	Description
Site Development			
Clearing & Grubbing		4 1/2 Acres	Clearing & grubbing of hatchery site, entrance road & pipeline R/W.
Entrance Road		1/2 Mile	16' wide, 8" pit run base over ave. 2' fill ht. Turnouts @ 500' intervals.
On Site Road & Drives		3,600 yd ²	8" base & 2" crushed rock topping.
Water Supply & Drains			
Stream Intake	1	14' x 4'	Coarse & fine screen reinforced concrete with rock check
Supply Lines			12" diameter & larger - CMP, under 12" - PVC
Drain Lines			12" diameter & larger - CMP, under 12" - PVC
Production Well	1	300 gpm	12" diameter x 200' deep with 20 HP submersible pump (170' lift x 0.75 eff.)
Domestic Well	1	5 gpm	6" diameter x 120' deep with 1/2 HP submersible pump. Pressure tank with wood frame house - PVC underground piping to buildings & spawning shed. (240' lift x 0.6 eff.)
Spring Intake	1	16' long	Concrete cut-off wall x 5' high with 2' x 4' concrete screened intake box.
Aeration Head Box	1	4'x4'	Plywood construction/compartments for spring and well water aeration through four packed column aerator units.
Stream Rock Check	1	20 yd ³	Heavy rock rip rap (30'x6'x3')

Theoretical Hatcheries

Facilities	No.	Size	Description
Fish Production Facilities			
Raceways	4	83'x8'	2,000 ft ³ water each - Prefab steel/plastic sheet lining.
Pond	1	100'x52'	Combination rearing & adult holding 13'000 ft ³ water, dirt sides & bottom/3:1 bank slopes. Pen fencing utilized for adult holding separation.
Hatching Tanks	9	16'x18"	9 deep tanks for egg incubation & 1 shallow tank for egg picking.
Adult Fish Rack	1	40 lin ft	Wood constr - annual installation
Fishway	1	6' lift	Plywood constr/4'W x 4'H x 48'L/six 8' pools with cyclone fencing on top of fishway for fish containment.
Buildings			
Hatchery	1	24'x24'	Metal building with tank, office, crew locker, mechanical, and rest rooms.
Storage	1	36'x24'	Metal building with gravel floor, three 12' bays for equipment and supply storage and diesel generator housing.
Cold Storage Fish Feed	1	6'x12'	Prefab 20'x12' freon cold storage unit/16,000 lb capacity with a 6'x12' add on for food handling and thawing.
Residence	1	46'x24'	3 BH. wood frame prefab unit/attached garage (residence would be marketable if facility closed).
Spawning Shed	1	10'x10'	Open sides & ends with roof for spawning at head end of holding pond.
Equipment			
General List			1 pick-up, nets, pumps' misc. tools & cleaning equip. (\$24,000)

Table 14. Facility development costs for Fall Chinook Salmon Hatchery No. 2.

Facility	Estimated cost
Site development	\$ 94,000.00
Water supply and drains	193,200.00
Fish production facilities	108,700.00
Buildings	154,400.00
Equipment	24,000.00
Total	\$574,300.00

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Table 15. Estimated annual operational costs and labor requirements for Fall Chinook Salmon Hatchery No. 2.

<u>Item</u>	<u>Estimated cost</u>
Food	
@ \$0.45/lb	\$13,500
conversion 1.5: 1	
Manpower (O & M)	
Superintendent 1 10 man months	20,000
Culturist 3 man months	4,500
standby 9 man months	1,800
	<u>39,800</u>
Misc. (10% all other costs - O & M)	<u>4,000</u>
	<u>43,800</u>
Electrical power	
general use	1,300
water delivery (20 HP, 7 months)	<u>3,220</u>
Total	<u>\$48,320</u>

3. Fall Chinook Salmon Hatchery No. 3

Goals:

Produce **4,000,000** fall chinook smolts at 80 fish/lb (50,000 lbs) from an early spawning adult stock for annual onstation releases in stream "A" between May 15 and June 10.

Summary of Biological Requirements:

Smolt production (no./size)	4,000,000 @ 80/lb
Fertilized eggs (no. spawned)	4,760,000
Females to spawn (no.)	1,060
Adults held at one time (no.)	1,340
Recommended minimum (gpm)	
ground and or spring water	1,715 @ 53F
surface water	8,700 @ (see Fig. 1)
Recommended minimum pond space	50,000 ft ³
or equivalent.	

Facilities Development:

Table 16 lists the facilities and the associated requirements of Fall Chinook Salmon Hatchery No. 3 and Fig. 6 illustrates the physical plan for the hatchery.

Operational Strategies:

Water and space utilization and all fish husbandry would be similar to the Fall Chinook Salmon Hatchery No. 2 previously described. The programming of the 12 man months for the fish culturist would be conducted as work level required. During the summer months, no culturist would be employed, but during fall and spring months two culturists would often be required.

Figure 6. Schematic of Fall Chinook Salmon Hatchery No. 3.

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Costs:

Table 17 shows the estimated capital cost for Fall Chinook Salmon Hatchery No. 3 and Table 18 shows the estimated annual operational costs and manpower requirements.

Table 16. Facility development for Fall Chinook Salmon Hatchery No. 3 (50,000 lbs, on-station releases).

Facilities	No.	Size	Description
Site Development			
Clearing & Grubbing	.	Acres	Clearing & grubbing of hatchery site, entrance road & pipeline R/Ws.
Entrance Road	1/2	Mile	16' wide, 8" pit run base over ave. 2' fill ht. Turnouts @500' intervals.
On Site Road & Drives	4,500	yd ²	8" base & 2" crushed rock topping.
Water Supply & Drains			
Stream Intake	1	22'x4'	Coarse & fine screen reinforced concrete with gabion stream check
Supply Lines			12" diameter & larger - CMP , under 12" - PVC
Drain Lines			12" diameter & larger - CMP , under 12" - PVC
Production Well	3	450 gpm	12" diameter x 200' deep with 25 HP submersible pump.
Domestic Well	1	5 gpm	6" diameter x 120' deep with 1/2 HP submersible pump. Pressure tank in storage building - PVC underground piping to buildings and spawning shed.
Spring Intake	1	16' long	Concrete cut-off wall x 5' high with 2' x 4' concrete screened intake box 450 gpm.
Aeration Head Box	1	4'x8'	Plywood construction/compartments for spring & well water aeration through eight packed column aerator units.
Stream Gabion	1	20 yd ³	Gabion rock-filled wire baskets
Checks			(30'x6'x3')

Theoretical Hatcheries

Facilities	No.	Size	Description
Fish Production Facilities			
Raceways	6	83'x8'	2,000 ft ³ water each - Prefab steel/plastic sheet lining.
Pond	1	132'x66'	Combination rearing & adult holding 23,650 ft ³ water, dirt sides & bottom/3:1 bank slopes. Pen fencing utilized for adult holding separation.
Hatching Tanks	22	16'x18"	22 deep tanks for egg incubation & one shallow tank for egg picking.
Pollution Control Pond	1	80'x25'	3,000 ft ³ water/1 hr detention time for pond cleaning wastes by vacuum system. Dirt sides & bottom/3:1 bank slope.
Adult Fish Barrier	1	40 lin ft	Electric fence barrier weir - 110 Volt annual installation
Fishway	1	6' lift	Plywood constr/4'W x 4'H x 48'L/Six 8' pools with cyclone fencing on side of fishway for fish containment.
Buildings			
Hatchery	1	36'x24'	Metal building -with tank, office, crew lockers, mechanical and rest rooms.
Storage	1	60'x24'	Metal bldg with gravel floor, five 12' bays for equipment and supply storage, domestic water pressure tank and diesel generator housing.
Cold Storage Fish Feed	1	28'x24'	Prefab 20'x24' freon cold storage unit/40,000 lb capacity with a 24'x8' add on for food handling and thawing. CMP feed delivery 2 x per year.
Residence	1	46'x24'	3 BR. wood frame prefab unit/attached garage (residence would be marketable if facility closed).
Spawning Shed	1	10'x10'	Open sides & ends with roof for spawning at head end of holding pond.
Equipment			
General List			1 pick-up, nets, pumps, misc. tools & cleaning equip. (\$26,000)

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Table 17. Facility development costs for Fall Chinook Salmon Hatchery No. 3.

<u>Facility</u>	<u>Estimated cost</u>
Site development	\$137,000.00
Water supply and drains	387,400.00
Fish production facilities	235,300.00
Buildings	204,400.00
Equipment	<u>26,000.00</u>
Total	\$990,100.00

Table 18. Estimated annual operational cost and labor requirements for Fall Chinook Salmon Hatchery No. 3.

<u>Item</u>	<u>Estimated cost</u>
Food	\$33,750
Manpower (O & M)	
Superintendent 1 12 man months	24,000
Culturist 12 man months	18,000
standby 9 man months	1,800
Subtotal	77,550
Misc. (10% all other costs - O & M)	<u>7,750</u>
Subtotal	85,300
Electrical power	
general use	2,500
water delivery (25 HP, 6 months)	<u>3,450</u>
Total	\$91,250

4. Fall Chinook Salmon Hatchery No. 4

Goals:

Produce 1,600,000 (20,000 lbs) fall chinook smolts at 80 fish/lb. This production is comprised of 800,000 smolts each from early and late spawning stocks for annual releases between May 13 and June 10. The early stock will be released off-station from a satellite facility located in another watershed.

Summary of Biological Requirements:

Smolt production (no./size)	
early spawning fall chinook	800,000 @ 80/lb
late spawning fall chinook	800,000 @ 80/lb
Fertilized eggs (no. spawned)	
early spawning fall chinook	952,000
late spawning fall chinook	952,000
Females to spawn (no.)	
early spawning fall chinook	212
late spawning fall chinook	191
Adults held at one time (no.)	
early spawning fall chinook	268
late spawning fall chinook	<u>297</u>
Total at one time	565

Theoretical Hatcheries

Recommended minimum water (gpm)	
Onstation:	
ground and/or spring	343 @ 53F
surface	1,760 @ (see Fig. 1)
Offstation:	
surface	2,083 @ (see Fig. 1)
Recommended minimum pond space or equivalent	
Onstation	10,000 ft ³
Offstation	10,000 ft ³

(Note: We recognize that it is unlikely that the two racial groups will overlap the holding period to the extent indicated in Fig. 8 for space requirements)

Facilities Development:

Table 19 lists the facilities and the associated requirements of Fall Chinook Salmon Hatchery No. 4 and Figs. 7a and 7b illustrate the physical plan for the hatchery and satellite, respectively.

Operational Strategies:

Early spawning fall chinook salmon will be programmed for space and water requirements for adult holding and spawning, incubation, and rearing and release as conducted by time with Fall Chinook Salmon Hatcheries Nos. 1, 2, and 3. However, after 30-40 days of rearing, all fish will be transferred 25 miles to a rearing and release pond located immediately below an irrigation diversion dam in another watershed. Upon return to the pond, the adults will be captured at the existing fish ladder and hauled to the onstation adult holding facility where water temperatures are suitable.

The late spawning fall chinook, which spawn 40 days after the early spawning fall chinook are cultured as documented for the 10,000 lb Fall Chinook Salmon Hatchery No. 1.

Provisions will be made within the adult pond to segregate early and late stocks to prevent excessive handling. Fig. 8 illustrates the strategies in fish husbandry within the rearing and adult holding ponds by time.

Costs:

Table 20 shows the estimated capital cost for Fall Chinook Salmon Hatchery No. 4 and Table 21 shows the estimated annual operational costs and manpower requirements.

Figure 7a. Schematic of Fall Chinook Salmon Hatchery No. 4 - On-station facilities.

Figure 7b. Schematic of Fall Chinook Salmon Hatchery No. 4 - Satellite facilities.

Figure 8. Rearing and holding space requirements by time for Fall Chinook Salmon Hatchery No. 4 - on and off-station.

Theoretical Hatcheries

Table 19. Facility development for Fall Chinook Salmon Hatchery No. 4 (20,000 lbs, on- and off-station releases).

Facilities	No.	Size	Description
Site Development - On Station			
Clearing & Grubbing	4	Acres	Clearing & grubbing of hatchery site, entrance road & pipeline R/W.
Entrance Road	1/2	Mile	16' wide, 8" pit run base over ave. 2' fill ht. Turnouts @ 500' intervals.
On Site Road & Drives	3,600	yd ²	8" base & 2" crushed rock topping.
Water Supply & Drains - On Station			
Stream Intake	1	10' x 4'	Coarse & fine screen reinforced concrete with rock check
Supply Lines			12" diameter & larger - CMP, under 12" - PVC
Drain Lines			12" diameter & larger - CMP, under 12" - PVC
Production Well	1	150 gpm	8" diameter x 200' deep with 10 HP submersible pump.
Domestic Well	1	5 gpm	6" diameter x 120' deep with 1/2 HP submersible pump. Pressure tank in storage building - PVC underground piping to buildings & spawning shed.
Spring Intake	1	16' long	Concrete cut-off wall x 5' high with 2'x4'.
Aeration Head Box	1	4'x4'	Concrete screened intake box - 200 gpm.
Stream Rock Check	1	20 yd ³	Plywood construction/compartments for spring & well water aeration through two packed column aerator units.
Fish Production Facilities - On-Station			
Raceways	2	83'x8'	2,000 ft ³ water each - Prefab steel/plastic sheet lining.
Pond	1	80'x36'	Combination rearing and adult holding. 6,200 ft ³ water, dirt sides & bottom/3:1 bank slopes. Pen fencing utilized for adult holding separation.
Hatching Tanks	9	16'x18"	9 deep tanks for egg incubation & one shallow tank for egg picking.
Adult Fish Rack	1	40 lin ft	Wood constr. - annual installation.
Fishway	1	6' lift	Plywood constr/4'W x 4'H x 48'L/six 8' pools with cyclone fencing on sides of fishway for fish containment.

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Facilities	No.	Size	Description
Buildings - On Station			
Hatchery	1	24'x24'	Metal building with tank, office, crew locker, mechanical, and rest rooms.
Storage	1	36'x24'	Metal bldg with gravel floor, three 12' bays for equipment and supply storage, water tank, and diesel generator housing.
Cold Storage Fish Feed	1	26'x12'	Prefab 20'x12' freon cold storage unit/16,000 lb capacity with a 6'x12' add-on for food handling and thawing. OMP feed delivery 2x per year.
Residence	1	46'x24'	3 BR. wood frame prefab unit/attached garage (residence would be marketable if facility closed).
Spawning Shed	1	10'x10'	Open sides & ends with roof for spawning at head end of holding pond.
Equipment - On- and Off-Station			
General List			1 pick-up, nets, pumps, misc. tools & cleaning equip. (\$25,000)
Site Development - Off Station			
Clearing & Grubbing	1.6	Acres	Clearing & grubbing of rearing site, entrance road & pipeline R/Ws.
Entrance Road	1,000	lin ft	12' wide, 8" pit run base over ave. 1' hill ht.
On Site Road & Courtyard	450	yd ²	8" base & 2" crushed rock topping.
Water Supply & Drains - Off Station			
Stream Intake Supply Lines	1	10' x 4'	Coarse & fine screen reinforced concrete 12" diameter & larger - CMP, under 12" - PVC
Drain Lines			12" diameter & larger - CMP, under 12" - PVC
Fish Production Facilities - Off Station			
Pond	1	94'x48'	10,700 ft ² water. Dirt rearing pond sides with 3:1 slope.
Adult Fish Trap, Brail & Hoist	1	8'x8'	Metal construction for separating adults from water for hauling to holding facility.

Theoretical Hatcheries

Facilities	No.	Size	Description
Buildings - Off Station			
Storage	1	12'x24'	Metal building with gravel floor for equipment and supply, security, and refrigerator housing.
Cold Storage	1	36ft ³	Liquid gas or propane refrigerator.

Table 20. Facility development costs for Fall Chinook Salmon Hatchery No. 4.

<u>Facility</u>	<u>Estimated cost</u>
Site development	\$110,000.00
Water supply and drains	185,300.00
Fish production facilities	105,800.00
Buildings	160,500.00
Equipment	25,000.00
Total	\$586,600.00

Table 2 1. Estimated annual operational costs and labor requirements for Fall Chinook Salmon Hatchery No. 4.

<u>Item</u>	<u>Estimated cost</u>
Food	
@ \$0.45/lb	\$13,500
conversion 1.5:1	
Manpower (O & M)	
Manager II 10 man months	20,000
Culturist 6 man months	9,000
standby 9 man months	1,800
Subtotal	44,300
Transportation	2,000
Misc. (10% all other costs - O & M)	4,000
Subtotal	50,300
Electrical power	
general use	1,500
water delivery (10 HP, 2 months)	450
Total	\$52,250

5. Fall Chinook Salmon Hatchery No. 5

Goods:

Produce 4 million fall chinook smolts @80 fish/lb (50,000 lbs) from a late spawning adult fall chinook stock for annual release between May 15 and June 10.

A total of 38,000 lbs will be released from an off-station production facility, and 12,000 lbs will be released at the station.

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Summary of Biological Requirements:

Smolt production (no./size)	4,000,000 @ 80 lb
Fertilized eggs (no. spawned)	4,760,000
Females to spawn (no.)	955
Adults held at one time (no.)	1,485
Recommended minimum water (gpm)	
On station	
ground and/or spring	1,715 @ 53F
surface	787 @ (see Fig. 1)
Off-station	
surface	7,917 @ (see Fig. 1)
Recommended minimum pond space	
or equivalent	
On-station	12,000 ft³
Off-station	38,000 ft³

Facilities Development:

Table 22 lists the facilities and the associated requirements of Fall Chinook Salmon Hatchery No. 5 and Figs. 9a and 9b illustrate the physical plan for the hatchery and satellite, respectively.

Operational Strategies:

All incubation and rearing will be programmed for space and water requirements as conducted with Fall Chinook Salmon Hatcheries No. 1-4; however, adult holding and spawning will occur at the off-station release pond, and the eggs transported to the hatchery.

Costs:

Table 23 shows the estimated capital cost for Fall Chinook Salmon Hatchery No. 5 and Table 24 shows the estimated annual operational costs and manpower requirements.

Table 22. Facility development for Fall Chinook Salmon Hatchery No. 5 (50,000 lbs, on- and of f-station releases).

Facilities	No.	Size	Description
Site Development - On Station			
Clearing & Grubbing	6	Acres	Clearing & grubbing of hatchery site, entrance road & pipeline R/Ws.
Entrance Road	1/2	Mile	16' wide, 8" pit run base over ave. 2' fill ht. Turnouts @ 500' intervals.
On Site Road & Drives	3,000	yd ²	8" base & 2" crushed rock topping.

Theoretical Hatcheries

Facilities	No.	Size	Description
Water Supply & Drains - On-Station			
Stream Intake	1	14' x 4'	Coarse & fine screen reinforced concrete with rock check
Supply Lines			12" diameter & larger - CMP, under 12" - PVC
Drain Lines			12" diameter & larger - CMP, under 12" - PVC
Production Well	3	450 gpm	12" diameter x 200' deep with 25 HP submersible pump.
Domestic Well	1	5 gpm	6" diameter x 120' deep with 1/2 HP submersible pump. Pressure tank in storage building - PVC underground piping to buildings.
Spring Intake	1	16' long	Concrete cut-off wall x 5' high with 2' x 4' concrete screened intake box.
Aeration Head Box	1	4'x8'	Plywood construction/compartments for spring & well water aeration through eight packed column aerator units.
Stream Rock Check	1	20yd ³	Heavy rock rip rap (30'x6'x3')
Fish Production Facilities - On Station			
Raceways	6	83'x8'	2,000 ft ³ water each - Prefab steel/plastic sheet lining.
Hatching Tanks	22	16'x18"	22 deep tanks for egg incubation & 1 shallow tank for egg picking.
Buildings - On-Station			
Hatchery	1	36'x24'	Metal building with tank, office, crew locker, toilet, and storage rooms.
Storage	1	48'x24'	Metal building with gravel floor four 12' bays for equipment and supply storage, domestic water pressure tank, and diesel generator housing.
Cold Storage Fish Feed	1	20'x12'	Prefab 15'x12' freon cold storage unit /12,000 lb capacity with a 5'x12' add-on for food handling and thawing. OMP feed delivery 2 x per year.
Residence	1	46'x24'	3 BR. wood frame prefab unit/attached garage (residence would be marketable if facility closed).

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Facilities	No.	Size	Description
Equipment - On-station and Off-station			
General List			1 pick-up, nets, pumps misc. tools & cleaning equip. (\$28,000)
Site Development - Off Station			
Clearing & Grubbing	5	Acres	Clearing & grubbing of rearing site, access road & pipeline R/ Ws.
Entrance Road	1,000	lin ft	12' wide, 8" pit run base over ave. 1' fill ht.
On Site Road & Courtyard	3,000	yd ²	8" base & 2" crushed rock topping.
Water Supply & Drains - Off Station			
Stream Intake	1	22' x 4'	Coarse & fine screen remforced concrete with gabion stream check.
Supply Lines			12" diameter & larger - CMP, under 12" - PVC
Drain Lines			12" diameter & larger - CMP, under 12" - PVC
Domestic Well	1	5 gpm	6" diameter x 120' deep with 1/2 HP submersible pump. Pressure tank in storage building - PVC underground piping to buildings & spawning shed.
Gabion Stream Check	1	20 yd ³	Gabion rock filled wire baskets (30'x 6'x3')
Fish Production Facilities - Off-Station			
Pond	2	132'x66'	23,650 ft ³ water each. Dirt sides & bottom/3:1 bank slope - One pond dual use for rearing & adult holding with pen, fencing utilized for adult holding separation
Adult Fish Barrier	1	40 lin ft	Electric fence barrier weir - 110 volts/portable electric generator. Annual installation.
Fishway	1	6' lift	Plywood const/4'W x 4' H x 48' L/six 8' pools with cyclone fencing on sides of fishway for fish containment.
Pollution Control Pond	1	80'x25'	3,000 ft ³ water/1 hr. detention time for pond cleaning wastes by vacuum system. Dirt sides & bottom/3:1 bank slope.

Theoretical Hatcheries

Facilities	No.	Size	Description
Buildings - Off Station			
Storage	1	36'x24'	Metal building with gravel floor three 12' bays for equipment and supply, storage and domestic water pressure tank housing.
Cold Storage Fish Feed	1	24'x24'	Prefab 18'x24' freon - cold storage unit/38,000 lb capacity with a 6'x24' add-on for food handling & thawing. OMP feed delivery 2 x per year.
Trailer House/Pad	1	24'x12'	Concrete pad/move on-move off housing unit and drainfield installation
Spawning Shed	1	10'x10'	Open sides & ends with roof for spawning at head end of holding pond.

Table 23. Facility development costs for Fall Chinook Salmon Hatchery No. 5.

Facility	Estimated cost
Site development	\$ 179,900.00
Water supply and drains	448,900.00
Fish production facilities	235,400.00
Buildings	246,400.00
Equipment	28,000.00
Total	\$1,138,600.00

Table 24. Estimated annual operational cost and labor requirements for Fall Chinook Salmon Hatchery No. 5.

Item	Estimated cost
Food	
@ \$0.45/lb	\$33,750
conversion 1.5:1	
Manpower (O & M)	
Manager II 12 man months	24,000
Culturist 14 man months	21,000
standby	1,800
Subtotal	80,550
Misc. (10% all other costs - O & M)	8,055
(including transportation)	
Subtotal	88,605
Electrical power	
general use	5,000
water delivery (25 HP, 6 months)	3,450
Total	\$97,055

Figure 9a. Schematic of Fall Chinook Salmon Hatchery No. 5 - On-Station Facilities.

Figure 9b. Schematic of Fall Chinook Salmon Hatchery No. 5 - Satellite Facilities.

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B. THEORETICAL SPRING CHINOOK SALMON HATCHERIES

The conceptual plans, operations, and costs of five theoretical spring chinook salmon hatcheries follow.

1. Spring Chinook Salmon Hatchery No. 1

Goals:

Produce 120,000 spring chinook smolts at 12 fish/lb (10,000 **lbs**) for annual release in stream "A" in April.

Summary of Biological Requirements:

Smolt production (no./size)	120,000 @ 12/lb
Fertilized eggs (no. spawned)	185,000
Females to spawn (no.)	37
Adults held at one time (no.)	115
Recommended minimum water (gpm)	
ground and/or spring	216 @ 48F
surface	1,095 @ (see Fig. 1)
Recommended minimum pond space	7,000 ft³
or equivalent	

Facilities Development:

Table 25 lists the facilities and the associated requirements of Spring Chinook Salmon Hatchery No. 1 and Fig. 10 illustrates the physical plan for the hatchery.

Operational Strategies:

The water and space requirements as related to the percentage of the total biological requirements by time are shown in Figs. 11 and 12, respectively. Comments follow on each life phase of husbandry.

(1) Adults The adult fish will ascend the **fishway** leading to the adult holding/rearing pond (3,500 **ft³**); where provisions are made to hold all fish until spawning has been completed (September 20). A minimum of 115 gpm of water from the 48F spring will be used, or reused from the juveniles **being** reared in the raceways.

(2) Incubation (See Fall Chinook Hatchery No. 1 regarding incubation units) Because there is a tendency for the spring chinook to grow faster than necessary, we will program the coolest clear water that is available. Generally, this will be the 48F gravity supply in the early fall, then cooler surface water when available during late fall and winter.

(3) Rearing Initial rearing will begin in two sectioned 2,000 **ft³** raceways and deep troughs as required. The older age group of **juveniles** will utilize the third 2,000 **ft³** raceway and the 3,500 **ft³** earthen pond. The need for the latter pond will occur about October 15. In order to prevent sun-burn (see Chapter 1), the raceways will be oriented in a north/south direction to provide shade, water

Figure 10. Schematic of Spring Chinook Salmon Hatchery No. 1.

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sprinklers will be used for refraction of the direct light rays, and dark-colored liners will be used on the raceways.

The fish will be fed by hand, and if their growth progresses too rapidly, feeding levels will be reduced through less frequent feedings.

(4) Release All fish will be allowed to emigrate through the pond drain systems to the river between March 30 and April 15. Those that do not leave will be forced into the river by draining the ponds.

Costs:

Table 26 shows the estimated capital cost for Fall Chinook Salmon Hatchery No. 1 and Table 27 shows the estimated annual operational costs and manpower requirements.

Table 25. Facility development for Spring Chinook Salmon Hatchery No. 1 (10,000 lbs, on-station release).

Facilities	No.	Size	Description
Site Development			
Clearing & Grubbing	4	Acres	Clearing & grubbing of hatchery site, entrance road & pipeline R/W.
Entrance Road	1/2	Mile	16' wide, 8" pit run base over ave. 2' fill ht. Turnouts @500' intervals.
On Site Road & Drives	3,600	yd ²	8" base & 2" crushed rock topping.
Water Supply & Drains			
Stream Intake	1	10' x 4'	Coarse & fine screen reinforced concrete with rock check
Supply Lines			12" diameter & larger - CMP, under 12" - PVC
Drain Lines			12" diameter & larger - CMP, under 12" - PVC
Domestic Well	1	5 gpm	6" diameter x 120' deep with 1/2 HP submersible pump. Pressure tank in storage building - PVC underground piping to buildings.
Spring Intake	1	16' long	Concrete cut-off wall x 5' high with 2' x 4' concrete screened intake box - 216 gpm.
Aeration Head Box	1	4'x4'	Plywood construction for spring water aeration through two packed column aerator units.
Stream Rock Check	1	20 yd ³	Heavy rock rip rap (30'x6'x3')

Theoretical Hatcheries

Facilities	No.	Size	Description
Fish Production Facilities			
Raceways	2	83'x8'	2,000 ft ³ water each - Prefab steel/plastic sheet lining.
Pond	1	52'x36'	Combination rearing & adult holding 3,500 ft ³ water, dirt sides & bottom/3:1 bank slopes Upwelling W.S. on pond bottom for adult holding.
Hatching Tanks	1	16'x18"	1 deep tank for egg incubation & 1 shallow tank for egg picking.
Adult Fish Rack	1	40 lin ft	Wood constr. - annual installation
Fishway	1	6' lift	Plywood constr./4'W x 4'H x 48'L/six 8' pools with canvas fencing on top of fishway for fish containment.
Buildings			
Hatchery	1	18'x24'	Metal building with tank, office, crew locker, mechanical, and rest rooms.
Storage	1	36'x24'	Metal bldg with gravel floor, three 12' bays for equipment and supply storage and domestic water pressure tank housing.
Cold Storage Fish Feed	1	16'x12'	Prefab 10'x12' freon cold storage unit/8,000 lb capacity with a 12'x6' add on for food handling and thawing. OMP feed delivery 3 x per year.
Residence	1	46'x24'	3 BR. wood frame prefab unit/attached garage (residence would be marketable if facility closed).
Equipment			
General List			1 pick-up, nets' pumps' misc. tools & cleaning equip. (\$2 4,000)

Table 26. Facility development costs for Spring Chinook Salmon Hatchery No. 1.

Facility	Estimated cost
Site development	\$ 81,700.00
Water supply and drains	83,000.00
Fish production facilities	54,604.00
Buildings	134,600.00
Equipment	24,004.00
Total	\$377,900.00

Figure 11. Water-use strategies for Spring Chinook Salmon hatchery No. 1.

Table 27. Estimated annual operational costs and labor requirements for Spring Chinook Salmon Hatchery No. 1.

Item		Estimated cost
Food		
@ \$0.40/lb		\$ 8,000
conversion 2.0:1		
Manpower (O & M)		
Superintendent 1	12 man months	21,600
Culturist	3 man months	4,500
standby		2,160
Subtotal		36,260
Misc. (10 % all other costs - O & M)		3,626
Subtotal		39,886
Electrical power		
general use		1,200
water delivery (10 HP, 7 months)		0
Total		\$41,086

Figure 12. Space-use requirements for Spring Chinook Salmon Hatchery No. 1.

2. Spring Chinook Salmon Hatchery No. 2

Goals:

Produce 240,000 spring chinook smolts at 12 fish/lb (20,000 lbs) for annual onstation release in April.

Summary of Biological Requirements:

Smolt production (no./size)	240,000 @ 12/lb
Fertilized eggs (no. spawned)	370,000
Females to spawn (no.)	74
Adults held at one time (no.)	230
Recommended minimum water (gpm)	
ground and/or spring	432 @ 48F
surface	2,190 @ (see Fig. 1)
Recommended minimum pond space or equivalent	14,000 ft ³

Facilities Development:

Table 28 lists the facilities and the associated requirements of Spring Chinook Salmon Hatchery No. 2 and Fig. 13 illustrates the physical plan for the hatchery.

Figure 13. Schematic of Spring Chinook Salmon Hatchery No. 2.

Theoretical Hatcheries

Operational Strategies:

The water and space requirements and operational procedures are as documented previously for Spring Chinook Salmon Hatchery No. 1.

Costs:

Table 29 shows the estimated capital cost for Spring Chinook Salmon Hatchery No. 2 and Table 30 shows the estimated annual operational costs and manpower requirements.

Table 28. Facility development for Spring Chinook Salmon Hatchery No. 2 (20,000 lbs, on-station release).

Facilities	No.	Size	Description
Site Development			
Clearing & Grubbing	4	1/2 Acres	Clearing & grubbing of hatchery site, entrance road & pipeline K/W.
Entrance Road	1/2	Mile	16' wide, 8" pit run base over ave. 2' fill ht. Turnouts @ 500' intervals.
Cn Site Road & Drives	3,600	yd ²	8" base & 2" crushed rock topping.
Water Supply & Drains			
Stream Intake	1	10' x 4'	Coarse & fine screen reinforced concrete with rock check
Supply Lines			12" diameter & larger - CMP, under 12" - PVC
Drain Lines			12" diameter & larger - CMP, under 12" - PVC
Domestic Well	1	5 gpm	6" diameter x 120' deep with 1/2 HP submersible pump. Pressure tank in storage building - PVC underground piping to buildings.
Production Well	1	200 gpm	8" diameter x 200' deep with 10 HP submersible pump.
Spring Intake	1	16' long	Concrete cut-off wall x 5' high with 2' x 4' concrete screened intake box - 250 gpm.
Aeration Head Box	1	4'x4'	Plywood construction/compartments for spring & well water aeration through two packed column aerator units.
Stream Rock Check	1	20 yd ³	Heavy rock rip rap (30'x6'x3')

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Facilities	NO.	Size	Description
Fish Production Facilities			
Raceways	4	83'x8'	2,000 ft³ water each - Prefab steel/plastic sheet lining.
Pond	1	80'x42'	Combination rearing & adult holding 7,400 ft³ water, dirt sides & bottom/3:1 bank slopes. Upwelling W.S. on pond bottom for adult holding.
Hatching Tanks	2	16'x18"	2 deep tanks for egg incubation & 1 shallow tank for egg picking.
Adult Fish Rack	1	40 lin ft	Wood constr. - annual installation
Fishway	1	6' lift	Plywood constr/4'W x 4'H x 48'L/six 8' pools with canvas fencing on top of fishway for fish containment.
Buildings			
Hatchery	1	18'x24'	Metal building with tank, office, crew locker, mechanical, and rest rooms.
Storage	1	36'x24'	Metal bldg with gravel floor, three 12' bays for equipment and supply storage and domestic water pressure tank housing.
Cold Storage Fish Feed	1	26'x12'	Prefab 20'x12' freon cold storage unit/16,000 lb capacity with a 12'x6' add-on for food handling and thawing. OMP feed delivery 3 x per year.
Residence	1	46'x24'	3 BR. wood frame prefab unit/attached garage (residence would be marketable if facility closed).
Equipment			
General List			1 pick-up, nets, pumps' misc. tools & cleaning equip. (\$2 \$000)

Table 29. Facility development costs for Spring Chinook Salmon Hatchery No. 2.

Facility	Estimated cost
Site development	\$ 90,600.00
Water supply and drains	152,700.00
Fish production facilities	90,304.00
Buildings	145,500.00
Equipment	24,000.00
Total	\$504,100.00

Theoretical Hatcheries

Table 30. Estimated annual operational costs and labor requirements for Spring Chinook Salmon Hatchery No. 2.

<u>Item</u>	<u>Estimated cost</u>
Food	
@ \$0.40/lb	\$16,000
conversion 2.0: 1	
Manpower (O & M)	
Superintendent 1	12 man months
Culturist	6 man months
standby	2,400
	<u>51,400</u>
Misc. (10% all other costs - O & M)	5,140
	<u>56,540</u>
Electrical power	
general use	1,700
water delivery (10 HP, 5 months)	1,150
Total	<u>\$59,390</u>

3. ~~Spring~~ Chinook Salmon Hatchery No. 3

Goals:

Produce 600,006 spring chinook smolts at 12 fish/lb (50,000 lbs) for annual on-station release in April.

Summary of Biological Requirements:

Smolt production (no./size)	600,000 @ 12/lb
Fertilized eggs (no. spawned)	925,000
Females to spawn (no.)	185
Adults held at one time (no.)	575
Recommended minimum water (gpm)	
ground and/or spring	1,080 @ 48F
surface	5,475 @ (see Fig. 1)
Recommended minimum pond space or equivalent	35,000 ft ³

Facilities Development:

Table 31 lists the facilities and the associated requirements of Spring Chinook Salmon Hatchery No. 3, and Fig. 14 illustrates the physical plan for the hatchery.

Operational Strategies:

X11 water and space requirements and operational procedures are as documented previously for Spring Chinook Salmon Hatcheries Nos. 1 and 2.

This station does not have a spring water supply, but depends upon a pumped shallow ground water supply (infiltration gallery). The 7.5 HP pump will be used as needed, or about 150 days.

Figure 14. Schematic of Spring Chinook Salmon Hatchery No. 3.

Costs:

Table 32 shows the estimated capital cost for Spring Chinook Salmon Hatchery No. 3 and Table 33 shows the estimated annual operational costs and manpower requirements.

Table 31. Facility development for Spring Chinook Salmon Hatchery No. 3 (50,000 lbs, on-station release).

Facilities	No.	Size	Description
Site Development			
Clearing & Grubbing	6.5	Acres	Clearing & grubbing of hatchery site, entrance road & pipeline R/W.
Entrance Road	1/2	Mile	16' wide, 8" pit run base over ave. 2' fill ht. Turnouts @ 500' intervals.
On Site Road & Drives	4,000	yd ²	8" base & 2" crushed rock topping.
Water Supply & Drains			
Stream Intake	1	18' x 4'	Coarse & fine screening, reinforced concrete with gabion stream check
Supply Lines			12" diameter & larger - CMP, under 12" - PVC
Drain Lines			12" diameter & larger - CMP, under 12" - PVC
Domestic Well	1	5 gpm	6" diameter x 120' deep with 1/2 HP submersible pump. Pressure tank in storage building - PVC underground piping to buildings & spawning shed.
Infiltration Gallery/Pump	150	lin ft	4'W trench gallery excavated to 6' below stream bed. 24" perforated drain tile backfilled with washed river gravel. Pump sump with 7.5 HP submersible pump - 1100 gpm
Aeration Head Box	1	4'x6'	Plywood construction/compartments for water aeration through three packed column aerator units.
Stream Gabion Check	1	20 yd ³	Gabion rock-filled wire baskets (30'x6'x3')

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Facilities	No.	Size	Description
Fish Production Facilities			
Raceways	4	83'x8'	2,000 ft ³ water each - Prefab steel/plastic sheet lining.
Ponds	2	96'x55'	13,200 ft ³ water each - Dirt sides & bottom/3:1 bank slopes. Average pond water depth, 3-1/2'.
Comb. Rearing Holding Pond	1	50'x40'	5,200 ft ³ water - Dirt sides & bottom with 2.5:1 bank slopes. Average pond water depth, 5-1/2'. Upwelling W.S. on pond bottom for adult holding.
Electric Fence	1	40 lin ft	Electric fence barrier weir - 110 volts. Annual installation.
Fishway	1	6' lift	Plywood constr/4'W x 4'H x 48'L/six 8' pools with canvas fencing on sides of fishway for fish containment. Auxilliary water added at top of ladder to provide for min. operational flow.
Hatching Tanks	5	16'x18"	5 deep tanks for egg incubation & 1 shallow tank for egg picking.
Pollution Control Pond	1	80'x25'	3,000 ft ³ water/1 hour detention time for pond cleaning wastes by vacuum system. Dirt sides & bottom/3:1 bank slopes. Average water depth, 3-1/2'.
Buildings			
Hatchery	1	18'x24'	Metal building with tank, office, crew locker, mechanical, and rest rooms.
Storage	1	60'x24'	Metal bldg with gravel floor, five 12' bays for equipment and supply storage, domestic water pressure tank, and diesel generator housing.
Cold Storage Fish Feed	1	24'x24'	Prefab 18'x24' freon cold storage unit/38,000 lb capacity with a 6'x24' add-on for food handling and thawing. OMP feed delivery 3 x per year
Spawning Shed	1	10'x10'	Open sides & ends with roof for spawning at head end of holding pond.
Residence	1	46'x24'	3 BH. wood frame prefab unit/attached garage (residence would be marketable if facility closed).
Equipment			
General List			1 pick-up, nets, pumps, misc. tools & cleaning equip. (\$26,000)

Theoretical Hatcheries

Table 32. Facility development costs for Spring Chinook Salmon Hatchery No. 3.

<u>Facility</u>	<u>Estimated cost</u>
Site development	\$ 111,900.00
Water supply and drains	215,400.00
Fish production facilities	150,800.00
Buildings	175,500.00
Equipment	26,000.00
Total	\$ 679,600.00

Table 33. Estimated annual operational costs and labor requirements for Spring Chinook Salmon Hatchery No. 3.

<u>Item</u>	<u>Estimated cost</u>
Food	
@ \$0.40/lb	\$40,000
conversion 2.0:1	
Manpower (O & M)	
Superintendent 1	12 man months
Culturist	6 man months
standby	
	2,400
	75,400
Misc. (10 % all other costs - O & M)	7,540
	82,940
Electrical power	
general use	2,500
water delivery (7.5 HP, 5 months)	863
Total	\$86,303

4. Spring Chinook Salmon Hatchery No. 4

Goals:

Produce 20,000 spring chinook juveniles of various sizes from a single racial stock for on-station and off-station production and releases as follows:

*Nos.	<u>Release</u>	<u>No./lb</u>	<u>Lbs</u>	<u>Date</u>	<u>Stream release site</u>
86,400	12		7,200	April	A (on-station)
21,600	12		1,800	April	B 1
21,600	12		1,800	April	B 2
160,000	1,600 (eyed eggs)	100		November	B 3
80,000	1,600 (eyed eggs)	50		November	Hatchery Transfer
180,000	60		3,000	June	B 4, 5
72,600	12		6,050	April	C

The goals of these releases are as follows:

Stream A - For brood stock and **all** fisheries

Stream B, 1-5 - To rebuild a very depressed stream and its tributaries for an eventual fishery.

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Stream C - To develop a tribal net fishery on Stream C which has very limited natural production capabilities.

Summary of Biological Requirements:

Smolt	202,200 @ 12/lb
Fingerling	180,000 @ 60/lb
Eyed-egg plants/transfers	240,000 @ 1,600/lb
Fertilized eggs (no. spawned)	
Smolt	311,000
Fingerling	217,000
Eyed-eggs	267,000
	<hr/> 795,000
Females to spawn (no.)	-159
Adults held at one time (no.)	495
Recommended minimum water (gpm)	
On-station	
ground and/or spring	225 @ 48F
surface	1,326 @ (see Fig. 1)
Offstation	
surface	672 @ (see Fig. 1)
Recommended minimum pond space or equivalent	
Onstation	10,000 ft ³
Offstation	3,360 ft ³

Facilities Development:

Table 34 lists the facilities and the associated requirements of Spring Chinook Salmon Hatchery No. 4, Fig. 15 is a vicinity map of the production- facilities and release sites, and Figs. 16a and 16b illustrate the physical plan for the hatchery.

Operational Strategies:

The water and space requirements as related to the total biological requirements are shown for on station production in Figs. 17 and- 18, respectively The programming of the fish within the rearing units is illustrated in Fig. 19.

On-station fish husbandry is similar to the previously described Spring Chinook Salmon Hatcheries Nos. 1, 2, and 3; however, brief comments follow for each life phase because of the off-station production.

(1) Adults The number of females required to be spawned for the smolt **production**, fingerling plants at **60/lb**, and eyed-egg plants and transfers are 62, 43, and 54, respectively; or a total of 159. Because these adults are of a single racial group they will be held together in the large on-station pond (Fig. 16a).

(2) Incubation The incubation program conducted is identical to Spring Chinook Salmon Hatchery No. 1. Eyed-egg plants will be made in the appropriate manner as described in Chapter 4. Also, see Steelhead Trout Hatchery No. 4 in this Chapter. Special care will be given to prevent freezing.

Figure 15. Vicinity map of the production facilities and release sites for Spring Chinook Salmon Hatchery No. 4.

Figure 16a. Schematic of Spring Chinook Salmon Hatchery No. 4 - On-station facilities.

Figure 16b. Schematic of Spring Chinook Salmon Hatchery No. 4 - Satellite facilities.

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(3) Rearing ~~Figs 19~~ The on-station and off-station production plan for each rearing unit by time. The off-station 3,360 ft^3 pond will require 672 gpm and extra predator control measures. The fish will be fed by students as a high school class science project.

(4) Releases On-station smolt releases will follow the program described under Spring Chinook Salmon Hatchery No. 1 and the off-station smolt transportation and release will be conducted as described in Chapter 6 - Transportation.

Costs:

Table 35 shows the estimated capital cost for Spring Chinook Salmon Hatchery No. 4 and Table 36 shows the estimated annual operational costs and manpower requirements.

Table 34. Facility development for Spring Chinook Salmon Hatchery No. 4 (20,000 lbs, on- and off-station release).

Facilities	No.	Size	Description
Site Development - On-Station			
Clearing & Grubbing	4	Acres	Clearing & grubbing of hatchery site, entrance road & pipeline R/W.
Entrance Road	1/2	Mile	16' wide, 8" pit run base over ave. 2' fill ht. Turnouts @ 500' intervals.
On Site Road & Drives	2,100	yd^2	8" base & 2" crushed rock topping.
Water Supply & Drains - On-Station			
Stream Intake	1	10' x 4	Coarse & fine screening, reinforced concrete with rock check
Supply Lines			12" diameter & larger - CMP, under 12" - PVC
Drain Lines			12" diameter & larger - CMP, under 12" - PVC
Domestic Well	1	5 gpm	6" diameter x 120' deep with 1/2 HP submersible pump. Pressure tank in storage building - PVC underground piping to buildings.
Infiltration Gallery with Pump	150	lin ft	4'W trench gallery excavated to 6' below stream bed. 12" perforated drain tile backfilled with washed river gravel, Pump sump with 3 HP submersible pump - 450 gpm and a 150 gpm respectively.
Aeration Head Box	1	4'x4'	Plywood construction/compartments for water aeration through two packed column aerator units.
Stream Rock Check	1	20 yd^3	Heavy rock rip rap (30'x6'x3")

Theoretical Hatcheries

Facilities	No.	Size	Description
Fish Production Facilities - On-Station			
Raceways	3	83'x8'	2,000 ft³ water each - Prefab steel/plastic sheet lining.
Corn b. Rearing Holding Pond	1	52'x40'	4,000 ft³ water - Dirt sides & bottom with 3:1 bank slopes. Average pond water depth, 3-1/2 . Upwelling W.S. on pond bottom for adult holding.
Hatching Tanks	4	16'x18"	4 deep tanks for egg incubation & 1 shallow tank for egg picking.
Adult Fish Rack	1	40 lin ft	Wood constr. - annual installation
Fishway	1	6' lift	Plywood constr/six 8' pools x 4'W x 4'H x 48'L with canvas fencing on sides of fishway for fish containment. Auxilliary water added at top of ladder to provide for min operational flow.
Buildings - On-Station			
Hatchery	1	18'x24'	Metal building with tank, office, crew locker, mechanical, and rest rooms.
Storage	1	36'x24'	Metal building with gravel floor, three 12' bays for equipment and supply storage, domestic water pressure tank, and diesel generator housing.
Cold Storage Fish Feed	1	12'x24'	Prefab 12'x18' freon cold storage unit/ 14,000 lb capacity with a 6'x12' add on for food handling and thawing.
Residence	1	46'x24'	3 BR. wood frame prefab unit/attached garage (residence would be marketable if facility closed).
Equipment - On-Station and Off-station			
General List (\$29,000)			1 pick-up, nets, pumps, misc. tools, cleaning equip. , & small fish-tank
Site Development - Off-Station Stream "C"			
Clearing & Grubbing	1	Acre	Clearing & grubbing of rearing site & access road.
Entrance Road	1,000	lin ft	12' wide, 8" pit run base over ave. 1' fill ht.
On Site Operations Road	240	yd²	8" base & 2" crushed rock topping.

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Facilities	No.	Size	Description
Fish Production Facilities - Off-Station, Stream "C"			
R.R. Cr. Pond	1	84'x20'	3,360 ft ³ water. 2' average pond bottom water depth. In stream development 6,000 lb production.
Upstream Wild Fish Barrier	1	12 lin ft	4'H screen structure to prevent wild fish migration into rearing pond.
Downstream Water Control	1	24 lin ft	4'H screen & stop log structure to contain fish and maintain pond water elevation.

Figure 17. Water-use strategies for Spring Chinook Hatchery No. 4 - On-station.

Figure 18. Space-use requirements for Spring Chinook Hatchery No. 4 - On-station.

Table 35. Facility development costs for Spring Chinook Salmon Hatchery No. 4.

Facility	Estimated cost
Site development	\$ 99,500.00
Water supply and drains	134,600.00
Fish production facilities	92,000.00
Buildings	143,200.00
Equipment	29,000.00
Total	\$498,300.00

Table 36. Estimated annual operational costs and labor requirements for Spring Chinook Salmon Hatchery No. 4.

Item	Estimated cost
Food	
@ \$0.40 for smolts	\$13,480
conversion 2:1 for smolts	
@ \$0.45 for 60/lb fish	2,025
conversion 1.5:1 for 60/lb fish	
Manpower (O & M)	
Superintendent 2	12 man months
Culturist	10 man months
standby	
Subtotal	56,905
Misc. (10% all other costs - O & M)	5,690
Subtotal	62,595
Electrical power	
general use	1,900
water delivery (3 HP, 5 months)	345
Total	\$64,840

336

*date action taken

Figure 19. Facility programming by time for Spring/Chinook Hatchery No. 4 - on and off-station.

5. Spring Chinook Salmon Hatchery No. 5Goals:

Produce 50,000 spring chinook juveniles of various sizes from a single racial stock for on-station and off-station production and releases as follows:

<u>Nos.</u>	<u>No./lb</u>	<u>Lbs</u>	<u>Release date</u>	<u>Stream release site</u>
291,600	12	24,300	April 15	A (on-station)
300,000 (Oct.)	15	20,000	September 30	B
60,000	12	5,000	April 15	C 1
42,000	60	700	June	C 2-3

The goals of these releases are as follows:

Stream A - For brood stock and all fisheries.

Stream B, 1-5 - For all fisheries **and** to rebuild natural production.

Stream C, 1-3 - To rebuild depressed stream.

Summary of Biological Requirements:Production (no./size)

Smolt	331,600 @ 12/lb
Fingerling	300,000 @ 15/lb
Eyed - egg plants/transfers	42,000 @ 60/lb
Fertilized eggs (no. spawned)	
Smolt	541,000
Fingerling	400,000
Eyed-eggs	<u>52,000</u>
	993,000
Females to spawn (no.)	199
Adults held at one time (no.)	619
Recommended minimum water (gpm)	
On-station	
ground and/or spring	225 @ 48F
surface	1,326 @ (see Fig. 1)
Offstation	
surface	6,412 @ (see Fig. 1)
or equivalent	
Recommended minimum pond space	
or equivalent	
On-station	20,000 ft ³
Off-station	
(Site No. 1) Outlet Creek pens	9,720 ft ³
(Site No. 2)	11,000 ft ³

Facilities Development:

Table 37 lists the facilities and the associated requirements of Spring Chinook Salmon Hatchery No. 5, Fig. 20 is a vicinity map of the production- facilities and release sites; and Figs. 21a, 21b, and 21c illustrate the physical plan for the hatchery.

Figure 20. Vicinity map of the production facilities and release sites for Spring Chinook Salmon Hatchery No. 5.

Figure 21a. Schematic of Spring Chinook Salmon Hatchery No. 5 - On-station facilities.

Figure 21b. Schematic of Spring Chinook Salmon Hatchery No. 5 - Off-station rearing pond at stream "C" (Note: Pond at stream "B" not shown.)

Figure 21c. Schematic of Spring Chinook Salmon Hatchery No. 5 - Pen rearing complex.

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Operational Strategies:

Water and space needs as related to the total biological requirements by time are shown in Figs. 22 and '23 respectively. Spring Chinook No. 1-4 are typical of the program for this hatchery. Comments on brief deviations follow.

(1) Adults A total of 199 adult female spring chinook are required for spawning and will be held in the large adult/rearing pond.

(2) Incubation The only deviation in the incubation program (see Spring Chinook Salmon Hatcheries No. 1-4) calls for the 48°F water to be used for the eggs and alevins programmed for the off-station September release (Stream "B"). This will accelerate development, and allow the fish more time to reach 15/lb (30 grams each) by late September.

(3) Rearing Rearing is conducted as with other spring chinook hatcheries with the **exception** of a pen-rearing program for the smolts for stream "C". Station personnel will care for these fish. The off-station pond (fish for stream "B") will be cared for by a part-time culturist.

(4) Releases The release program will be similar to other spring chinook hatcheries. The exception is a "smolt" release in September.

costs:

Table 38 shows the estimated capital cost for Spring Chinook Salmon Hatcher> No. 5 and Table 39 shows the estimated annual operational costs and manpower requirements.

Table 37. Facility development for Spring Chinook Salmon Hatchery No. 5 (50,000 lbs, on- and off-station releases).

Facilities	No.	Size	Description
Site Development - On-Station			
Clearing & Grubbing	5	Acres	Clearing & grubbing of hatchery site, entrance road, water ditch & pipeline R/Ws.
Entrance Road	1/2	Mile	16' wide, 8" pit run base over ave. 2' fill ht. Turnouts @ 500' intervals.
On Site Road & Drives	4,000	yd ²	8" base & 2" crushed rock topping.

Theoretical Hatcheries

Facilities	NO.	Size	Description
Water Supply & Drains - On-Station			
Stream Intake	1	10' x 4'	Coarse screen, reinforced concrete with Gabion screen check
Water supply open ditch	1,000	lin ft	Unlined canal/3' depth x 3' bottom width & 2 1/2:1 side slopes - grade of 0.03 % max.
Rotary Drum Screen	1	3'dia.x4'L	Electric power - fine screen/fish bypass pipe.
Supply Lines	-		12" diameter & larger - CMP, under 12" - PVC
Drain Lines	-		12" diameter & larger - CMP, under 12" - PVC
Spring Intake	1	16' long	Concrete cut-off wall x 5' H with 2' x 4' concrete screened intake box - 630 gpm.
Domestic Well	1	5 gpm	6" diameter x 120' deep/1 1/2 HP submersible pump. Pressure tank in storage building - PVC underground piping to buildings and spawning shed.
Infiltration Gallery with Pump	150	lin ft	4'W trench gallery excavated to 6' below stream bed. 12" perforated drain tile backfilled with washed river gravel . Pump sump with 3 HP submersible pump - 450 gpm.
Stream Gabion Check	1	20 yd ³	Gabion rock-filled wire baskets (30'x6'x3')
Aeration Head BOX	1	4' x 6'	Plywood construction/compartments for spring and infiltration water aeration through three packed column units.
Fish Production Facilities - On-Station			
Raceways	6	70'x20'	2,000 ft³ water each with 3' average water depth. Dirt sides & bottoms with 3:1 bank slopes.
Corn b. Rearing Holding Pond	1	75'x46'	8,000 ft³ water - Dirt sides & bottom with 3:1 bank slopes. Average water depth, 3-1/2'. Upwelling w.S. on pond bottom for adult holding.
Hatching Tanks	6	16'x18"	6 deep tanks for egg incubation & 1 shallow tank for egg picking.
Electric Fence Rack	1	40 lin ft	Electric fence barrier weir - 110 volts. Annual installation.
F ishway	1	6' lift	Plywood constr/4'W x 4'H x 48'L/six 8' pools with canvas fencing on sides of fishway for fish containment.

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Facilities	No.	Size	Description
Fish Production Facilities - On-Station (cont.)			
Pollution Control Pond	1	80'x25'	3,000 ft ³ water/1 hour detention time for pond cleaning wastes by vacuum system. Dirt sides and bottom/3:1 bank slopes. Average pond bottom water depth 3-1/2'.
Buildings - On-Station			
Hatchery	1	18'x24'	Metal building with tank, office, crew locker, mechanical, and rest rooms.
Storage	1	60'x24'	Metal building with gravel floor, five 12' bays for equipment and supply storage, domestic water pressure tank, and diesel generator housing.
Cold Storage Fish Feed	1	26'x12'	Prefab 20'x12' freon cold storage unit/16,000 lb capacity with a 6'x12' add on for food handling and thawing. OMP feed deliveries 3 x per year.
Spawning Shed	1	10'x10'	Open sides and ends with roof for spawning at head end of holding pond.
Residence	1	46'x24'	3 BR. wood frame prefab unit/attached garage. (residence would be marketable if facility closed).
Equipment - On-Station and Off-Station			
General List			1 pick-up, nets, pumps, misc. tools, cleaning equip., & small fish-tank (\$32,000)
Site Development - Off-Station, Stream "B" Tributary			
Clearing & Grubbing	1	Acre	Clearing & grubbing of pond site operations and entrance road.
Entrance Road	1,000	lin ft	12' wide, 8" pit run base over ave. 1' fill ht.
On Site Road & Courtyard	700	yd ²	8" base & 2" crushed rock topping.

Theoretical Hatcheries

Facilities	No.	Size	Description
Fish Production Facilities - Off-Station, Stream "B" Tributary			
No Name Cr. Pond	1	140'x40'	11,000 ft ³ water. Average pond bottom water depth 2'. In-stream development 18,000 lb production.
Upstream Wild Fish Barrier	1	20 lin ft	4'H screen structure to prevent wild fish migration into rearing pond.
Downstream Water Control	1	44 lin ft	4'H screen & stop log structure to contain fish and maintain pond water elevation.
Buildings - Off-Station, Stream "B" Tributary			
Storage	1	24'x24'	Metal building with gravel floor, two 12' bays for equipment and supply storage.
Cold Storage Fish Feed	1	26'x12'	Prefab 20'x12' freon cold storage unit/ 16,000 lb capacity with a 6'x12' add on for food handling and thawing. Comp. unit powered by LPG or propane. OMP feed deliveries 2 x per year.
Site Development - Off-Station, Stream "C" Tributary			
Clearing & Grubbing	1/20	Acre	Clearing & grubbing of courtyard.
Net Pen Lake Bottom Clearing	2/10	Acre	Inspection & clearing of lake bottom for net pen snag prevention.
Entrance Road	-	-	Existing - 1,000' bladed and surfaced with 4" pit run gravel x 16' wide.
Cn Site Courtyard	250	yd ²	4" base & 2" crushed rock topping.
Fish Production Facilities - Off-Station Stream "C" Tributary			
Existing dock			Rehabilitate as required.
Net Pens	6	15'x18'x6'	6' water depth pens - 6,000 lb production.
Buildings - Off-Station, Stream "C" Tributary			
Storage	1	12'x12'	Metal building with gravel floor, one 12' bay for equipment and supply storage.
Cold Storage Fish Feed	1	12'x12'	Prefab 7'x12' freon cold storage unit/5,400 lb capacity with a 5'x12' add-on for food handling and thawing. Comp. unit powered by LPG or propane. OMP feed deliveries 2 x per year.

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Figure 22. Water-use strategies for Spring Chinook Salmon Hatchery No. 5 - On-station.

Table 38. Facility development costs for Spring Chinook Salmon Hatchery ho. 5.

Facility	Estimated cost
Site development	\$132,000.00
Water supply and drains	156,100.00
Fish production facilities	153,400.00
Buildings	201,100.00
Equipment	32,000.00
Total	\$674,600.00

Figure 23. Space-use requirements for Spring Chinook Salmon Hatchery No. 5 - On-station.

Table 39. Estimated annual operational costs and labor requirements for Spring Chinook Salmon Hatchery No. 5.

<u>Item</u>		<u>Estimated cost</u>
Food		
for smolt, \$0.40/lb		\$ 39,440
conversion 2: 1		
for fingerling, \$0.45/lb		472
conversion 1.5:1		
Manpower (O & M)		
Superintendent 2	12 man months	24,000
Culturist	15 man months	22,500
standby		2,400
	Subtotal	88,812
Misc. (10% all other costs - O & M)		8,881
	Subtotal	97,693
Electrical power		
general use		3,000
water delivery (3 HP, 6 months)		414
	Total	\$101,107

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C. THEORETICAL FALL CHINOOK/COHO SALMON HATCHERIES

The conceptual plans, operations, and costs of three theoretical hatcheries that culture both fall chinook and coho salmon follow.

1. Fall Chinook/Coho Salmon Hatchery No. 1

Goals:

Produce 5,000 lbs each of fall chinook and coho salmon smolts at 80 fish/lb and 20/lb respectively, for onstation releases.

Summary of Biological Requirements:

Smolt production (no./size)

chinook	400,000 @ 80/lb
coho	100,000 @ 20/lb

Fertilized Eggs (no. spawned)

chinook	476,000
coho	133,000

Females to spawn (no.)

chinook	106
coho	36

Adults held at one time (no.)

chinook	134
coho	62

(Est. 21 on hand when 134 chinook are being held)

Recommended minimum water (gpm)

ground and/or spring	171 @ 50F
surface	946 @ (see Fig. 1)

Recommended minimum pond space

7,000 ft³

Facilities Development:

Table 40 lists the facilities and the associated requirements of Fall Chinook/Coho Salmon Hatchery No. 1 and Fig. 24 illustrates the physical plan for the hatchery.

Operational Strategies:

For the water and space requirements as related to the percentage of the total biological requirements by time, respectively, refer to Fall Chinook/Coho Salmon Hatchery No. 2 which follows. The two hatcheries only differ in the magnitude of production.

costs:

The facility development costs for Fall Chinook/Coho Salmon Hatchery No. 1 are documented in Table 41 and the estimated annual operational costs and manpower requirements in Table 42.

Figure 24. Schematic of Fall Chinook/Coho Salmon Hatchery No. 1.

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Table 40. Facility development for Fall Chinook/Coho Salmon Hatchery ho. 1 (10,000 lbs, onstation releases).

Facilities	NO.	Size	Description
Site Development			
Clearing & Grubbing	3	Acres	Clearing & grubbing of hatchery site, entrance road W.S. ditch & pipeline R/Ws.
Entrance Road	1/2	mile	16' wide, 8" pit run base over ave. 2' fill ht. Turnouts @ 500' intervals.
On Site Road & Drives	2,000	yd ²	8" base & 2" crushed rock topping.
Water Supply & Drains			
Stream Intake	1	10' x 4'	Coarse & fine screen reinforced concrete with rock check
Stream Rock Check	1	20 yd ³	Heavy rock rip rap (30'x6'x3')
Water Supply Open Ditch	1,000	lin ft	Unlined canal 1/2' bottom width & 2 1/2:1 side slopes x 3' deep. Grade = 0.03 % max.
Supply Lines			12" diameter & larger - CMP, under 12" - PVC
Drain Lines			12" diameter & larger - CMP, under 12" - PVC
Spring Intake	1	16' long	Concrete cut-off wall x 5' high with 2' x 4' concrete screened intake box - 173 gpm.
Domestic Well	1	5 gpm	6" diameter x 120' deep with 1/2 HP submersible pump. Pressure tank in well house - PVC underground piping to buildings & spawning shed.
Aeration Head Box	1	4'x4'	Plywood construction for spring water aeration through two packed column aerators.
Fish Production Facilities			
Kaceways	3	60'x6'	1,000 ft ³ water each. 2.75' average pond water depth - Prefab steel/plastic sheet lining.
Comb. Rearing/Holding Pond	1	50'x10'	1,000 ft ³ water - 2' average pond bottom water depth. In-stream development.
Upstream Wild Fish Barrier	1	12 lin ft	4'H screen structure to prevent wild fish migration into pond.
Pond	1	60'x28'	3,100 ft ³ water - Dirt sides & bottom with 3:1 bank slopes. 3-1/2 average pond bottom water depth.

Theoretical Hatcheries

Facilities	No.	Size	Description
Fish Production Facilities (cont.)			
Hatching Tanks	4	16'x18"	4 deep tanks for egg incubation & 1 shallow tank for egg picking.
Adult Fish Rack	1	40 lin ft	Wood constr., annual installation to divert adults into side creek.
Downstream Rack & Fish Barrier	1	12 lin ft	4'H screen & stop log structure to contain fish, maintain pond water elev. & finger weir for adult entrance.
Buildings			
Hatchery & Storage	1	54'x24'	Metal building combination for equipment & supply storage and hatchery. Three 12' bays for storage/gravel floor. Hatchery with tank, office, crew lockers, mechanical, & rest rooms. Hatchery = 1a' x 24' & Storage = 24'x36'.
Cold Storage Fish Feed	1	16'x12'	Prefab 10'x12' freon cold storage unit/8,000 lb capacity with a 12'x6' add-on for food handling & thawing. OVP feed delivery 3 x per year.
Residence	1	46'x24'	3 B.R. wood frame prefab unit/attached garage (residence would be marketable if facility closed.)
Equipment			
General List			1 pick-up, nets, pumps, misc. tools & cleaning equip. (\$24,000)

Table 41. Facility development costs for Fall Chinook/Coho Salmon Hatchery No. 1.

<u>Facility</u>	<u>Estimated cost</u>
Site development	\$ 72,600.00
Water supply and drains	71,400.00
Fish production facilities	56,200.00
Buildings	132,900.00
Equipment	24,000.00
Total	<u>\$357,100.00</u>

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Table 42. Estimated annual operational costs and labor requirements for Fall Chinook/Coho Salmon Hatchery No. 1.

<u>Item</u>	<u>Estimated cost</u>
Food	
Chinook @ \$0.45/lb	\$ 3,400
conversion 1.5:1	
Coho @ 0.40/lb	3,600
conversion 1.8:1	
Manpower (O & M)	
Superintendent 1 12 man months	2 1,600
Culturist 4 man months	6,000
standby	2,160
	<u>36,760</u>
Misc. (10% all other costs - O & M)	3,676
	<u>40,436</u>
Electrical power	
general use	1,200
water delivery	0
Total	\$41,636

2. Fall Chinook/Coho Salmon Hatchery No. 2

Goals:

Produce 10,000 lbs each of fall chinook and coho salmon smolts at 80 fish/lb and 20 fish/lb respectively, for on-station releases.

Summary of Biological Requirements:

Smolt production (no./size)	
chinook	800,000 @ 80/lb
coho	200,000 @ 20/lb
Fertilized Eggs (no. spawned)	
chinook	952,000
coho	266,000
Females to spawn (no.)	
chinook	212
coho	111
Adults held at one time (no.)	
chinook	268
coho	123
(Est. 42 coho on hand when 268 chinook are being held)	
Recommended minimum water (gpm)	
ground and/or spring	342 @ 50F
surface	1,891 @ (see Fig. 1)
Recommended minimum pond space	14,000 ft ³

Facilities Development:

Table 43 lists the facilities and the associated requirements of Fall Chinook/Coho Salmon Hatchery No. 2 and Fig. 25 illustrates the physical plan for the hatchery.

Operational Strategies:

Water and space requirements as related to the percentage of the total biological requirements by time are shown in Figs. 26 and 27 respectively. Fig. 28 shows the programming of each rearing unit by time. Brief comments follow for each life phase.

(1) Adults All of the returning adults will be held in the large 6,000 ft³ pond. **Because the** early portion of the **coho** return will arrive while the chinook are being held provisions are made for segregation. Water from the juvenile **coho** being reared in the raceways will be re-used for the adults. Cool water (50F) will be required to cool the surface water during the early part of the fall chinook holding and spawning period.

(2) Incubation All eggs will be eyed in deep troughs and all fall chinook eggs will be hatched and alevins incubated in deep troughs using **artificial** substrate. Coho eggs will be hatched in barrel incubators and the alevins incubated using **artificial** substrate. The densities of chinook alevins in the five deeps is 175,000 each, and in the barrel incubators the **coho** density is 80,000 each. If slight overages occur, pond trays will be used to hatch eggs and incubation will occur in the ponds.

All chinook will be incubated in warm water to accelerate development while **coho** will be incubated in the coolest water available. This will accelerate chinook development, provide more rearing time, and retard **coho** development so that fewer pounds will be on hand during the chinook rearing **program and** during the warm summer period.

(3) Rearing Fall chinook will be transferred from the hatchery to the 2,000 ft³ raceways (Nos. 2, 3, and 4, Fig. 28) and reared until May 2. **At** this time the smolt **coho** will have been planted from the 6,000 ft³ pond (No. 5) **and** all fish from pond No. 2 and portions of ponds 3 & 4 will be transferred to Pond No. 5. The chinook will be programmed to provide a release of 2,000 lbs each from ponds 3 and 4, and 6,000 lbs from pond No. 5. Coho will receive their initial rearing in the four deep troughs and pond No. 1. They will be split into ponds Nos. 2 and 3 as the chinook are removed (Fig. 28). Pond No. 4 will remain unused or available until the next cycle of chinook requires its use. After the adults are spawned from pond No. 5 (November 15), juvenile **coho** at 30/lb will be transferred in from ponds Nos. 1, 2, and 3 providing 200,000 smolts until release the following May (Fig. 28). Water used for the younger **coho** and fall chinook will be reused as required for the smolt **coho**. The latter will receive only reused water.

Theoretical Hatcheries

(4) Release All fish will be allowed to emigrate from the ponds two weeks prior to the final release. The final release will require completely draining fish and water from the ponds.

Costs:

The facility development costs for Fall Chinook/Coho Salmon Hatchery No. 2 are documented in Table 44, and the estimated annual operational costs and manpower requirements in Table 45.

Table 43. Facility development for Fall Chinook/Coho Hatchery No. 2 (20,000 lbs, onstation release).

Facilities	No.	Size	Description
Site Development			
Clearing & Grubbing	3	Acres	Clearing & grubbing of hatchery site,
Entrance Road	1/2	Mile	entrance road W.S. ditch & pipeline K, w.s. 16' wide, 8" pit run base over ave. 2' fill ht. turnouts @ 500' intervals.
On Site Road & Drives	2,300	yd ²	8" base & 2" crushed rock topping.
Water Supply & Drains			
Stream Intake	1	10' x 4'	Coarse & fine screen reinforced concrete with rock check
Stream Rock Check	1	20 yd ³	Heavy rock rip rap (30'x6'x3')
W.S. Open Ditch	1,000	lin ft	Unlined canal/2' bottom width & 2-1/2:1 side slopes x 3' deep. Grade of 0.03% max.
Earth Ditch Plug w.C. Riser & Spillway Supply Lines	1	36" dia riser	8'w dike top plug/4' H riser. Kiser equip. with screen and stop logs. Cone slab spillway. 12" diameter & larger - CMP, under 12" - PVC
Drain Lines			12" diameter & larger - CMP, under 12" - PVC
Spring Intake	1	16' long	Concrete cut-off wall x 5' high with 2' x 4' concrete screened intake box - 350 gpm.
Domestic Well	1	5 gpm	6" diameter x 120' deep with 1/2 HP submersible pump. Pressure tank in well house - PVC underground piping to buildings.
Aeration Head Box	1	4'x4'	Plywood construction for spring water aeration through two packed column aeration units.

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Facilities	No.	Size	Description
Fish Production Facilities			
Raceways	4	83'x8'	2,000 ft ³ water each. Prefab steel/plastic sheet lining.
Comb. Rearing/ Holding Pond	1	110'x20'	6,200 ft ³ water - 3' average pond water depth. Un-lined dirt pond/pen fencing utilized for adult holding separation.
Upstream Wild Fish Barrier	1	24 lin ft	6'H screen and stop-log structure to prevent fish movement.
Downstream Rack & Fish Barrier	1	2-t lin ft	6'H screen and stop log structure to contain fish, maintain pond water elev. and finger weir for adult entrance.
Hatching Tanks	4	16'x18"	4 deep tanks for egg incubation & one shallow tank for egg picking.
Barrell Incubators	3	55 gals. ea.	Incubators for coho eggs.
Adult Fish Rack	1	40 lin ft	Wood constr. - annual installation to divert adults into side channel.
Buildings			
Hatchery	1	18'x24'	Metal building with tank, office, crew locker, mechanical and restrooms.
Storage	1	36'x24'	Metal building with gravel floor, three 12' bays for equipment and supply storage.
Cold Storage Fish Feed	1	26'x12'	Prefab 20'x12' freon cold storage unit/16,000# capacity with a 12'x6' add on for food handling & thawing. OMP feed delivery 3 x per year.
Residence	1	46'x24'	3 B.R. wood frame prefab unit/attached garage (residence would be marketable if facility closed.)
Spawning Shed	1	10'x10'	Open sides and ends with roof for spawning at head end of holding pond.
Equipment			
General List			1 pick-up, nets, pumps, misc. tools & cleaning equip. (\$24,000)

Figure 26. Water-use requirements for Fall Chinook/Coho Salmon Hatchery No. 2.

Table 44. Facility development costs for Fall Chinook/Coho Salmon Hatchery No. 2.

Facility	Estimated cost
Site development	\$ 72,400.00
Water supply and drains	69,704.00
Fish production facilities	81,100.00
Buildings	148,800.00
Equipment	24,000.00
Total	\$396,000.00

Figure 27. Space-use requirements for Fall Chinook/Coho Salmon Hatchery No. 2.

Table 45. Estimated annual operational costs and labor requirements for Fall Chinook/Coho Salmon Hatchery No. 2.

<u>Item</u>		<u>Estimated cost</u>
Food		
Chinook @ \$0.45/lb		\$ 6,750
conversion 1.5:1		
Coho @ 0.40/lb		7,200
conversion 1.8: 1		
Manpower (O & M)		
Superintendent	2 12 man months	24,000
Culturist	6 man months	9,000
standby		2,400
	Subtotal	49,350
Misc. (10% all other costs - O & M)		4,935
	Subtotal	54,285
Electrical power		
general use		1,600
water delivery		0
	Total	\$ 55,885

*date action taken

Figure 28. Facility production programming by time for Fall Chinook/Coho Salmon Hatchery No. 2.

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3. Fall Chinook/Coho Salmon Hatchery No. 3

Goals:

Produce 25,000 lbs each of early fall chinook and coho salmon smolts at 80 fish/lb and 20/lb respectively, for on-station releases.

Summary of Biological Requirements:

Smolt production (no./size)

chinook	2,000,000 @ 80/lb
coho	500,000 @ 20/lb
Fertilized Eggs (no. spawned)	
chinook	2,380,000
coho	665,000
Females to spawn (no.)	
chinook	530
coho	280
Adults held at one time (no.)	
chinook	670
coho	310
(Est. 105 coho on hand when chinook are being held)	
Recommended minimum water (gpm)	
ground and/or spring	855 @ 50F
surface	4,727 @ (see Fig. 1)
Recommended minimum pond space	44,300 ft ³

Facilities Development:

Table 46 lists the facilities and the associated requirements of Fall Chinook/Coho Salmon Hatchery No. 3 and Fig. 29 illustrates the physical plan for the hatchery.

Operational Strategies:

The operational strategies for this station only differ from Fall Chinook/Coho Salmon Hatchery No. 2 by the magnitude in size. Thus we refer you to the illustrations and details provided previously.

costs:

The facility development costs for Fall Chinook/Coho Salmon Hatchery No. 3 are documented in Table 47 and the estimated annual operational costs and manpower requirements in Table 48.

Figure 29. Schematic of Fall Chinook/Coho Salmon Hatchery No. 3.

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Table 46. Facility development for Fall Chinook/Coho Hatchery No. 3 (50,000 lbs, onstation release).

Facilities	No.	Size	Description
Site Development			
Clearing & Grubbing	4	Acres	Clearing & grubbing of hatchery entrance road, W.S. ditch & pipeline R/Ws.
Entrance Road	1/2	Mile	16' wide, 8" pit run base over ave. 2' fill ht. Turnouts @ 500' intervals.
On Site Roaa & Drives	4,000	yd ²	8" base & 2" crushed rock topping.
Water Supply & Drains			
Stream Intake	1	14' x 4'	Coarse & fine screen reinforced concrete intake with stop log water control
Gabion Stream Check	1	20 yd ³	Gabion rock-filled wire baskets (30'x6'x3')
Water Supply Open Ditch	1,000	lin ft	Unlined canal/3' bottom width & 2 1/2:1 side slopes x 3' deep. Grade of 0.03% max.
Earth Ditch Plug/ Water Control Riser	1	36' dia riser	8'W dike top plug/4'H riser. Riser equipped with screen and stop logs.
Drain Ditch Plug	1	24" dia culv.	8'W dike top plug/28' long culvert
Open culvert Supply Lines			12" diameter & larger - CMP, under 12" - PVC
Drain Lines			12" diameter & larger - CMP, under 12" - PVC
Spring Intake	1	16' long	Concrete cut-off wall x 5' high with 2' x 4' concrete screened intake box - 425 gpm.
Production Well	1	4 5 0 g p m	12" dia x 200' gpm with 25 HP sub. pump.
Domestic Well	1	5 gpm	6" dia. x 120' deep with 1/2 HP submersible pump. Pressure tank in well house - PVC underground piping to buildings & spawning shed.
Aeration Head Box	1	4'x6'	Plywood construction for spring water aeration through three packed column units.

Theoretical Hatcheries

Facilities	No.	Size	Description
Fish Production Facilities			
Raceways	6	83'x8'	2,000 ft ³ water ea. Prefab steel/plastic sheet lining
Com b. Rearing/ Holding Pond	1	86'x20'	5,160 ft ³ water - 3' ave. pond water depth. Unlined dirt pond - 3:1 bank slopes with pen fencing utilized for adult holding separation.
Outlet Cr. Pond Barrier	1	110'x30'	9,900ft ³ water - 3' ave. pond bottom water depth. Instream development.
Coho Pond	1	120'x56'	17,500 ft ³ water - 3-1/2 ave. pond bottom water depth. Dirt pond/3:1 side slopes.
Hatching Tanks	10	16'x18"	10 deep tanks for egg incubation & 1 shallow tank for egg picking.
Barrel Incubators	8	gals. ea.	Incubators for coho eggs.
Adult Fish Barrier	1	40 lin ft	Electric fence barrier weir - 1 10 V. Annual inst. to divert adults into side creek.
Pollution Control Pond	1	80'x25'	3,000 ft ³ water with one-hour detention time by cleaning wastes by vacuum system. Dirt sides & bottom with 3:1 bank slopes - 3-1/2' average pond bottom water depth.
Buildings			
Hatchery	1	30'x24'	Metal bldg. with tank, office, crew locker, toilet, and mechanical rooms.
Storage	1	60'x24'	Metal bldg with gravel floors, five 12' bays for equipment, supply storage, and diesel generator housing.
Cold Storage Fish Feed	1	28'x24'	Prefab 20'x24' freon cola storage unit/40,000 lb capacity with a 24'x8' aaa on for food handling & thawing. OMP feed delivery 3 x per year.
Spawning Shed	1	10'x10'	Open sides and ends with roof for spawning at head end of holding pond.
Residence	1	46'x24'	3 BR wood frame prefab unit/attached garage (residence would be marketable if facility closed.)
Equipment			
General List			1 pick-up, nets, pumps, misc. tools & cleaning equip. (\$26,000)

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Table 47. Facility development costs for Fall Chinook/Coho Salmon Hatchery No. 3.

<u>Facility</u>	<u>Estimated cost</u>
Site development	<u>\$108,100.00</u>
Water supply and drains	228,100.00
Fish production facilities	197,100.00
Buildings	198,800.00
Equipment	<u>26,000.00</u>
Total	<u>\$758,100.00</u>

Table 48. Estimated annual operational costs and labor requirements for Fall Chinook/Coho Salmon Hatchery No. 3.

<u>Item</u>	<u>Estimated cost</u>
Food	
Chinook @ \$0.45/lb	\$16,875
conversion 1.5:1	
Coho @ 0.40/lb	18,000
conversion 1.8:1	
Manpower (O & M)	
Superintendent 2	12 man months
	24,000
Culturist	15 man months
	22,500
standby	2,400
	<u>83,775</u>
Misc. (10 % all other costs - O & M)	8,377
	<u>\$92,152</u>
Electrical power	
general use	2,800
water delivery	(25 HP, 6 months)
	3,450
Total	<u>\$98,402</u>

D. THEORETICAL COHO HATCHERIES

The conceptual plans, operations, and costs of two theoretical coho salmon hatcheries follow.

1. Coho Salmon Hatchery No. 1

Goals:

Produce 20,000 coho juveniles of various sizes from a single racial stock with on-station and off-station production and releases as follows:

Nos.	<u>No./lb</u>	Lbs	Release date	<u>Stream release site</u>
137,600	20	6,880	May	A (on-station)
162,400	20	8,120	Slay	B
800,000	180	4,444	June	C 1-10
890,000	1,600	556	February	C 11-16

Theoretical Hatcheries

The goals of these releases are:

Stream A - For brood stock and all fisheries.

Stream B - For tribal and other fisheries.

Stream C, 1-16 - To rebuild a very depressed stream system.

Summary of Biological Requirements:

Production (no./size)	
Smolt	300,000 @ 20/lb
Fingerling	800,000 @ 180/lb
Eyed - egg plants/transfers	890,000 @ 1,600/lb
Fertilized eggs (no. spawned)	
Smolt	400,000
Fingerling	955,800
Eyed-eggs	989,000
	2,344,800
Females to spawn (no.)	977
Adults held at one time (no.)	1,081
Recommended minimum water (gpm)	
Onstation	
ground and or spring	90 @ 48F
surface	770 @ (see Fig. 1)
Offstation	
surface	634 @ (see Fig. 1)
Recommended minimum pond space	
or equivalent	
onstation	8,000 ft ³
of fstation	4,776 ft ³

Facilities Development:

Table 49 lists the facilities and the associated requirements of Coho Salmon Hatchery No. 1, Fig. 30 is a vicinity map of all production and release sites, and Fig. 31a and 31b, illustrate the facilities.

Operational Strategies:

For the water and space requirements as related to the total biological requirements by time, we refer you to the Coho Salmon Hatchery No. 2 which follows immediately. The two hatcheries only differ in the magnitude of production. (Note: We have illustrated dirt raceways in order to show they are a viable option.)

Costs

The facility development costs for Cono Salmon Hatchery No. 1 is documented in Table 50, and the annual operational costs and labor requirements in Table 51.

Figure 30. Vicinity map of the production and release sites for Cono Salmon Hatchery No. 1. - on and off-station facilities.

Figure 31a. Schematic of Coho Salmon Hatchery No. 1 - On-station facilities.

Figure 31b. Schematic of Coho Salmon Hatchery No. 1 - Off-station pond.

Table 49. Facility development for Coho Salmon Hatchery No. 1. (20,000 lbs, on- and off-station releases).

Facilities	No.	Size	Description
Site Development - On-Station			
Clearing & Grubbing	3	1/2 Acres	Clearing & grubbing of hatchery site, entrance road, & pipeline R/Ws.
Entrance Road	1/2	Mile	16' wide, 8" pit run base over ave. 2' fill ht. Turnouts @ 500' intervals.
On Site Road & Drives	3,600	yd ²	8" base & 2" crushed rock topping.
Water Supply & Drains - On-Station			
Stream Intake	1	10'x4'	Coarse & fine screen, reinforced concrete with stop log water control.
Stream Rock Check	1	20 yd ³	Heavy rock rip rap (30'x6'x3')
Supply Lines			12" dia. & larger - CMP, under 12" - PVC
Drain Lines			12" dia. & larger - CMP, under 12" - PVC
Drain ditch	200	lin ft	Unlined canal/3' bottom width & 2 1/2:1 side slopes x 3' deep - Grade of 0.03% max.
W.C. Structure/ Finger Weir	1	6' wide	Wood constr/wood stop logs - Finger Weir - metal fingers for adult holding pond.
Spring Intake	1	16' long	Concrete cut-off wall x 5' H with 2' x 4' concrete screened intake box - 90 gpm.
Domestic Well	1	5 gpm	6" dia. x 120' deep/1/2 HP submersible pump. Pressure tank in storage building - PVC underground piping to buildings and spawning shed.
Aeration Head Box	1	2' x 4'	Plywood construction/compartments for water aeration through one packed column aerator unit.
Fish Production Facilities - On-Station			
Race ways	4	70'x20'	2,000 ft ³ water each - 3' average pond water depth. Dirt sides & bottoms with 3:1 bank slopes.
Holding Pond	1	65'x34'	4'324 ft ³ water - 3 1/2' average pond bottom water depth. Dirt sides & bottom with 3:1 bank slopes. Pen fencing utilized for adult holding separation.
Hatching Tanks	7	16'x18"	7 deep tanks for egg incubation & 1 shallow tank for egg picking.
Adult Fish Rack	1	40 lin ft	Wood constr. - annual installation to divert adults into side ditch.

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Facilities	No.	Size	Description
Equipment - On-Station and Off-Station			
General List			1 pick-up, nets, pumps, misc. tools, cleaning equip., & small fish-tank (\$29,000)
Buildings - On-Station			
Hatchery	1	22'x24'	Metal bldg with tank, office, crew locker, toilet, and mechanical rooms.
Storage	1	36'x24'	Metal bldg with gravel floors, three 12' bays for equipment and supply storage, domestic water pressure tank housing.
Spawning Shed	1	10'x10'	Open sides and ends with roof for spawning at head end of holding pond.
Cold Storage Fish Feed	1	12'x24'	Prefab 18'x12' freon cold storage unit/14,000 lb capacity with a 6'x12' add on for food handling and thawing. OMP feed deliveries 3 x per year.
Residence	1	46'x24'	3 BR wood frame prefab unit/attached garage. (residence would be marketable if facility closed).
Site Development - Off-Station "Clear Cr."			
Clearing & Grubbing	0.9	Acres	Clearing & grubbing of pond site operations and entrance road K/W.
Entrance Road	1,000	lin ft	12' wiae, 8" pit run base over ave. 12' fill ht.
On Site Road	400	yd ²	8" base & 2" crushed rock topping.
Fish Production Facilities - Off-Station "Clear Cr."			
Clear Cr. Pond	1	100'x25'	Instream development, 5,000 ft³ water with 2' ave. water depth. 8,000 lb coho production.
Upstream Wild Fish Barrier	1	30 lin ft	4'H screen structure to prevent wild fish migration into rearing pond.
Downstream Water Control	1	30 lin ft	4'H screen & stop-log structure to contain fish and maintain pond water elevation.

Theoretical Hatcheries

Table 50. Facility development capital costs for Coho Salmon Hatchery No. 1.

<u>Facility</u>	<u>Estimated cost</u>
Site development	<u>\$ 98,300.00</u>
Water supply and drains	85,500.00
Fish production facilities	88,000.00
Buildings	149,600.00
Equipment	29,000.00
Total	<u>\$450,400.00</u>

Table 51. Estimated annual operational costs **and** labor requirements for **Coho** Salmon Hatchery No. 1 with on-station and off-station production.

<u>Item</u>	<u>Estimated cost</u>
Food	
for smolts @ \$0.40	\$10,000
conversion 2.0: 1	
for fingerlings @ \$0.45	3,000
conversion 1.5: 1	
Manpower (O & M)	
Superintendent 1 12 man months	21,600
Culturist 6 man months	9,000
standby	<u>2,160</u>
Subtotal	45,760
Misc. (10% all other costs - O & M)	<u>4,576</u>
Subtotal	<u>50,336</u>
Electrical power	
general use	1,500
water delivery	<u>0</u>
Total	<u>\$51,836</u>

2. Coho Salmon Hatchery No. 2

Goals:

Produce 50,000 lbs of **coho** juveniles of various sizes from a single racial stock with on-station and off-station production and releases as follows:

Nos.	<u>No./lb</u>	Release Lbs	<u>Date</u>	<u>Stream release site</u>
344,000	20	17,200	<u>May</u>	A (on-station)
406,000	20	20,300	May	B
2,000,000	180	11,110	June	C 1-10
2,225,000	1,600	1,390	February	C 11-16

The goals of these releases are:

Stream A - For brood stock and all fisheries.

Stream B - For tribal **and** other fisheries.

Stream C, 1-16 - To rebuild a very depressed stream system.

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Summary of Biological Requirements:

Production (no./size)	
Smolt	750,000 @ 20/lb
Fingerling	2,000,000 @ 180/lb
Eyed - egg plants/transfers	2,225,000 @ 1,600/lb
Fertilized eggs (no. spawned)	
Smolt	1,000,000
Fingerlings	2,390,000
Eyed-eggs	2,475,000
	5,865,000
Females to spawn (no.)	2,443
Adults held at one time (no.)	2,703
Recommended minimum water (gpm)	
Onstation	
ground and/or spring	225 @ 48F
surface	1,924 @ (see Fig. 1)
Of f-station	
surface	1,586 @ (see Fig. 1)
Recommended minimum pond space	
or equivalent	
Onstation	24,880 ft ³
Of fstation	13,140 ft ³

Facilities Development:

Table 52 lists the facilities and the associated requirements of Coho Salmon Hatchery No. 2, Fig. 32 is a vicinity map of all production and release sites, and Fig. 33a and 33b illustrate the station's facilities.

Operational Strategies:

Water and space requirements as related to the percentage of the total biological requirements by time are shown in Figs. 34 and 35, respectively. Brief comments follow on each life phase.

(1) Adults All adults will be held in the large rearing/adult pond. Their space requirement is equal to the total ft³ space within the pond, and the water requirements are 1,351 gpm of new water. Water from the juveniles being reared in the raceways (2,149 gpm) will be passed through the adult pond.

(2) Incubation All eggs (5,865,000) will be eyed in six or seven of the 16 deep troughs. A total of 2,225,000 eyed eggs will be transferred to the stream for planting or final incubation in stream-side box incubators as described in Chapter 4. Protection from the extreme cold weather will be required. Either burial in the ground or earth insulation will generally be used. This latter program will be conducted largely with volunteer assistance.

The remaining eyed eggs (3.0 million) will be incubated in the 16 deep troughs with artificial substrate for hatching and alevin incubation. The coolest clear water available will be utilized for incubation. This will slow development

Figure 32. Vicinity map of the production and release sites for Coho Salmon Hatchery No. 2.

Figure 33a. Schematic of Coho Salmon Hatchery No. 2 - Onstation facilities.

Figure 33b. Schematic of Coho Salmon Hatchery No. 2 - Off-station pond.

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rates and result in less poundage of fry and fingerlings during the spring, summer, and **fall** months. For the egg plants, slower development will allow the fry to emerge at a time that is most favorable to their survival.

(3) **Rearing** Sixteen deep troughs are available (if needed) for fry rearing once the incubation of the alevins is completed. All fingerling **coho** for smolt on-station releases will be in the large pond (see Fig. **33a**), thus the seven 2,000 **ft³** raceways will also be **utilized** for starting fry and continued rearing until mid-November when the adults no longer utilized the rearing and holding pond. At this time the maximum densities of fish will exist in all ponds. Programming the feeding levels so the juvenile **coho** are smaller than 30 fish/lb (**15** grams each) at this time will be conducted. When appropriate, the 48F water will be used to cool surface water and help prevent icing problems during the winter. The off-station rearing program will be conducted by a paid hourly employee.

(4) **Releases** Fry from stream-side incubators will be provided direct access to the stream. Fingerling plantings will be conducted by the various means documented in Chapter 6. For on-station smolt releases, the fish will be allowed to exit the rearing units beginning in mid-April, and all fish will be forced to leave during the first week in May.

Costs

The facility development costs for Coho Salmon Hatchery No. 2 is documented in Table 53, and the annual operational costs and labor requirements in Table 54.

Table 52. Facility development for Coho **Salmon Hatchery** No. 2 (50,000 lbs, on- and off-station releases).

Facilities	No.	Size	Description
Site Development - On-Station			
Clearing & Grubbing	5	Acres	Clearing & grubbing of hatchery site, entrance road, & pipeline R/Ws.
Entrance Road	1/2	Mile	16' wide, 8" pit run base over ave. 2' fill ht. Turnouts @ 500' intervals.
On Site Road & Drives	4,000	yd ²	8" base & 2" crushed rock topping.

Facilities	No.	Size	Description
Water Supply & Drains - On-Station			
Stream Intake	1	10' x 4'	Coarse & fine screen, reinforced concrete with stop log water control.
Stream Gabion Check	1	20 yd ³	Gabion rock-filled baskets (30'x6'x3')
Supply Lines			12" diameter & larger - CMP , under 12" - PVC
Drain Lines			12" diameter & larger - CMP , under 12" - PVC
Infiltration Gallery with Pump	1	120 lin ft	4'W trench gallery excavated to 6' below stream bed . 12" perforated drain tile backfilled with washed river gravel. Pump sump with 1 1/2 HP submersible pump = 225 gpm.
Domestic Well	1	5 gpm	6" diameter x 120' deep/1/2 HP submersible pump. Pressure tank in storage building - PVC underground piping to buildings and spawning shed.
Aeration Head Box	1	2' x 4'	Plywood construction/compartments for water aeration through one packed column aerator unit.
Fish Production Facilities - On-Station			
Raceways	7	83'x8'	2,000 ft ³ water each. Prefab steel with plastic sheet lining.
Com b . Rearing Holding Pond	1	96'x48'	10,880 ft ³ water - 3-1/2 average pond water depth. Dirt sides & bottom/3:1 bank slopes. Pen fencing utilized for adult holding separation.
Hatching Tanks	16	16'x18"	16 deep tanks for egg incubation & 1 shallow tank for egg picking.
Adult Fish Barrier	1	40 lin ft	Electric fence barrier weir - 110 volt. Annual installation.
Fishway	1	6' lift	Plywood constr /4'W x 4'H x 48'L/six 8' pools with canvas fencing on sides of fishway for fish containment.
Pollution Control Pond	1	80'x25'	3,000 ft ³ water/1 hr detention time for pond cleaning wastes by vacuum system. Dirt sides and bottom/3:1 bank slopes. 3 1/2' average pond bottom water depth.

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Facilities	No.	Size	Description
Buildings - On-Station			
Hatchery	1	32'x24'	Metal bldg with tank, office, crew locker, toilet, and mechanical rooms.
Storage	1	60'x24'	Metal building with gravel floor, five 12' bays for equipment and supply storage, domestic water pressure tank, and diesel generator housing.
Cold Storage	1	24'x24'	Prefab 18'x24' freon cold storage unit/ 34,500 lb capacity with a 6'x24' add on for food handling and thawing. OMP feed deliveries 3 x per year.
Spawning Shed	1	10'x10'	Open sides and ends with roof for spawning at head end of holding pond.
Residence	1	46'x24'	3 BR wood frame prefab unit/attached garage. (residence would be marketable if facility closed).
Equipment			
General List			1 pick-up, nets, pumps , misc. tools' cleaning equip., & small fish-tank (\$32,000)
Site Development - Of f-Station Stream (Railroad Cr.)			
Clearing & Grubbing	2 1/2 Acres		Clearing & grubbing of pond site operations and entrance road & pipeline R/Ws.
Entrance Road	1,000 lin ft		12' wide, 8" pit run base over ave. 12' fill ht.
On Site Road	2,000 yd ²		8" base & 2" crushed rock topping.
Water Supply & Drains - Off-Station Stream (Railroad Cr.)			
Stream Intake	1	10'x4'	Coarse & fine screen reinf. concrete with stop log water control .
Stream Rock Check	1	10 yd ³	Heavy rock rip rap (15'x6'x3')
Supply Lines Drain Ditch	200	lin ft	12" dia and larger - CMP, under 12" PVC. Unlined canal/3' bottom width and 2 1/2:1 side slopes x 3' deep. Grade of 0.03% max.
Domestic Well	1	5 gpm	6" dia.x120' deep with 1/2 HP submersible pump. Press. tank with wood frame house - PVC underground piping to storage bldg. and trailer pad.

Facilities	No.	Size	Description
Fish Production Facilities - Off-Station Stream (Railroad Creek)			
Pond	1	106'x52'	14,000 ft ³ water. Dirt sides and bottom/3:1 bank slopes. 3 1/2' average pond water depth.
Buildings - Off-Station, Stream (Railroad Creek)			
Storage	1	24'x24'	Metal bldg with gravel floor, two 12' bays for equipment and supply storage.
Trailer Pad	1	16'x20'	Concrete pad with septic tank and drainfield and trailer.

Figure 34. Water-use strategies for Coho Salmon Hatchery No. 2 - on-station.

Figure 35. Space-use requirements for Coho Salmon Hatchery No. 2 - on-station.

Table 53. Facility development capital costs for Coho Salmon Hatchery No. 2.

Facility	Estimated cost
Site development	\$146,400.00
Water supply and drains	22,600.00
Fish production facilities	201,400.00
Buildings	216,600.00
Equipment	32,000.00
Total	\$809,000.00

Table 54. Estimated annual operational costs and labor requirements for Coho Salmon Hatchery No. 2 with on-station and off-station production.

Item	Estimated cost
Food	
for smolts @ \$0.40/lb	\$27,000
conversion 2.0:1	
for fingerlings @ \$.45/lb	7,500
conversion 1.5: 1	
Manpower (O & M)	
Superintendent 2	12 man months
Culturist	15 man months
standby	
Subtotal	\$83,400
Misc. (10% all other costs - O & M)	8,340
Subtotal	\$91,740
Electrical power	
general use	2,750
water delivery (1.5 If P, 5 months)	173
Total	\$94,663

E. THEORETICAL STEELHEAD TROUT HATCHERIES

To illustrate that salmon and steelhead trout rearing programs are feasible using numerous types of facilities, we show some of these here. It is recognized that where fish, as steelhead, are to be handled numerous times, pond-type is more critical. The units illustrated were observed in use during our facility review process.

1. Steelhead Trout Hatchery No. 1

Goals:

Produce 70,000 winter-run steelhead trout smolts at seven fish/lb (10,000 lbs) for annual on-station releases between April 15 and May 10.

Summary of Biological Requirements:

Production (no./size)	70,000 @ 7/lb
Fertilized eggs (no. spawned)	108,000
Females to spawn (no.)	31
Adults held at one time (no.)	34
Recommended minimum water (gpm)	
ground and/or spring	214 @ 50F
surface	934 @ (see Fig. 1)
Recommended minimum pond space	
on-station	7,150 ft ³

Facilities Development:

Table 55 lists the facilities and the associated requirements of Steelhead 1 trout Hatchery No. 1, and Fig. 36 illustrates the physical plan for the hatchery.

Operational Strategies:

Water and space requirements as related to the percentage of the total biological requirements by time are shown in Figs. 37 and 38 respectively. Brief comments follow on each life phase of husbandry.

(1) Adults All adults will be placed in the appropriate size acrylic tubes and held in 50 ft³ Capilano troughs located inside the hatchery building. Up to 15 fish per trough will be held. To accelerate maturation, lights and hormone injection will be used, especially on late spawners. Water shall be from the 50F gravity source and will not be re-used for rearing. Minimum labor for Security is programmed as all fish will be held inside a locked building.

(2) Incubation In consideration of IHN disease, the eggs from each female will be isolated by using 1-gallon jug incubators, a minimum of 27. Assuming no IHN virus is detected prior to hatching, the eggs for alevin incubation will be placed in 11 j-gallon bucket incubators with substrate (see Chapter 4). Fry for rearing will be collected in Capilano troughs as they leave the incubators.

The water supply will be obtained from the 50F gravity source and supplied separately to each incubation unit.

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Figure 37. Water-use strategies for Steelhead Trout Hatchery No. 1.

(3) Rearing The 97,000 fry that survive the incubation of 108,000 fertilized eggs will receive their first 3 to 4 weeks of feeding within the three **Capilano** troughs, sectioned as required. When they reach about twice their original size by weight, or about 1,400 fish/lb, they will be transferred into the two 6'x60'x3.0' ponds, again sectioned as necessary with the older fry positioned downstream.

Grading or sizing of the steelhead trout fingerlings will be required about three times. All fish will eventually be joined into one population in the 5,000 ft³ pond prior to release. We anticipated the final transfer to occur in March.

The gravity spring water at 50F will be used for trough rearing. On May 1, with 94,000 fry @ 1,400/lb on hand, these will have a water demand of 30-40

Figure 38. Space-use requirements for Steelhead Trout Hatchery No. 1.

gpm and the smolts will require 1,111 gpm. Because of the small amount of water used for the adults, incubation, and fry rearing, none of the water is programmed to be used a second time for the large fingerling fish. The option could be made available, however, with minimal cost.

In summary, the **50F** water will be used for adult holding, incubation, early rearing, to cool surface water during the summer, and during the winter to advance the smallest fish and prevent the icing of ponds. The surface water will be used during a shortage of **50F** spring water, or when temperatures are appropriate for its use. It will be used to acclimatize fish during the winter and spring for late April and early May **smolt** releases.

(4)

Releases Screens in the pond where smolts are being reared will be removed **April 15** to allow a natural out-migration. On May 10, all fish will be drained into the river. As an option to the final release, we would evaluate the "**smolt**" population remaining and determine if a high percentage of the fish are non-smolts. **If** so, and depending on their size, the use of these fish for a resident trout fishery would be proposed.

Costs

Table 56 shows the estimated capital costs for Steelhead Trout Hatchery No. 1, and Table 57 shows the estimated annual operational costs and manpower requirements.

Theoretical Hatcheries

Table 55. Facility development for Steelhead Trout Hatchery No. 1 (10,000 lbs, onstation releases).

Facilities	No.	Size	Description
Site Development			
Clearing & Grubbing	3	Acres	Clearing & grubbing of hatchery site, entrance road' & pipeline R/Ws.
Entrance Road	1/2	Mile	16' wide, 8" pit run base over ave. 2' fill ht. Turnouts @ 500' intervals.
On Site Road & Drives	2,500	yd ²	8" base & 2" crushed rock topping.
Water Supply & Drains			
Stream Intake	1	10' x 4'	Coarse & fine screen, reinforced concrete with stop log water control.
Stream Rock Check	1	20 yd ³	Heavy rock rip rap (30'x6'x3')
Supply Lines			12" diameter & larger - CMP, under 12" - PVC
Drain Lines			12" diameter & larger - CMP, under 12" - PVC
Spring Intake	1	16' long	Concrete cut-off wall x 5' H with 2' x 4' concrete screened intake box - 214 gpm.
Domestic Well	1	5 gpm	6" dia. x 120' deep/1/2 HP submersible pump. Pressure tank in storage building - PVC underground piping to buildings.
Aeration Head Box	1	2' x 4'	Plywood construction/compartments for water aeration through one packed column aerator unit.
Fish Production Facilities			
Raceways	2	60'x6'	1,000 ft ³ water each - 2.75' average pond water depth. Prefab steel/plastic sheet lining.
Pond	1	124'x22'	5,000 ft ³ water - 3' average pond water depth. Dirt sides & bottom/2-1/2:1 bank slopes
Hatching Jars	41	Units	27 1-gallon & 14 5-gallon jars,
Egg Picking Tank	1	12'x18'	Shallow tank for egg picking.
Capilano Tanks	3	Units	50 ft ³ water each - housed in building tank room.
Adult Trap	1	100 ft ³	Upstream and downstream broom handle picket rack with V-trap entrance weir.

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Facilities	No.	Size	Description
Buildings			
hatchery	1	30'x24'	Metal bldg with tank, office, crew locker, toilet, and mechanical rooms. 36 ft ³ freezer in tank room for OMP starter feed.
Storage	1	36'x24'	Metal bldg with gravel floors, three 12' bays for equipment and supply storage, domestic water pressure tank housing and 8,000 lbs of dry fish feed storage and 36ft ³ chest freezer.
Residence	1	46'x24'	3 BR wood frame prefab unit/attached garage. (residence would be marketable if facility closed).
Equipment			
General List			1 pick-up, nets, pumps' misc. tools & cleaning equip. (\$24,000)

Table 56. Facility development costs for **Steelhead** Trout Hatchery No. 1.

<u>Facility</u>	<u>Estimated cost</u>
Site development	\$ 72,000.00
Water supply and drains	89,200.00
Fish production facilities	35,500.00
Buildings	140,000.00
Equipment	24,000.00
Total	\$360,700.00

Table 57. Estimated annual operational. costs and labor requirements for Steelhead Trout Hatchery No. 1.

<u>Item</u>	<u>Estimated cost</u>
Food	\$ 8,000
at \$0.40/lb	
conversion 2.0:1	
Manpower (O & M)	
Superintendent 1	12 man months 21,600
Culturist	4 man months 6,000
standby	2,160
Subtotal	37,760
Misc. (10% all other costs - O & M)	3,776
Subtotal	41,536
Electrical power	
general use	1,200
water delivery	0
Total	\$42,736

2. Steelhead Trout Hatchery No. 2

Goals:

Produce 140,000 winter-run steelhead trout smolts at seven fish/lb (20,000 lbs) for annual on-station releases between April 15 and May 10.

Summary of Biological Requirements:

Production (no./size)	140,000 @ 7/lb
Fertilized eggs (no. spawned)	216,000
Females to spawn (no.)	62
Adults held at one time (no.)	68
Recommended minimum water (gpm)	
ground and/or spring	428 @ 50F
surface	1,868 @ (see Fig. 1)
Recommended minimum pond space	14,300 ft ³

Facilities Development:

Table 58 lists the facilities and the associated requirements of Steelhead Trout Hatchery No. 2, Fig. 39 illustrates the physical plan for the hatchery.

Operational Strategies:

Water and space requirements are directly proportional as for the Steelhead Trout Hatchery No. 1. Also, procedures for fish husbandry will be followed according to Steelhead Trout Hatchery No. 1. It should be noted that this station does not have a spring-water supply but relies on a deep well as a source of 50F water. In addition, we have chosen to illustrate the use of four circular swimming pools for rearing. We consider these an option for small low-cost rearing units.

Costs

Table 59 shows the estimated capitol costs for Steelhead Trout Hatchery No. 2, and Table 60 shows the estimated annual operational costs and manpower requirements.

Table 58. Facility development for Steelhead Trout Hatchery No. 2 (20,000 lbs, on-station releases).

Facilities	No.	Size	Description
Site Development			
Clearing & Grubbing	4	Acres	Clearing & grubbing of hatchery site, entrance road, & pipeline R/Ws.
Entrance Road	1/2	Mile	16' wide, 8" pit run base over ave. 2' fill ht. Turnouts @ 500' intervals.
On Site Road & Drives	2,800	yd ²	8" base & 2" crushed rock topping.

(Table 58 continues on page 389) - - - - -

Figure 39. Schematics of Steelhead Trout Hatchery No. 2.

(Continued from page 387)

Facilities	No.	Size	Description
Water Supply & Drains			
Stream Intake	1	10' x 4'	Coarse & fine screen, reinforced concrete with stop log water control .
Stream Sill Check	1	12 lin ft	Concrete sill with 3' cut-off depth x 5' total ht. x 8" thick.
Supply Lines			12" diameter & larger - CMP, under 12" - PVC
Drain Lines			12" diameter & larger - CMP, under 12" - PVC
Drain Ditch	100	lin ft	Unlined canal /3' bottom width and 2-1/2:1 side slopes x 3' deep - Grade 0.0003 /.
Product ion Well	1	430 gpm	2" dia x 200' deep with 25HP sub. pump.
Domestic Well	1	5 gpm	" dia x 120' deep/1/2 HP submersible pump. Pressure tank in storage building - PVC underground piping to buildings.
Aeration Head Box	1	4' x 4'	Plywood construction/compartments or water aeration through two packed column aeration units.
Fish Production Facilities			
Circular Ponds	4	21' Dia.	1,000 ft ³ water each - 3' average pond water depth. Above ground backyard type swimming pools. Prefab steel/plastic sheet lining.
Pond	1	94'x45'	10,000 ft ³ water - 3-1/2' average pond water depth. Dirt sides & bottom/3:1 bank slopes.
Hatching Jars	27	Units	5-gallon jars each.
Capilano Tanks	6	Units	50ft ³ water each. Aluminum construction with lids.
Egg Picking Tank	1	12'x18'	Shallow egg picking tank.
Adult Trap	1	100 ft3	Upstream and downstream broom handle picket racks with V-trap
Buildings			
Hatchery	1	34'x24'	Metal bldg with tank, office, crew locker , toilet, and mechanical rooms.
Storage	1	48'x24'	Metal bldg with gravel floors, four 12' bays for equipment and supply storage, 15,000 lbs of dry fish feed storage, domestic water pressure tank, and diesel generator housing.

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Facilities	No.	Size	Description
Buildings (cont.)			
Residence	1	46'x24'	3 BR wood frame prefab unit/attached garage. (residence would be marketable if facility closed).
Cold Storage Fish Feed	1	18'x12'	Prefab 12'x12' freon cold storage unit/10,000 lb capacity, with a 6'x12' add-on for food handling & thawing. OMP feed delivery 2 x per year.
Equipment			
General List			1 pick-up, nets, pumps, misc. tools & cleaning equip. (\$24,000)

Table 59. Facility development capital costs for Steelhead Trout Hatchery No. 2.

Facility	Estimated cost
Site development	\$ 84,500.00
Water supply and drains	179,300.00
Fish production facilities	30,300.00
Buildings	168,200.00
Equipment	24,000.00
Total	\$486,300.00

Table 60. Estimated annual operational costs and labor requirements for Steelhead Trout Hatchery No. 2.

Item	Estimated cost
Food	
@ \$0.40/lb	\$15,000
conversion 2.0:1	
Manpower (O & M)	
Superintendent 2	12 man months
Culturist	6 man months
standby	2,400
	Subtotal
	\$50,400
Misc. (10% all other costs - O & M)	5,040
	Subtotal
	\$55,440
Electrical power	
general use	1,700
water delivery (25 HP, 12 months)	6,900
Total	\$64,040

3. Steelhead Trout Hatchery No. 3

Goals:

Produce 350,000 winter-run steelhead trout smolts at seven fish/lb (50,000 lbs) for annual on-station releases between April 15 and May 10.

Summary of Biological Requirements:

Production (no./size)	350,000 @ 7/lb
Fertilized eggs (no. spawned)	540,000
Females to spawn (no.)	155
Adults held at one time (no.)	170
Recommended minimum water (gpm)	
ground and/or spring	1,070 @ 50F
surface	4,670 @ (see Fig. 1)
Recommended minimum pond space	32,500 ft ³
4 units @ 2,000 ft ³	8,000 ft ³
1 unit @ 24,400 ft ³	24,400 ft ³
2 units @ 50 ft ³	100 ft ³

Facilities Development:

Table 61 lists the facilities and the associated requirements of Steelhead Trout Hatchery No. 3, Fig. 40 illustrates the physical plan for the hatchery.

Operational Strategies:

Water and space requirements are directly proportional to Steelhead Trout Hatchery No. 1, previously described. Procedures for fish husbandry are also the same with minor deviations. The adult holding program at this hatchery calls for all adult fish to be held in a 2,000 ft³ sectioned raceway, however, when the numbers of fish left to spawn is less than 25, holding in acrylic tubes within Capilano troughs inside the hatchery will be conducted if deemed advantageous.

For the rearing program, two of the 2,000 ft³ raceways will be used to rear fish until they are 7 fish/lb or smolt size. All four will then be used for fry and fingerling rearing.

Costs

Table 62 shows the estimated capital costs for Steelhead Trout Hatchery No. 3, and Table 63 shows the estimated annual operational costs and manpower requirements.

Table 61. Facility development for Steelhead Trout Hatchery No. 3 (50,000 lbs, onstation releases).

Facilities	No.	Size	Description
Site Development			
Clearing & Grubbing	6 1/2	Acres	Clearing & grubbing of hatchery site, entrance road, w.s. ditch & pipeline R/Ws.
Entrance Road	1/2	Mile	16' wide, 8" pit run base over ave. 2' hill ht. Turnouts @ 500' intervals.
On Site Road & Drives	4,100	yd ²	8" base & 2" crushed rock topping.

(Table 61 continues on page 393)

Figure 40. Schematics of Steelhead Trout Hatchery No. 3.

(Continued from page 391)

Facilities	No.	Size	Description
Water Supply & Drains			
Stream In take	1	18' x 4'	Coarse screen reinforced concrete with stop log water control .
Stream Gabion Check	1	20 yd ³	Gabion rock-filled wire baskets (30'x 6'x3')
Water supply & Drain Ditches	2	1,200 lin ft	Unlined canal/3' bottom width & 2-1/2:1 side slopes x 3' deep. Grade of 0.03% max.
Rotary Drum Screen	1	3' dia x 6' L	Electric power - fine screen/fish bypass pipe .
Drain ditch plug/ Open culvert	1	36" dia culv.	8' W dike top plug/28' long culvert.
Supply Lines	-		12" diameter & larger - CMP, under 12" - PVC
Drain Lines	-		12" diameter & larger - CMP, under 12" - PVC
Spring Intake	1	16' long	Concrete cut-off wall x 5' high with 4'x4' concrete screened intake box - 400 gpm.
Infiltration Gallery with Pump	1	160 lin ft	4' W trench gallery excavated to 6' below stream bed - 18" perforated drain tile backfilled with washed river gravel . Pump sump with 5 HP sub. pump.
Domestic Well	1	5 gpm	6" diameter x 120' deep with 1/2 HP submersible pump. Pressure tank in storage building - PVC underground piping to buildings & holding pond.
Aeration Head Box	1	4'x4'	Plywood constr./compartments for spring & infiltration gallery water aeration through four packed column units.
Fish Production Facilities			
Raceways/Adult Holding	4	70'x20'	2,000 ft ³ water each. 3' average pond water depth. Dirt sides and bottom with 3:1 bank slopes. One raceway for dual adult holding/rearing.
Pond	1	140'x65'	24' 500 ft ³ water 3-1/2' average depth. Dirt sides & bottom/3:1 bank slope.
Hatching Jars	77	Units	5-gallon jars each.
Capilano Tank	2	Units	50 ft ³ each. Aluminum constr./lids.
Egg Picking Tank	1	12'x18'	Shallow egg picking tank.
Pollution Control	1	80'x25'	3,000 ft ³ water/one hour detention time for pond cleaning wastes with vacuum system. Dirt sides & bottom/3:1 average pond bottom water depth.
Adult Trap	1	100 ft ³	Upstream and downstream broom handle picket racks with V-trap.

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Facilities	No.	Size	Description
Buildings			
Hatchery	1	32'x24'	Metal bldg with tank, office, crew locker, mechanical, and rest rooms.
Storage	1	60'x24'	Metal bldg with gravel floors, five 12' bays for equipment and supply storage, domestic water pressure tank, and diesel generator housing.
Cold & Dry Fish Feed	1	38'x24'	Prefab 12'x24' freon cold storage unit/25,000 lb capacity. A 6'x24 add-on for food handling and thawing and a 20'x24' ad&on for 38,000 lb capacity dry food storage with dehumidifier. OMP and dry feed deliveries each 2 x per year.
Residence	1	46'x24'	3 BR wood frame prefab unit/attached garage. (residence would be marketable if facility closed.)

Equipment	
General List	1 pick-up, nets, pumps, misc. tools & cleaning equip. (\$26,000)

Table 62. Facility development capital costs for Steelhead Trout Hatchery No. 3.

Facility	Estimated cost
Site development	\$112,300.00
Water supply and drains	134,000.00
Fish production facilities	89,300.00
Buildings	205,400.00
Equipment	26,000.00
Total	\$567,000.00

Table 63. Estimated annual operational costs and labor requirements for Steelhead Trout Hatchery No. 3.

Item	Estimated cost
Food	
@ \$0.40/lb	\$40,000
conversion 2.0: 1	
Manpower (O & M)	
Superintendent 2	12 man months
Culturist	12 man months
standby	2,400
Subtotal	84,400
Misc. (10% all other costs - O & M)	8,440
Subtotal	92,840
Electrical power	
general use	2,800
water delivery (5 HP, 7 months)	805
Total	\$96,445

4. Steelhead Trout Hatchery No. 4Goals:

Produce 20,000 lbs of winter-run steelhead trout juveniles of various sizes from three racial stocks for on-station and off-station releases as follows:

<u>Stock No.</u>	<u>Nos.</u>	<u>No./lb</u>	<u>Lbs</u>	<u>Release date</u>	<u>Stream release site</u>
1	56,000	7	8,000	May 1	A (on-station)
1	42,000	7	6,000	May 1	B (enclosure)
1	14,000	7	2,000	May 1	B pens (2 each)
2	26,600	7	3,800	May 1	C pens (2 each)
3	300,000	1667	180	July	D 2, 3
3	63,000	3,150 (eyed eggs)	20	Mar.	D 4

The goals of these releases are:

Stream A - For brood stock and all local sport fisheries.

Stream B - For tribal harvest, sport fishery, and spawner recruitment.

Stream C - For snort fishery and spawner recruitment.

Stream D - To rebuild depressed runs in all tributaries of stream D for an eventual fisheries.

Summary of Biological RequirementsProduction (no./size)

smolt stock No. 1	112,000 @ 7/lb
smolt stock No. 2	26,600 @ 7/lb
fingerlings No. 3	300,000 @ 167/lb
eyed-eggs No. 3	63,000 @ 3,150
Fertilized eggs (no. spawned)	
smolt stock No. 1	172,000
smolt stock No. 2	41,000
fingerlings No. 3	375,000
eyed-eggs No. 3	69,000
	<u>657,000</u>
Females to spawn (no.)	
stock No. 1	49
stock No. 2	12
stock No. 3	<u>127</u>
	188
Adults held at one time (no.)	218
Recommended minimum water (gpm)	
ground and or spring	428 @ 50F
surface	1,422 @ (see Fig. 1)
(Note: Pens and enclosures used off-station)	
Recommended minimum pond space	8,000 ft ³
Onstation raceway!	
(plus 8 units @ 50ft ³)	

Off-station	
5 pens	9,720 ft ³
1 enclosure	20,000 ft ³

Facilities Development:

Table 64 lists the facilities and **the** associated requirements of Steelhead Trout Hatchery No. 4, Fig. 41 is a vicinity map illustrating the production units and release sites, and Fig. 42 is a schematic of on-station facilities.

Operational Strategies:

Water and space requirements as related to the total biological requirements by time are shown in Figs. 43 and 44, respectively. **On-station** husbandry is illustrated for onstation production units (Fig. 45) and is similar to previously described steelhead hatcheries (see Steelhead **Trout** Hatchery No. 1); however, because of the complexity of the program brief explanations for on- and offstation activities of each life phase follow.

(1) **Adults Stock** No. 1: A total of 49 females are required for spawning purpose-with 57 fish (males & females) held at one time. All fish will be captured at the hatchery and held inside the hatchery in acrylic tubes within Capilano troughs.

Stock No. 2: A total of 12 females are required for spawning purposes with 15 fish (males & females) held at one time. All fish will be captured by volunteer sports fishermen and transported **and** held for maturation as with Steelhead **Trout** Hatchery No. 1.

Stock No. 3: A total of 127 females are required for spawning purposes with 147 fish (males & females) held at one time. Fish will be captured in tributary streams by seining, **electro** shocking, **and** from a trap on an existing dam. Volunteer help will be used. All fish will **be** transported to the hatchery for holding and spawning, and held in **the** lower 1/3 of a 2,000 ft³ rearing pond until only a few remain. At this time they can be transferred to troughs inside the hatchery if outside rearing space is needed.

(2) Incubation Incubation will be conducted as with Steelhead **Trout** Hatchery No. 1 with the exception of **stock** No. 3. On this latter group, 63,000 eyed eggs will be transported to incubation systems in remote areas of stream "D" to complete their incubation in gravel-filled 5-gallon bucket incubators, perforated boxes, drainfield pipe, or hand dug redds as appropriate (See Chapter 4). Volunteer help will be utilized as a continuation of their efforts. Freezing will not be a problem at this time of year.

(3) Rearing Fig. 45 illustates the rearing program **by** the units included for on- and off-station production. Also refer to Steelhead Trout Hatchery No. 1 for onstation procedures.

Figure 4 1. Vicinity map of production and release sites for Steelhead Trout Hatchery No. 4.

Figure 42. Schematic of Steelhead Trout Hatchery No. 4 - on-station.

Theoretical Hatcheries

As noted in Fig. 45, **the** fish for **the** net-pens **and** enclosures will be transferred during mid-February after serious icing problems are reduced. This **75-day** rearing program will require an hourly culturist to assist the on-station personnel. Volunteer help will be used especially for week-end duties at all off-station sites. Predation control will be conducted using techniques described in Chapter 7.

(4) Releases All smolt releases are similar to Steelhead Trout Hatchery No. 1. Fry releases shall be scatter planted to **each** identified site using techniques as described in Chapter 6, II-C (TRANSPORTATION).

Costs

Table 65 **shows** the estimated capital costs for Steelhead Trout Hatchery No. 4, and Table 66 **shows** the estimated annual operational costs and manpower requirements.

Table 64. Facility development for Steelhead Trout Hatchery No. 4 (20,000 lbs, on- and off-station releases).

Facilities	No.	Size	Description
Site Development - On-station			
Clearing & Grubbing	2 3/4	Acres	Clearing & grubbing of hatchery site, entrance road, & pipeline R/Ws.
Entrance Road	1/2	Mile	16' wide, 8" pit run base over ave. 2' fill ht. Turnouts @ 500' intervals.
On Site Road & Drives	1,900	yd ²	8" base & 2" crushed rock topping.
Water Supply & Drains - On-station			
Stream Intake	1	10' x 4'	Coarse & fine screen reinforced concrete with stop log water control.
Stream Rock Check	1	10 yd ³	Heavy rock rip rap (15'x6'x3')
Supply Lines			12" diameter & larger - CMP, under 12" - PVC
Drain Lines			12" diameter & larger - CMP, under 12" - PVC
Production Well	1	430 gpm	12" dia x 200' deep with 25 HP sub. pump.
Domestic Well	1	5gpm	6" diameter x 120' deep with 1/2 HP submersible pump. Pressure tank with wood frame house - PVC underground piping to buildings & holding pond.
Aeration Head Box	1	4'x4'	Plywood constr./compartments for water aeration through two packed column units.

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Facilities	No.	Size	Description
Fish Production Facilities - Onstation			
Raceways	4	83 'x 8'	2,000 ft³ water each. Prefab steel with plastic sheet lining. One raceway R/H.
Adult Trap	1	100 ft ³	Upstream and downstream broom handle picket racks with V-trap.
Hatching Jars	47	units	Five gal jars each.
Capilano Tanks	8	units	50 ft ³ water each. Aluminum constr./lids.
Egg Picking Tank	1	12'x18"	Shallow egg-picking <u>tank</u> .
Buildings - On-Station			
Hatchery	1	42'x24'	Metal bldg with tank, office, crew locker, mechanical and restrooms.
Storage	1	36'x24'	Metal bldg with gravel floor - three 12' bays for equip. & supply storage, 15,000 lbs of dry fish feed storage, and diesel generator housing.
Cold Storage Fish Feed	1	18'x12'	Prefab 12'x12' freon cold storage unit with 10,000 lb capacity. A 6'x12' add-on for food handling & thawing. OMP feed deliveries 2x per year.
Residence	1	46'x24'	3 BR wood frame prefab unit/garage.
Equipment .			
General List			1 pick-up, nets, pumps, misc. tools, cleaning equip., rowboat, 2 each (\$34,000).
Fish Production Facilities - Offstation - Stream "B"			
Net Pens	2	15'x18'x6'	6' water depth pens - 2,000 lbs production.
Res. Clearing			
Net Enclosure	1	100'x50'x4'	4' water depth enclosure - 6,000 10s production
Incl. Res. Clear.			
Fish Production Facilities - Off-station - Stream "C"			
Net Pens	3	15'x15'x10'	10' water depth pens - 4,000 lbs production.
Res. Clearing			
Buildings - Offstation - Stream "C"			
Storage	1	8'x10'	Metal bldg. with gravel floor for equip. & supply storage, a 36 ft³ LPG or propane powered chest freezer and up to 6,000 lbs of dry feed storage housing.

Figure 43. Water-use strategies for Steelhead Trout Hatchery No. 4 - on-station.

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Figure 44. Space-use requirements for Steelhead Trout Hatchery No. 4 - on-station.

Table 65. Facility development costs for Steelhead Trout Hatchery No. 4.

<u>Facility</u>	<u>Estimated cost</u>
Site development	\$ 78,400.00
Water supply and drains	154,900.00
Fish production facilities	90,800.00
Buildings	174,800.00
Equipment	34,000.00
Total	\$532,900.00

Table 66. Estimated annual operational costs **and** labor requirements for Steelhead Trout Hatchery No. 4.

<u>Item</u>	<u>Estimated cost</u>
Food	
@ \$0.40/lb	\$16,000
conversion 2.0: 1	
Manpower (O & M)	
Superintendent 2	12 man months
Culturist	10 man months
standby	
	24,000
	15,000
	2,400
	57,400
Misc. (10% all other costs - O & M)	5,740
	63,140
Electrical power	
general use	1,900
water delivery (25 HP, 12 months)	6,900
Total	\$71,940

*date action taken

Figure 45. Facility production programming by time for Steelhead Trout Hatchery No. 4 - on and off-station.

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5. Steelhead Trout Hatchery No. 5

Goals:

Produce 50,000 **lbs** of winter-run steelhead trout juveniles of various sizes from three racial stocks for onstation and offstation releases as follows:

<u>Stock No.</u>	<u>Nos.</u>	<u>No./lb</u>	<u>Lbs</u>	<u>Release date</u>	<u>Stream release site</u>
1	140,000	7	20,000	May 1	Stream A
1	142,310	7	20,330	May 1	Stream B
2	46,200	7	6,600	May 1	Stream C
3	20,000	7	2,870	May 1	Stream D 1
3	50,000	250	200	June	Streams D 2, 3, 4

The goals of these releases are:

Stream A - For brood stock recruitment.

Stream A/B - For sport fisheries

Stream B - To return for a tribal harvest and natural production.

Stock No. 2, Stream C - For a sport fishery and spawning recruitment.

Stock No. 3, Stream D - For a very limited sport fishery and spawning recruitment.

Stream D, 2, 3, 4 - Improve depressed stocks in tributaries of stream D.

Summary of Biological Requirements:

<u>Production (no./size)</u>	
Stock No. 1	282,310 @ 7/lb
Stock No. 2	46,200 @ 7/lb
Stock No. 3	20,000 @ 7/lb
Fingerling production	
Stock No. 3	50,000 @ 250/lb
Fertilized eggs (no. spawned)	
Stack No. 1	434,000
Stack No. 2	71,000
Stack No. 3 (smolt)	31,000
Stock No. 3 (fingerling)	61,000
	<u>597,000</u>
Females to spawn (no.)	
Stock No. 1	124
Stock No. 2	20
Stock No. 3	27
	<u>171</u>
Adults held at one time (no.)	199
Recommended minimum water (gpm)	
onstation	
ground and or spring	1,070 @ 50F
surface	2,070 @ (see Fig. 1)
of fstation	
surf ace	2, 260 @ (see Fig. 1)

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Recommended minimum pond space

On station

raceways at 2,000 ft³ each
(plus 8 @ 50 ft³ each)

16,000 ft³
400 ft³

Off station

5 pens

9,180 ft³

1 pond (minimum)

8,920 ft³

Facilities Development:

Table 67 lists the facilities and the associated requirements of Steelhead **Trout** Hatchery No. 5, Fig. 46 is a vicinity map, and Figs. 47a and 47b are schematics of on- and off-station facilities.

Operational Strategies:

Water requirements as related to the total biological requirements by time are shown in Fig. 48. General fish husbandry is similar to the previously described steelhead trout hatcheries (See Steelhead **Trout** Hatchery No. 4 for a smaller but comparable operation). A brief summary follows.

(1) Adults Stock No. 1 will be held in the lower half of a 2,000 ft³ raceway and **stock No.'s 2 and 3** inside the hatchery (see Steelhead **Trout** Hatchery No. 1 for holding and Hatchery No. 4 for capture methods).

(2) Incubation See Steelhead Trout Hatchery No. 1 and No. 4 for operations.

(3) Rearing See Fig. 49 for the production programming by pond (See Steelhead Trout Hatchery No. 4 for volunteer help program).

(4) Releases All fish will be released as described earlier with the exception of 28,000 from stock No. 2, and 20,000 smolt and 250,000 fingerlings from **stock** No. 3 which will be trucked from onstation pond No. 8 on May 1 and during June, respectively.

A 1,000 gallon **tank truck** will be rented from a fishery agency.

Costs

Table 68 shows the estimated capital costs for Steelhead **Trout** Hatchery No. 5, and Table 69 shows the estimated annual operational costs and manpower requirements.

Figure 46. Vicinity map of production and release sites for Steelhead Trout Hatchery No. 5.

Figure 47a. Schematic of Steelhead Trout Hatchery No. 5 - On-station facilities.

Figure 47b. Schematic of Steelhead Trout Hatchery No. 5 - Off-station pond.

Table 67. Facility development for Steelhead 'Trout Hatchery No. 5 (50,000 **lbs**, on- and off-station releases).

Facilities	No.	Size	Description
Site Development - Onstation			
Clearing & Grubbing	4	1 1/2 Acres	Clearing & grubbing of hatchery site, entrance road, & pipeline R/ Ws.
Entrance Road	1/2	Mile	16' wide, 8" pit run base over ave. 2' fill ht. Turnouts @ 500' intervals,
On Site Road & Drives	3,600	yd ²	8" base & 2" crushed rock topping.
Water Supply & Drains - On-station			
Stream Intake	1	10' x 4'	Coarse & fine Screen reinforced concrete with stop log water control.
Gabion Stream Check	1	20 yd ³	Gabion rock-filled wire baskets (30'x 6'x3')
Supply Lines			12" diameter & larger - CMP, under 12" - PVC
Drain Lines			12" diameter & larger - CMP, under 12" - PVC
Production Wells	3	360 gpm ea	12" dia x 200' deep with 20 HP sub. pump.
Domestic Well	1	5 gpm	6" diameter x 120' deep with 1/2 HP submersible pump. Pressure tank in storage building - PVC underground piping to buildings & holding pond.
Aeration Head Box	1	4'x6'	Plywood constr./compartments for spring dc infiltration gallery water aeration through three packed column units,
Pollution Control	1	80'x25'	3,000 ft ³ water/l hr. detention time for pond cleaning wastes/vacuum system. Dirt sides & bottom with 3:1 bank slopes 3 1/2' ave. pond bottom water depth.
Fish Production Facilities - Onstation			
Raceways	8	83'x8'	2,000 ft ³ water ea. Prefab steel with plastic sheet lining. One raceway R/H. 5-gallon jars each
Hatching Jars	85	Units	
Capilano Tank	8	Units	50 ft ³ each Aluminum constr./lids.
Egg Picking Tank	1	12'x18"	Shallow egg picking tank.
Adult Trap	1	100 ft ³	Upstream and downstream broom handle picket racks with V-trap.

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Facilities	No.	Size	Description
Buildings - On-Station			
Combination Hatchery & Fish Feed Storage	1	80'x24'	Metal bldg 46,x24, hatchery area. 16'x24' dry feed storage with de-humidifier for 32,000 lbs of feed, 12,x24, cold storage for 25,000 lbs of OMP, and 6'x24' for food handling & thawing. OMP & dry fish feed deliveries 2x per year. Hatchery area for tank, office, crew locker, mechanical, and rest rooms.
Storage	1	60'x24'	Metal bldg with gravel floor. Five 12' bays for equip. and supply storage, domestic water pressure tank and diesel generator housing.
Residence	1	46'x24'	3 BR wood frame prefab unit/attached garage. (residence would be marketable if facility closed.)
Equipment - Onstation and Off-Station			
General List			1 pick-up, nets, pumps, misc. tools, cleaning equip., small fish-tank, & one rowboat (\$34,000)
Site Development - Offstation - Stream "B"			
Clearing & Grubbing	1.5	Acres	Clearing & grubbing of intake, water transportation ditches & pond sites
Entrance Road	1,000	lin ft	Blade existing entr. road & gravel road/1 6'W x 4" thick pit run base.
On Site Road & Drives	2,000	yd ²	4" base & 2" crushed rock topping.
Water Supply & Drains - Off-station - Stream "B"			
Intake-Creek	1	10' x 4'	Coarse & fine screen reinforced concrete intake with stop log water control
Stream Rock Check	1	10 yd ³	Heavy rock rip rap (15'x6'x3')
Water Supply Open Ditch & Drain Ditch	1,000	lin ft	Unlined can al/3 ' bottom width & 2 1/2:1 side slopes x 3' deep. Grade of 0.03% max.
Ditch plug/open culvert	2	24" dia culverts	8'W dike top plug/28' long culverts.

Facilities	No.	Size	Description
Fish Production Facilities - Off-station - Stream "B"			
Pond	1	96'x45'	10,000 ft ³ water. 3-1/2 average pond bottom water depth. Dirt sides & bottom/3:1 side slopes. 18,500 lbs production
Site Development - Off-station - Stream "C" Dam			
Clearing & Grubbing	1/100 Acres		Clearing & grubbing of metal bldg. site & bldg. courtyard.
Entrance Road	1,000 lin ft		Blade existing entr. road & gravel road/16'W x 4" thick pit run base.
On Site Courtyard	32 yd ²		4" base & 2" crushed rock topping.
Fish Production Facilities - Off-station - Stream "C" Dam			
Net Pens	2	15'x18'x8'	8' water depth - 2,600 lbs production.
Res. Clearing			
Fish Production Facilities - Off-station - Mill Creek Pond			
Net Pens	3	15'x18'x6'	6' water depth - 2,900 lbs production.
Res. Clearing			
Buildings - Off-station - Stream "C" Dam			
Storage	1	8'x10'	Metal bldg with gravel floor for equip. & supply storage, 36 cu. ft LPG or propane powered chest freezer housing and up to 6,000 lbs of dry feed storage.
Trailer Pad	1	16'x20'	Conc. pad with septic tank & drainfield. Water supplied from facilities dev. for dam requirements.

Table 68. Facility development costs for **Steelhead** Trout Hatchery No. 5.

Facility	Estimated cost
Site development	\$131,000.00
Water supply and drains	301,300.00
Fish production facilities	166,000.00
Buildings	232,800.00
Equipment	34,000.00
Total	\$865,100.00

Figure 48. Water-use strategies for Steelhead Trout Hatchery No. 5 - onstation.

- FRY OF STOCK NO'S 1, 2 & 3
- FINGERLING OR SMOLT OF STOCK NO'S 1, 2 & 3
- FINGERLING OR SMOLT OF STOCK NO. 1
- FINGERLING OR SMOLT OF STOCK NO. 3
- EMPTY SPACE
- * DATE OF ACTION

Figure 49. Facility production programming by time for Steelhead Trout Hatchery No. 5 - on-station.

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Table 69. Estimated annual operational costs and labor requirements for Steelhead Trout Hatchery No. 5.

<u>Item</u>		<u>Estimated cost</u>
Food		
@ \$0.40/lb		\$40,000
conversion 2.0:1		
Manpower (O & M)		
Superintendent 2	12 man months	24,000
Culturist	15 man months	22,500
standby		2,400
	Subtotal	<u>88,900</u>
Misc. (10% all other costs ~ O & M)		8,890
smolt transportation		500
	Subtotal	98,290
Electrical power		
general use		3,000
water delivery (20 HP 20 months)		9,200
	Total	<u>\$110,490</u>

SUMMARY AND DISCUSSION

The 20 theoretical **low-cost** salmon and steelhead trout hatcheries presented in this Chapter are based on an average developmental situation expected to exist within the Columbia River Basin. The hatcheries are all small, ranging from 10,000 to 50,000 pounds of production; and to a large extent are programmed to enhance natural production. We believe that these facilities, while neither the least nor the most expensive, are adequate for the job intended, and would be accepted by most fish culturists.

An analysis of the costs of these **facilities**, as summarized for the 20 hatcheries (Tables 70 and 71), reveals:

- (1) Based on the cost of producing one pound of juvenile fish, the capital and O & M cost decreases for all hatcheries as the production levels increase.
- (2) The capital and O & M costs are similar for all hatcheries of equal size regardless of the targeted species.
- (3) The capital and O & M costs required for the 10,000 pound facilities are sufficiently high to justify purchasing fish from private operators.
- (4) The O & M cost to produce a pound of fish (Table 71) for the 20,000 and 50,000 pound hatcheries is comparable to the average production cost of state-operated hatcheries, where the average pounds of production per station is greater.
- (5) The estimated capital dollar expenditure required to produce one pound of fish (Table 70) is considerably less than the dollar now being spent for the new Columbia River Basin hatcheries.

Theoretical Hatcheries

In Chapter 8 three concepts for developing a 50,000 lb and a 10,000 lb **coho** hatchery were made (a total of six hatcheries). The concepts for development were based on hatcheries: (1) similar to the new Columbia River **Basin** hatcheries; (2) similar to concepts presented in **this** Chapter; and (3) that embrace the concept of very low cost and higher risk. The analysis shows that for a given production goal, a wide range of capital expenditures exists depending upon the selection of facilities for the hatchery.

Because of these many options that are available to save costs in hatchery development and operations, we strongly recommend that each developer be challenged to minimize capital and O & M cost by analysing "**all**" the options available prior to construction.

Examples of alternatives for cost reductions beyond those we have illustrated so far in this Chapter are:

- (1) For the Site
Develop an intake from existing **instream** structure; develop a site where a road exists (we chose to develop 1/2 mile of road); select a larger spring water supply or obtain water from very shallow aquifers; consider building the facilities at sites far removed from the point of release, then transporting the fish to release ponds.
- (2) For Adults
Use existing facilities as a site of adult collection (as a dam or hatchery); obtain eggs from other hatcheries.
- (3) For Incubation
Utilize existing facilities (excess incubation water is often available).
- (4) For Rearing
Utilize more net pens, net-enclosures, and in-stream ponds (costly intakes and water supply systems will be saved). Use quality dry food when feasible (dry food costs less to use and saves freezer cost).
- (5) For Buildings
Use surplus travel trailers or truck vans (acceptable for short **programs** and suitable-for work areas, storage, or as an incubation room); utilize rental units (especially freezer space for a Fall Chinook program); eliminate concrete floors and flumes in hatchery buildings where short-lived programs are in order; eliminate the incubation room of the hatchery building for short-term programs (where a spring water supply prevents freezing, outside incubation is possible).
- (6) Labor considerations
At the 10,000 pound stations, other daily work activities should be assigned to personnel (as a creel census, law enforcement, special studies); develop a low-capital and low-maintenance landscape surrounding the hatchery.

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In addition to **all** the alternatives mentioned for saving costs, we believe that the most important single factor needed is to have a firm directive from **the** controlling authorities requiring that **"all"** developmental cost-saving options be explored to reduce the capital and **O & M** costs while maintaining quality fish. Unless this is done, significant cost-saving options may not be properly explored, especially where public or mitigative funding is provided.

Table 70. **Summary** of the estimated **facility** development cost for 20 theoretical salmon and **steelhead** trout hatcheries for-the Columbia River Basin.

Facility	Prod.	Water		Fish	Equip.		Dev.
	lbs in 1,000's	Site Dev.	Supply & D r a i n s	Production Facilities	Bldgs.	& Supplies	
	lbs	\$		\$	\$	\$	Per lb prod. \$/lb
In 1,000's							
Fall Chinook No. 1	10	85.8	148.2	63.4	135.8	24.0	45.7 2
Fall Chinook No. 2	20	994.0	193.2	108.7	154.4	24.0	28.72
Fall Chinook No. 3	50	137.0	387.4	235.3	204.4	26.0	19.80
Fall Chinook/Satellite No. 4	20	110.0	185.3	105.8	160.5	25.0	29.33
Fall Chinook/Satellite No. 5	50	179.9	448.9	235.4	246.4	28.0	22.77
Spring Chinook No. 1	10	81.7	83.0	54.6	134.6	24.0	37.79
Spring Chinook No. 2	20	90.6	152.7	90.3	145.4	24.0	25.15
Spring Chinook No. 3	50	111.9	215.4	150.8	175.5	26.0	13.59
Spring Chinook/Satellite No. 4	20	99.5	134.6	92.0	143.2	29.0	24.92
Spring Chinook/Satellite No. 5	50	132.0	156.1	153.4	201.1	32.0	13.49
Fall Chinook/Coho No. 1	10	72.6	71.4	56.2	132.9	24.0	35.71
Fall Chinook/Coho No. 2	20	72.4	69.7	81.1	148.8	24.0	19.80
Fall Chinook/Coho No. 3	50	108.1	228.1	197.1	198.8	26.0	15.16
Coho No. 1	20	98.3	85.5	88.0	149.6	29.0	22.52
Coho No. 2	50	146.4	212.6	201.4	216.6	32.0	16.18
Steelhead No. 1	10	72.0	89.2	35.5	140.0	24.0	36.07
Steelhead No. 2	20	84.5	179.3	30.3	168.2	24.0	24.32
Steelhead No. 3	50	112.3	134.0	89.3	205.4	26.0	11.34
Steelhead/Satellite No. 4	20	78.4	154.9	90.8	174.8	34.0	26.65
Steelhead/Satellite No. 5	50	131.0	301.3	166.0	232.8	34.0	17.30

Theoretical Hatcheries

Table 71. Summary of the estimated annual operational and maintenance cost for 20 theoretical salmon and steelhead trout hatcheries for the Columbia River **Basin**.

<u>Facility</u>	<u>Prod. lbs in 1,000's lbs</u>	<u>Annual O & M (\$) \$</u>	<u>Production cost per lb of prod. \$/lb</u>
Fall Chinook No. 1	10	\$ 36,572	3.66
Fall Chinook No. 2	20	48,320	2.42
Fall Chinook No. 3	50	91,250	1.83
Fall Chinook/Satellite No. 4	20	52,250	2.61
Fall Chinook/Satellite No. 5	50	97,055	1.94
Spring Chinook No. 1	10	41,086	4.11
Spring Chinook No. 2	20	59,390	2.97
Spring Chinook No. 3	50	86,303	1.73
Spring Chinook Satellite No. 4	20	64,840	3.24
Spring Chinook Satellite No. 5	50	101,107	2.02
Fall Chinook/Coho No. 1	10	41,636	4.16
Fall Chinook/Coho No. 2	20	55,885	2.79
Fall Chinook/Coho No. 3	50	98,402	1.97
Coho No. 1	20	51,836	2.60
Coho No. 2	50	94,663	1.89
Steelhead No. 1	10	41,536	4.15
Steelhead No. 2	20	64,040	3.20
Steelhead No. 3	50	96,445	1.93
Steelhead/Satellite No. 4	20	71,940	3.60
Steelhead/Satellite No. 5	50	110,490	2.21

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PERMITS: FISH FACILITY DEVELOPMENT AND OPERATION

All projects that require land development and construction work adjacent to surface waters are regulated by various permits from State and Federal agencies. On Indian tribal lands, the tribal regulations apply. In this chapter we identify and describe the required permits, and name the agencies issuing them, for (1) project development, and (2) fish culture operations. Local government permits are not described, but project developers should be aware that county and city governments have regulations that may apply. Agency addresses and telephone numbers are provided.

PART I. FACILITY DEVELOPMENT PERMITS

Permits that are required, or may be required, for the construction of a fish cultural facility are identified in this section. The permit requirements generally provide for the protection of the natural environment, including the **salmonid** resources.

A. FEDERAL GOVERNMENT

- U.S. Army Corps of Engineers
- Section 10 Permit
- Section 404 Permit

Section 10 of the Rivers and Harbors Act of 1899 gives authority to the U.S. Army Corps of Engineers to regulate development in navigable waters. The Corps also requires a permit for disposal of dredge and/or fill material in “waters of the United **States**” under Section 404 of the Clean Waters Act. The Corps circulates permit applications to other agencies for review, including the Environmental Protection Agency, Fish and Wildlife Service, National Marine Fisheries Service, state resource agencies, and local governments.

Any Federal government action, including decisions on permit applications, requires compliance with the National Environmental Policy Act. This is commonly satisfied by preparation of an environmental assessment by the responsible agency, but major developments may require an environmental impact statement (**EIS**) to identify areas of environmental concern.

For developments in coastal portions of the basin, the Federal permits must consider the Coastal Zone Management Act. Under this law, the states developed coastal management programs that received Federal approval. Projects must be consistent with the guidelines set forth in these programs.

Permits: Fish Facility Development and Operation

The U. S. Fish and Wildlife Service administers the Endangered Species Act of 1973. If a proposed facility is expected to **propagate** or impact an endangered species in any way, the USFWS must be consulted as required under Section 7 of the Act.

If a proposed fish culture facility is to be located on federal lands, involve federal funds or federal land, the USFWS should be consulted as required under the Fish and Wildlife Coordination Act as amended.

Federal regulatory agencies:

U.S. Army Corps of Engineers
Seattle District
P.O. Box 3-3755
Seattle, WA 98134
(206) 764-3495

Walla Walla District
Building 602
City-County Airport
Walla Walla, WA 99362
(509) 525-5500

Portland District
P.O. Box 2946
Portland, OR 97208
(503) 221-6997

National Marine Fisheries Service
Environmental & Tech. Svcs. Div.
847 NE 19th Avenue
Portland, OR 97232
(503) 230-5400

Environmental Protection Agency
Mail Stop 423
1200 Sixth Avenue
Seattle, WA 98101
(206) 442-1096

U.S. Fish and Wildlife Service
Division of Ecological Services
727 NE 24th
Portland, OR 97232
(503) 231-6179

B. STATE GOVERNMENT

In addition to participating in the review of Corps of Engineer permits, the states have other permit or approval requirements. These are summarized in Tables 1, 2, and 3 for Oregon, Washington and Idaho, respectively. Addresses for all regulatory agencies in each state are also provided.

Oregon

Oregon law requires that a permit, or "**water** right", must be obtained from the Oregon Water Resources Department for the appropriation of either surface water or ground water.

The Division of State Lands (DSL) requires a permit for dredging or filling any waters of the state, when 50 cubic yards or more of material is involved. **Riprap** permits are also issued under this law. DSL uses a joint permit application with the Corps of Engineers, since many activities also require a federal permit. Other state agencies, including the Department of Fish and Wildlife and the Department of Land Conservation and Development, submit recommendations during the permit review process.

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Table 1. Facility development permits required and regulating agencies for fish hatcheries in the State of Oregon.

<u>Type of permit or instrument</u>	<u>Regulating agency</u>
Water Right Permit	Water Resource Department
Removal and Fill Permit	Division of State Lands
Riprap Permit	Division of State Lands
Lease (Navigable Waters)	Division of State Lands
Archaeological/Historical Consultation	State Historic Preservation Office
Water Quality Approval	Department of Environmental Quality
Forestry Notification	Department of Forestry
Road Access Permit	Department of Transportation

Consultation is required with the State Historic Preservation Office, Oregon State Parks, to determine if the project site has potential historical or archaeological value.

Other Oregon developmental permits that may be required:

- 1) The state owns most lands under navigable waters, and a state lease may be required from the Division of State Lands.
- 2) The Department of Environmental Quality regulates water quality and may require approval if there will be sedimentation.
- 3) If timber is to be removed from the site, a Notification of Operation must be filed with the Department of Forestry.
- 4) A state road access permit may be required from the Transportation Department regional engineer.

General information regarding permit requirements in Oregon may be obtained from the Department of Fish and Wildlife.

Oregon regulatory agencies

Department of Environmental Quality
522 SW Fifth Ave.
P.O. **Box** 1760
Portland, OR 97204
(503) 229-5696

Department of Fish and Wildlife
Environmental Management Section
506 SW Mill St.
P.O. Box 3503
Portland, OR 97204

Division of State Lands
Permit Coordinator
1445 State St.
Salem, OR 97310
(503) 378-3805

State Historic Preservation Office
Oregon State Parks
525 Rade St. SE
Salem, OR 97310
(503) 378-5023

Permits: Fish Facility Development and Operation

Oregon Water Resources Department
555 13th St. NE
Salem, OR 97310
(503) 378-3671

Department of Forestry
2600 State St.
Salem, OR 97310
(503) 378-2560

Department of Transportation
Transportation Building
Salem, OR 97310
(503) 378-6388

Washington

Table 2. Facility development permits required and regulating agencies for fish hatcheries in the State of Washington.

<u>Type of permit or instrument</u>	<u>Regulating agency</u>
State Environmental Policy Act	Department of Ecology
Water Right Permit	Department of Ecology
Flood Control Zone Permit	Department of Ecology
Water Quality Exception or Certification	Department of Ecology
Wastewater Facility Plan Approval	Department of Ecology
Hydraulic Project Approval	Departments of Game or Fisheries
Archaeological/Historical Consultation	Office of Archaeological and Historical Preservation
Forest Practices Act Permit	Department of Natural Resources
Surface Mining Permit	Department of Natural Resources
State Leases or Easements	Department of Natural Resources

Most hatchery projects in Washington will involve activities covered by the State Environmental Policy Act (**SEPA**). This Act requires that, before certain permits or approvals are issued, consideration is given to environmental impacts. SEPA guidelines are available upon request from the Washington Department of Ecology.

The Washington Department of Ecology (**WDOE**) regulations require a Permit to Appropriate Public Water (Water Right) for the withdrawal of surface water or more than 5,000 gallons per day of ground water.

Other permits that may be required by WDOE include:

- (1) A Flood Control Zone Permit, if any portion of the project is located in a designated Flood Control Zone.
- (2) A Water Quality Exception or Certification, for any construction activity that may result in a temporary violation of state water quality standards.
- (3) A Wastewater Facilities Plan Approval, if it is determined that the project involves a production level sufficient to require waste treatment.

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- (4) A Reservoir Permit may be required for any man-made reservoir with a surface area greater than 10 acres or greater than 10 feet in depth.

The Department of Fisheries and the Department of Game jointly issue Hydraulic Project Approvals for any work in waters of the state. Construction provisions are included for protection of fish and their habitat.

The Office of Archaeology and Historic Preservation is responsible for the protection of cultural sites and resources, and should be contacted before construction starts.

The Department of Natural Resources (DNR) should be contacted if construction is planned on forested land, or if surface disruption covers more than 2 acres or involves more than 10,000 tons of material. A Forest Practices Application or Surface Mining Permit may be required. DNR **also** requires a lease for development on state lands and an easement or road right-of-way may also be necessary.

Information regarding permit requirements in Washington may be obtained at the Environmental Permit Information Center, Department of Ecology, Olympia.

Washington regulatory agencies

Department of Ecology
Mailstop PV-11
Olympia, WA 98504
(206) 753-2800

Department of Fisheries
Habitat Management Division
115 General Administration Bldg.
Olympia, WA 98504
(206) 753-6650

Department of Game
600 North Capitol Way
Olympia, WA 98504
(206) 753-6600

Department of Natural Resources
Public Lands Building
Olympia, WA 98504
(206) 753-5327

Office of Archaeology
and Historic Preservation
111 21st Avenue West
Olympia, WA 98504
(206) 754-1625

Idaho

Table 3. Facility development permits required and regulating agencies for fish hatcheries in the State of Idaho.

<u>Type of permit or instrument</u>	<u>Regulating agency</u>
Water Right Permit	Department of Water Resources
Stream Channel Alteration Permit	Department of Water Resources
Encroachment on Navigable Waters	Department of Lands
Surface Mining Permit	Department of Lands
State Lease, Easement or Purchase	Department of Lands
Archaeological/Historical Consultation	Historic Preservation Office

Permits: Fish Facility Development and Operation

Regulations governing water right permits in Idaho are similar to those of Oregon and Washington. An Application for Permit form is submitted to the Department of Water Resources for either surface or ground water.

The Department of Water Resources also regulates work in streams, and requires a Stream Alteration Permit that may include conditions for the protection of environmental quality. A "Joint Application for Permit" form is used in conjunction with the Corps of Engineers and the Idaho Department of Lands. Application review considers the recommendations of other state resource agencies, including the Department of Fish and Game.

The Department of Lands requires a state permit for any encroachment on navigable waters, a surface mining permit if more than one acre is involved, and issues leases and easements for state lands.

The Department of Health and Welfare examines project impacts on water quality and provides a state water quality certification on Corps of Engineers permits. They may also respond to applications for a Stream Channel Alteration permit. If a project is likely to cause siltation or temporary water quality impairment during construction, contact should be made with this agency.

The State Historic Preservation Office maintains a register of potential archaeological and historical sites, and should be contacted when planning new projects.

Idaho regulatory agencies

Department of Water Resources
Statehouse
Boise, ID 83720
(208) 334-2190

Department of Lands
Statehouse
Boise, ID 83720
(208) 334-3280

Department of Fish and Game
P.O. Box 25
Boise, ID 83707
(208) 334-3700

Department of Health and Welfare
Division of Environment
450 West State
Boise, ID 83720
(208) 334-4059

State Historic Preservation Office
610 North Julia Davis Drive
Boise, ID 83702
(208) 334-3847

C. INDIAN TRIBAL GOVERNMENT

Any fish cultural development on Indian reservation land should be closely coordinated with the tribal government and the U. S. Bureau of Indian Affairs office in Portland.

The Confederated Tribes of the Umatilla Reservation list the following permit requirements for orderly land use and development:

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- (1) Water Use Permit, for diversion of either ground or surface water, with terms and conditions pertaining to pollution and maintenance of water quality.
- (2) Stream Zone Alteration Permit
- (3) Zoning Permit
- (4) Conditional Use Permit

The Confederated Tribes of the Warm Springs Reservation of Oregon list these requirements before construction can begin:

- (1) Approval of site, from the Land Use Committee
- (2) Approval of water source, from the Water Control Board
- (3) Lease agreement for land, from the Bureau of Indian Affairs Realty
- (4) Building Permit, from the Tribal Building Inspector% Office

The Yakima and Nez Perce tribes do not have formal regulation or permit requirements pertaining to fish cultural facilities at this time. They do require, however, that Tribal Realty and Zoning offices be contacted to **assure** proper and non-conflicting usage of the land.

Indian tribal agencies

Confederated Tribes of the
Umatilla Reservation
P.O. Box 638
Pendleton, OR 97801
(503) 276-8221

Nez Perce Tribe
P.O. Box 365
Lapwai, ID 83540
(208) 843-2253

Confederated Tribes and Bands
Yakima Indian Nation
P.O. Box 151
Yakima, WA 98948
(509) 865-5121

Confederated Tribes of the
Warm Springs Reservation of Oregon
Box C
Warm Springs, OR 97761
(503) 553-1161

PART II. FACILITY OPERATIONS PERMITS

Regulations governing salmon and steelhead trout culture are less complex than the numerous laws covering construction and development. The states implement most of the laws or policies that regulate important phases of salmon and steelhead culture, and these are similar in Oregon, Washington and Idaho. Federal permits, when required, are identical throughout the basin. Tribal and local government requirements are likely to be minor, but should not be disregarded.

Permits: Fish Facility Development and Operation

Details of the required permits and approvals follow. Agency addresses are also provided.

A. FEDERAL GOVERNMENT

Federal permits may be required for discharge of pollutants, predatory bird and mammal control, or for fish imported from outside the United States. A National Pollution Discharge Elimination System (NPDES) Permit may be required if fish production from a facility reaches 20,000 pounds. Determination of the need for this permit is **normally** made on a case-by-case basis. The U.S. Environmental Protection Agency (EPA) has final responsibility for this permit, but in Oregon and Washington they have delegated the task of issuing it to the Oregon Department of Environmental Quality and the Washington Department of Ecology, respectively. The Idaho Department of Health and Welfare has not been so delegated, however EPA requires their review and certification before a permit is issued.

If migratory predator birds are to be destroyed, a permit is required from the U.S. Fish and Wildlife Service. **This** agency must also be consulted when any live fish or **fish parts** are imported from outside the United States.

Federal regulatory agencies

Environmental Protection Agency
1200 Sixth Avenue
Seattle, WA 98101
(206) 442-1200

U.S. Fish and Wildlife Service
Division of Hatcheries and Fisheries
Resource Management
500 NE Multnomah St.
Portland, OR 97232
(503) 230-6216

Delegated state regulatory agencies for NPDES permit

Oregon Department of Environmental Quality
522 SW Fifth Avenue
P.O. Box 1760
Portland, OR 97204
(503) 229-5256

Washington Department of Ecology
Mail Stop PV-11
Olympia, WA 98504
(206) **753-2800**

Idaho Department of Health and Welfare (Reviews and certifies only)
Division of Environment
450 West State
Boise, ID 83720
(208) 334-4059

B. STATE GOVERNMENT

The state fish and game agencies of Idaho, Oregon and Washington all implement regulations or policies for the control of salmon and steelhead propagation. Their purpose is to ensure orderly development, **compatibility** with existing stocks, and disease control. All have regulations dealing with transfer of fish into and out of the state, including the

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requirement of health inspection reports by an approved pathologist. Washington and Oregon also have strict regulations for transfer and release of salmonids within the state and both require and maintain records of disease history for all facilities.

Due to the occurrence of the virus diseases, infectious hematopoietic necrosis and infectious pancreatic necrosis in the Columbia River system, Oregon discourages the movement of these fish into coastal streams and Washington does not permit transplants of Columbia River stock into other watersheds. Both states will consider exceptions on a case-by-case basis. In Idaho, a fish health program is presently being developed that will identify specific requirements governing the movement of fish and fish products.

Addresses for the fish and game agencies of Idaho, Oregon, and Washington are listed earlier in this chapter in the discussion of facility development permits required by each of the three states.

C. INDIAN TRIBAL GOVERNMENT

Only the Confederated Tribes of the Warm Springs Reservation of Oregon listed necessary fish cultural permits. Their Fish and Wildlife Committee must approve release sites, species, and numbers of fish.

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APPENDIX 1

TERMINOLOGY AND AGENCY ABBREVIATIONS

TERMINOLOGY

Acclimatization - the adaptation of fishes to a new environment or habitat.

Adult - a sexually mature fish, In salmon species, precocious individuals that mature sexually before reaching full size are called jacks

Aeration - to combine or charge water with air or oxygen.

Alevin - larval salmon from the time of hatching to resorption of the yolk sac.

Artificial Substrate - a medium, other than gravel, in which eggs or **alevins** are incubated.

Brood fish - adult fish retained for spawning.

Capital costs - funds used for **acquisition** or construction of major capital facilities as opposed to operational costs

Carcass - the dead spawned out salmon or steelhead trout.

Conversion rate - the growth of fish relative to the amount of feed used.

Degassing - the process of removing gases from water; usually nitrogen, but applies to all supersaturated gases. Sometimes called deaeration.

Egg - the matured female germ cell, ovum.

Eyed egg - the stage where pigmentation of the eyes of the embryo becomes visible through the egg **shell**.

Feeder - usually refers to mechanical devices to distribute fish food.

Fingerling - **juvenile** fish from 15 days after beginning of feeding to one year after egg **fertilization**.

Fry - **juvenile** salmon at the time of yolk absorption, or the initiation of feeding in rearing **units**.

Gametes - sexual cells which conjugate and form a fertilized ovum.

Gene pool - the total genetic information possessed by the reproductive members of a population of sexually reproducing organisms.

Genetic integrity - a fish population with an unimpaired gene **pool**.

Green egg - female germ cell prior to the eyed-egg stage.

Hatchery efficiency ratio (H.E.R.) - a measure to compare economic efficiency of several alternative subsystems one might use in a hatchery. The ratio of present value of total project (or subsystem) benefits divided by present value of total project (or subsystem) cost.

Incubation period - period from fertilization of the egg until beginning of active feeding **by fry**.

Incubator - device for artificial incubation of eggs and alevins from fertilization of the egg to the fry stage.

Infertile egg - egg that failed to fertilize.

Interchange rate - the number of times the water in a pond is completely replaced during one hour.

Matrix - substrate occupied by eggs and/or alevins.

Maturation - the process of becoming mature.

Natural production - the production of salmon in their natural habitat.

Pathogen - any disease-producing organism.

Predatory birds - birds that prey on hatchery fish.

Present value - the value of a benefit derived or a cost incurred, or used in the future, divided by a discount rate.

Race - a genetically unique group within a species.

Rearing - the husbandry of fish from first feeding to time of release.

Sediment - settleable solids in water which form deposits.

Shocking eggs - rough handling of eyed eggs, causing infertile eggs to turn white so they can be identified and removed.

Sizing - the use of grading devices to separate fish into uniform size groups.

Smolt - juvenile salmon at the time of initial physiological adaptation to life in the marine environment.

Smoltification - the process of a fish smolting.

Appendix 1

Spawning - the process whereby the sex products are stripped from mature (or ripe) male and female fish and mixed to achieve fertilization. This is often referred to as the artificial spawning process.

Sperm - male sex cell.

Stock - group of fish that share a common environment and gene pool.

Substrate - gravel or plastic materials placed in an incubator to provide a medium for incubation of eggs or alevins.

Suspended particles - solids retained in suspension in the water column.

Temperature unit (TU) - defined as one degree of temperature above freezing for 24 hours.

Tender stage - period of early development during which the embryo is highly sensitive to shock, from a few hours after fertilization to the time pigmentation of the eyes becomes evident. Often called green eggs.

Turbidity - the extent of cloudiness of water, including both suspended and settleable particles.

Upwelling - water passing upward.

Water hardening - process where an egg absorbs water, generally at the time of fertilization.

Yolk sac stage - newly hatched fish with a visible yolk sac.

AGENCY ABBREVIATIONS

AFG - Alaska Department of Fish and Game

BIA - Bureau of Indian Affairs

BPA - Bonneville Power Administration

CRITFC - Columbia River Inter-Tribal Fish Commission

DFO - Canada Department of Fisheries and Oceans

FMC - Fish Management Consultants

IFG - Idaho Department of Fish and Game

IPSC - International Pacific Salmon Fisheries Commission

NFH - National Fish Hatchery

NMFS - National Marine Fisheries Service

OFW - Oregon Department of Fish and Wildlife

SSCEA - **Salmon** and Steelhead Conservation and Enhancement Act of 1980.

USFWS - U.S. Fish and Wildlife Service

WDF - State of Washington Department of Fisheries

WDG - State of Washington Department of Game

APPENDIX 2

VENDORS

Disclaimer: The manufacturers, distributors and their products mentioned herein are for informational purposes only and do not imply endorsement by the authors. Further, it is not intended to be a complete list of products or vendors.

NAME OF FIRM

PARTIAL SUPPLY LISTING

Air-Oil Products, Corp.
2400 E. **Burnside**
Portland, OR 97214
(also Seattle WA & Eugene, OR)

Compressors, vacuum pumps, animators

Agri-Glass
P.O. Box 4474
Greenville, **MS** 38701

Fiberglass tanks, troughs, and planting tanks, fish farming supplier, seines, diffusers and agitators, flow meters

American Plastics
P.O. Box 238
Cheshire, OR 97419

Pond liners

American Scientific Products
3660 148th Ave. NE
Redmond, WA 98052

Scientific testing equipment, microscopes, water analysis, small pumps, balances, etc.

Ameron Pipe Division, NW
750 NE Columbia Blvd.
Portland, OR 972 11

Concrete cylinder pipe, tanks.

Aquaculture Research
Environmental Associates
P.O. Box 1303
Homestead, FL 33090

Aeration equipment, immersion heaters, low/highwater alarm, compressors

Aquadyne, Inc.
1440 Rollins Rd.
Burlingame, CA 94010

Water powered screen

Aquafarms Canada Limited
RR 1
Feversham, Ontario
Canada NOC 1C0

Demand and automatic feeders, timers, transport tanks, **degassers**, small rearing tanks, shallow and deep troughs, fish graders, fiberglass tanks, etc.

NAME OF FIRMPARTIAL SUPPLY LISTING

Aquafine Corp.
1869 Victory Place
Burbank, CA 91504

Ultraviolet water sterilizers

Aquashade
P.O. Box 198
Eldred, NY 12732

Aquatic weed control

Aquatic Ecosystems, Inc.
P.O. Box 1446
Apopka, FL 32703

Gauges, spray nozzles, polyethylene fittings,
air diffusers, air blowers, air
compressor, 02 meter, tubing

Argent Chemical Labs
14929 NE 40th St.
Redmond, WA 98052

Chemicals for aqua culture, including fish
eradication, induced spawning, algae
control

Armco Construction
Products Division
P.O. Box 517
Hillsboro, OR 97123

Steel pipe and pipe arch, aluminized steel
pipe, risers, flumes

Atco Metal Buildings
5115 Crowchild Trail SW
Calgary, Alberta
Canada T3E 1T9

Metal buildings (Fold-A-Way)

Babington Enterprises
Rt. 1 Box 264
Hagerman, ID 83332

Demand feeders, fish tanks, fiberglass
products

Beal Pipe and Tank Corp.
5320 SW Macadam Ave.
Portland, OR 97201

Pipe and tanks.

Becker Industries
Rt. 3 Box 3272A
Clatskanie, OR 97016

Air and water treatment equipment, waste
treatment, drum screens, other

Began Equipment
100 NE 11th Ave.
Portland, OR 97232

Electronic vacuum pond cleaning unit,
petroleum, liquid handling equipment

Biomed Research Labs, Inc.
1115 E. Pike St.
Seattle, WA 98122

Fish health care products

Appendix 2

NAME OF FIRM

Bioproducts, Inc.
P.O. Box 429
Warrenton, OR 97146

Boatcycle Co.
P.O. Box 494
Henderson, TX 75653-0495

Borden Metal Products Co.
P.O. Box 172
Elizabeth, NJ 07207

Burke Concrete Accessories
5750 NE **Hassalo** St.
Portland, OR 972 13

Byron Jackson Pumps
1920 116th NE
Bellevue, WA 98005

Capilano Plastic
300 120th Ave. NE, Bldg. 5
Bellevue, WA 98005

Carolina Biological Supply, Co.
Box 187
Gladstone, OR 97027

Carus Chemical Co.
1500 8th St.
LaSalle, IL 61301

C. E. Shepard Co.
P.O. Box 9445
Houston, TX 7726 1-9445

Cessco, Inc.
740 SE Oak St.
Portland, OR 97214

Che **m-Tainer** Industries
361 Neptune Ave.
N. Babylon, NY 11704

PARTIAL SUPPLY LISTING

Dry and moist fish food

Agitators and chemicals, general fish culture equipment, seines, tanks, **12-volt** car battery submersible pumps, feeders

Metal grating all types, slip resistant surface material

Pond sealing strips

Pumps including submersibles

Small shipping containers, buckets and Aids, space saver rectangular containers, square salmon roe containers, others

Biological supplies, displays, apparatus, diagnostics, media, chemicals

Potassium permanganate

Vinyl coated wire mesh

Construction equipment, pumps, generators, pressure washers

Small plastic tanks (all types), stainless steel tanks and custom processing equipment

NAME OF FIRM

Chemical Proof Corp.
19205 144th Ave. NE
Woodinville, WA 98072

Classic Pool and Spa Distributors, Inc.
5558 SE International Way
Milwaukie, OR 97222

Colossus-Multi-Tainer Corp.
P.O. Box 2004
Wenatchee, WA 98801

Concrete Products of Moses Lake
Moses Lake, WA

Common Sensing
7595 Finch Rd. NE
Bainbridge Island, WA 98110

Conde Milking Machine Co.
Box 99
Sherrill, NY 13461

Construction Materials, Inc.
2603 151st Place NE
Redmond, WA 98052

Corrosion Controls, Inc.,
2930 Ford St.
Washougal, WA 98671

Crescent Research Chem.
5301 N. 37th Place
Paradise Valley, AZ 85253

Crestline Supply Corp.
Salt Lake City, UT

Daco Co.
P.O. Box 4
Bellevue, WA 98009

PARTIAL SUPPLY LISTING

Fiberglass tanks, piping, rearing units,
fishways, tower **shell**.

Pools

Rigid structural foam, polyethelene
containers - carcass holding, egg
boxes, etc.

Pipe

Total dissolved gas pressure instrument

Aeration pumps

Engineering fabrics

Fiberglass fishways, large and small
plastic-reinforced pipes, tanks,
raceways, tower shell.

Anesthetics, foam, antifoaming agents,
malachite green

Rubber sheet pond liners

Barrels, eggbaskets, aluminum processing
tables, hand trucks, wire mesh
containers, **pallets**, insect electrocutors,
lifting equipment, etc.

Appendix 2

NAME OF FIRM

Delta Net and Twine Co.
P.O. Box 356
Greenville, MS 38701

Demorest, H. Al
10912 Tempo Lake Drive SE
Olympia, WA 98503

Design Space International
27457 Pacific Hwy. S.
Kent, WA 98031

Don Sprague Sales, Inc.
2660 Progress Way
Woodburn, OR 97071

Duraframe Dipnet
Route 2 Box 166
Viola, WI 54664

Eastside Net Shop
14207 100th NE
Bothell, WA 98011

Environmental Marketing Associates
5065 SW Nash Rd.
Corvallis, OR 97333

Ershigs, Inc.
Bellingham, WA

FAL Products, Inc.
P.O. Box 9416
Tacoma, WA 98409

Fisheries Supply Co.
1900 N. Northlake Way
Seattle, WA 98103

Floy Tag and Mfg., Inc.
P.O. Box 5357
Seattle, WA 98105

PARTIAL SUPPLY LISTING

Plastic containers, fish and egg
transport equipment, seines, cages,
rope and twine, scales, dip nets, algicide,
rain gear, other

Paddle egg counter

Buildings, office and job trailers

Chemical sprayers and repairs

Dipnets, aerators, balances, netting,
PH & 02 meters

Seines, net construction

Fish screens, micro screens, rotary
screens, volclay pond sealing,
fiberglass raceways, aeration, UVT,
hydro generators, water treatment
systems

Plastic tower shell.

Vertical cabinet incubator

Plumbing fittings, all types of marine
hardware, ropes, twine, nets, clothing,
paints, fishing gear and safety gear

Fish tags - spaghetti, disc and oval,
streamers

NAME OF FIRM

Flurocarbon Fab. Div.
3711 S. Hudson St.
Seattle, WA 98118

Fresh-Flow Corp.
Rt. 1 - Hwy. 28 SW
Cascade, WI 53011

Gaco Western
6108 Highway 99
Vancouver, WA 98665

Garon
915 W. 12th St.
P.O. Box 114
Vancouver, WA 98666

Gator Dock and Marine
865 N. Dixie Highway
Lantana, FL 33465-3318

Gator Gates
P.O. Box 3318
Lantana, FL 33464-33 18

Glitsch, Inc.
P.O. Box 226227
Dallas, TX 75266

Great Western Chem. Co.
N. 1402 Thierman Rd.
Spokane, WA 98206
or
808 SW 15th
Portland, OR 97205

Hach Co.
P.O. Box 389
Loveland, CO 80537

H. D. Fowler Co., Inc.
13440 SE 30th St.
P.O. Box 160
Bellevue, WA 98009

PARTIAL SUPPLY LISTING

Free-style incubators

Aerators

Liquid rubber

Automatic fish feeder

Docks and aluminum water gates

Aluminum gates

Tower packings, tower internals, substrates -
saddles, bio-rings

Specialty cleaning and sanitation products,
defoamers, many other products

Test kits, laboratory instruments,
dissolved oxygen meters, chemicals,
reagents, **labware**, technical
information, service

Aerators and pumps

Appendix 2

NAME OF FIRM

Heath Tecna Corp.
Structures, Inc.
19819 84th Ave. S.
Kent, WA 98031

Helnie Manufacturing Co., Inc.
8174 Berry Ave.
Sacramento, CA 95828

Herrington Manufacturing Co.
Twin Falls, Idaho

Hinds Supply Co.
4000 SW **Hoken**
Beaverton, OR 97005

Hydrolab Corp.
P.O. Box 50116
Austin, TX 78763

Industrial Fiberglass
Rt. 1 Box 34L
Cheney, WA 99004

Industrial Plastics, Inc.
680 S. 28th St.
Washougal, WA 98671-2597

Infilco Degremont, Inc.
Koger Executive Center
Box K-7
Richmond, VA 23288

Inqua Corp.
P.O. Box 86
Dobbs Ferry, NY 10522

Internet, Inc.
2730 Nevada Ave. N.
Minneapolis, MN 55427

J. L. **Eagar**, Inc.
P.O. Box 476
N. Salt Lake, UT 84054

PARTIAL SUPPLY LISTING

Fiberglass tanks, vertical incubator,
tanks, troughs, live egg shipping cases

Feeders

Blower-feeder

Pipe and plumbing supplies

Water quality systems - surface or
ground

Egg sorter

Machining/fabrication all **plast ics**,
polyethylene piping (large)

Aerators

Cage culture

Heavy and light plastic netting, many
varieties, predator netting, live **box** netting

Fish culture supplies of **all** types, rainwear,
foot wear, gloves, hatching containers,
nylon mesh, nets, plastic netting, **live-**
haul tanks, twine, other

NAME OF FIRM

PARTIAL SUPPLY LISTING

Jensorter
Greg K. Jensen
189 34 River wood Drive
Bend, OR 97701

Jensorter - egg sorter and other makes of
egg sorters

Jon B. or Jolly **Inc.**
5416 California SW
Seattle, WA 98136

Fish counter (adult), temp printer, feeder
control system

Johnson Screens Division
P.O. Box 3118
St. Paul, MN 55165

Well and intake screens, well development
information

Justin Enterprises, Inc.
Westminister, CA

Plastic shell towers

Keir and Sons, Ltd.
715 W. 16th **Ave.**
Vancouver, BC **V5Z 1S8** Canada

Fin clipping scissors

Kelly Klosure Systems
P.O. Box 1058
Fremont, NE 68025

Temporary modular buildings, semi-permanent
modular buildings

Ken's Fish Hatchery
P.O. Box 449
Alapaha, GA 31622-0449

Fish cultural **equipment** of all kinds,
demand feeders, chemicals in fish culture,
plastic mesh

Kinney Spring Steel Broom Co.
Topsfield, MA 01983

Steel brooms

Koch Engineering Co., Inc.
4111 E. 37th St. N
Wichita, KN 67220

Tower **packings and internals, substrates,**
bio-rings.

Landa, Inc.
4920 NE **122nd**
Portland, OR 97230

Pressure Washer

Larry **Harrington** Co., Inc.
515 116th Ave. NE
Suite 260
Bellevue, WA 98004

Hydronic specialties, centrifugal pumps.
Heat transfer products, plumbing.

Appendix 2

NAME OF FIRM

LTI, Inc.
P.O. Box 433
Lynden, WA 98264

Magic Valley Ileri-Arc
and Manufacturing
Twin Falls, ID

Mariculture Northwest
Rochester, WA 98579

Markson Science
7815 S. 46th St.
Phoenix, AZ 85040

McCrary's Farm Supply
114 Park St.
Lonoke, AR 72086

Memphis Net and Twine Co., Inc.
P.O. Box 8331
Memphis, TN 38108

Micro-Por, Inc.
P.O. Box 12218
Wichita, KS 67277

Mirafi, Inc.
P.O. Box 240967
Charlotte, NC 28224
(also Redmond, WA)

Modutank, Inc.
29-24 40th Ave.
Long Island City, NY 11101

Moore-Clark., Inc.
P.O. Box M
LaConner, WA 98257

Muskin
14545 S. Sunnyside Ave.
San Bernadino, CA 92408

PARTIAL SUPPLY LISTING

Contract fish hauling

Fish transfer pipe and tower

Contract rearing

Scientific testing equipment and supplies

Fish farm supplies, chemical, netting, nets,
graders, agitators, pumps, many fish culture
needs

Netting, nets, bird netting, ropes, twine,
numerous small items for aquaculture needs

Air and fluid dispersers

Geotextiles

Pond liners, round steel tanks

Oregon moist pellets. Abernathy dry salmon
feeds. New age dry salmon and trout feeds

Swimming pools

NAME OF FIRM

M & W Fabricators
717 E. Hastings St.
Vancouver, B.C. Canada
VGA1 R3

National Tank & Pipe Co.
P.O. Box 7
Clackamas, OR 97015

Neilsen Metal Industries
3501 Portland Rd. NE
Salem, OR 97303

Nichols Net & Twine
RR 3 - Bend Rd.
E. St. Louis, IL 62201

NOPAD Co.
P.O. Box 3029
Juneau, AK 99803

The Northstar Co.
Rt. 1 Box 229
Gaston, OR 97119

Northwest Linings
& Geotextile Products
20222 87th Ave. S.
Kent, WA 98032

Northwest Marine Technology
Shaw Island, WA 98286

Norton Company
Chem. Prod. Division
Worcester, MA 01606

Novatech Designs Ltd.
830 - C Pembroke St.
Victoria, BC Canada **V8T 1H9**

Nylon Net Co.
P.O. Box 592
Memphis, TN 38101

PARTIAL SUPPLY LISTING

Capilano rearing trough

Wood tanks, pipe, and flumes

Fish feeders, grader, fish pump and tower,
aluminum trough

Hatchery seines (heavy and light),
rope and twines, dip nets, netting

Fish incubators

Automatic fish feeder

Geotextile products

Binary-coded tagging machines, fry and egg
counters

Substrate - plastic, plastic bio-rings,
bio-saddles

Tensionometer (to check gas pressure)

Ropes, twines, nets, netting, commercial
fishing supplies

Appendix 2

NAME OF FIRM

PARTIAL SUPPLY LISTING

Otterbine Barebo, Inc.
P.O. Box 217 R.D. #1
Emmaus, PA 18049

Aerators, including paddlewheel aerators,
oxygen monitors

Oregon Aqua Foods
Springfield, OR

Contract rearing

OVA, Incorporated
P.O. Box 1288
Wrangell, AK 99929

Egg planting device

Pacific Metal Co.
P.O. Box C 88440
Tukwilla, WA 98188
(also Portland, OR)

1/8" perforated aluminum screen plate

Pacific States Cast Iron Pipe Co.
9450 SW Barnes Road
Portland, OR 97225

Pipe, valves and hydrants

Pacific Water Works Supply Co.
P.O. Box 3515
Seattle, WA 98124
(also Portland, **OR**)

Aerators

Pacific Wire Works, Inc.
2743 13th SW
P.O. Box 3824
Seattle, WA 98134

Wire screens, wire egg baskets

Pace-Pacific Pump Co.
2551 NW 30th Ave.
Portland, OR 972 10

High pressure and trash pumps
Pump systems, fish pumps

Peterson Fiberglass Laminates, Inc.
P.O. Box 158
Shell Lake, WI 54871

Transport tanks (fiberglass)
(complete line)

Phipps Water Alarm Co.
3529 NE 121st
Portland, OR 97220

Water alarm

Pro-Line
P.O. Box 1348
Crystal River, FL 32629

Fiberglass tanks, all shapes and sizes

NAME OF FIRMPARTIAL SUPPLY LISTING_

Prometco
P.O. Box 119
Kenmore, WA 98028

Aluminum prefabrication tanks, raceways &
fish tanks transport

Queen Pump Co.
305 NE Russell
Portland, OR 97227

Pumps

Rangen, Inc.
P.O. Box 706
Buhl, ID 83316

Rangen dry salmon and trout feeds

Ranger Boat
25802 Pacific Hwy. S.
Kent, WA 98031

Fiberglass incubation tank

Red Ewald, Inc.
P.O. Box 519
Karnes City, TX 78118-0519

Fiberglass fish culture tanks

Redden Net, Inc.
2626 Harbor Loop
Bellingham, WA 98225

Seine and net building, marine supplies

Reiff Fiberglass Co.
Rt. 4 Box 183
City Co. Airport
Walla Walla, WA 99362

Aqua culture tanks, hatchery tanks

Roe, Inc.
Rt. 1 Box 240
Paymyra, WI 53156

Roe egg counter and sorter, hand tweezers
for egg picking

Roescan
Rt. 1 Box 34L
Cheney, WA 99004

Roescan egg sorter

Scientific Supply &
Equipment, Inc.
1818 E. Madison St.
Seattle, WA 98122

Complete line of scientific equipment and
supplies including respirators and safety gear.

Shelter Shed
2200 South 144th St.
Seattle, WA 98168

Ocean cargo containers

Appendix 2

NAME OF FIRM

Sims Fiberglass Co.
P.O. Box 36
Jefferson, OR 97352

SIR Mail Order
1869 Burrows Ave.
Winnipeg, Manitoba
R2X 2V6 Canada

Skane Fish Farm
Rt. 4 Box 137
Stratford Rd.
Moses Lake, WA 98837

Skretting
P.O. Box 319
400 1 Stavanger, Norway

Quentin Smith
Claskanine Fish Hatchery
Rt. 1 Box 764
Astoria, OR 97013

Smith-Root, Inc.
14014 NE Salmon Creek Ave.
Vancouver, WA 98665

Soule Buildings
P.O. Box 6222
Carson, CA 90749

Spencer Turbine Co.
600 Day Hill Rd.
Windsor, CT 06095

Staff Industries
P.O. Box 759
78 **Dryden** Rd.
Upper Montclair, NJ 07043

Sterling H. Nelson & Sons
118 W. 4800 S.
Murray, UT 84107

PARTIAL SUPPLY LISTING

Fiberglass tanks, incubation and rearing

Camping supplies

Contract rearing

Dry food and technical equipment for fish farming, hatching trough, hatching cylinder, fish feeders, transport boxes, net pens, other

Fish killing clubs

Boats and work barges, electro-fishing equipment (battery and gas powered)

Buildings

Vortex blowers

Pond liners (flexible impermeable membranes)

Silver cup dry salmon and trout feeds

NAME OF FIRM

Sterling Net & Twine Co., Inc.
18 Label St.
Montclair, NJ 07042

Swecker Salmon Farm
Rochester, WA

Sweeney Enterprises, Inc.
Rt. 2 Box 2452
Boerne, TX 78006

Syndel Laboratories Ltd.
8879 Selkirk St.
Vancouver, BC Canada **V6P 4J6**

Temcor
P.O. Box 3039
Torrance, CA 90510

Terra Aqua Conservation Co.
Reno, NV

Tetko, Inc.
420 Saw Mill Rd.
Elmsford, NY 10523

Topper Industries, Inc.
P.O. Box 1587
Vancouver, WA 98668

Tri-Core Plastics Ltd.
702 W. 59th Ave.
Vancouver, BC Canada **V6P 1X6**

Trout Springs, Inc.
P.O. Box 11
McMillan, WA 98352

Valentine Equipment Co.
P.O. Box 53
Hinsdale, IL 60521

VWR Scientific, Inc.
P.O. Box 3551
Seattle, WA 98124
or
P.O. Box 14070
Portland, OR 97214

PARTIAL SUPPLY LISTING

Nylon netting material, nets, live boxes,

Contract rearing

Automatic feeding systems

Hormones for inducing maturation, steroids
for sex control, **UV-chemicals**

All aluminum dome building

Gabion wire

Screening and filtration media, synthetic
fabrics, wire cloth, (all types)

Full line of floating structures for
rearing pens, including aluminum frame net
pen, marina docks

Vertical incubators, plastic

Sustaf egg sorter, contract rearing

Wire netting all kinds, poultry water and
chemical dispensers, farm supplies

Very large line of scientific instruments,
equipment and supplies, including safety
gear

Appendix 2

NAME OF FIRM

Warner Fish Ways WPM Corp.
P.O. Box 370
Point Roberts, WA 98281
or
St. **Tsawwassen**, Delta, B.C.

Warren Water Broom
Rt. 1 Box 764
Astoria, OR 97103

Western Concord Mfg. Ltd.
880 Cliveden Ave.
New Westminster, B.C. **V3M 5V9**

Western Farmers Association
201 Elliott Ave. W
Seattle, WA 98119

Western Wire Works
4025 NW Express Ave.
Portland, OR 972 10

Wildlife Control Technology
6408 S. Fig
Fresno, CA 93706

Worcester Brush Co.
P.O. Box 658
Worcester, MA 01601

Yellow Springs Instrument Co., Inc.
Scientific Division, Box 279
Yellow Springs, OH 45387

Zak Tackle Mfg. Co.
2321 104th St. S.
Tacoma, WA 98444

PARTIAL SUPPLY LISTING

Adult fish lift

Pond brooms

Collapsible roll poly

Many farm supplies, plastic netting for birds

Screens, cloth, perforated metals, baskets

Bird netting, chemical protectors of birdnets

Pond brushes (stainless steel and nylon), fiberglass extension rods

Environmental study equipment, including oxygen monitor, thermometers, other

Spawning knife

APPENDIX 3

SALMON - STEELHEAD TROUT PRODUCTION FACILITIES VISITED

Alaska

Medvejie Central Incubation Facility - Private cooperative - Sitka

Canada (B.C.) - (DFO, Cooperatives and Tribes)

Alouette River Cooperative
The Bell-Irving Hatchery - Kanacka Creek
Big Qualicum Salmon Hatchery
Chehalis Salmon Hatchery
Courtney Rod and Gun Club Side Channel
Ed Leon Side Channel of the Chehalis Indian Reservation
French Creek Fish and Game Club Facility
Little Mt. Side Channel of the Chehalis River
North Vancouver Outdoor School Mini Hatchery
Puntledge River Fish Hatchery
Quinsam River Salmon Hatchery
Railroad Creek Side Channel
Tenderfoot Salmon and Steelhead Hatchery
Upper Paradise Side Channel - Cheakamus River
Worth Creek Side Channel

Idaho

Clear Springs Fish Hatchery - Private
Dworshak National Fish Hatchery - USFWS
Hagerman Fish Hatchery - IFG
Hngerman National Fish Hatchery - USFWS
Hayden Creek Research Station - U of **Idaho**/IFG
Niagara Springs Steelhead Hatchery - IFG
Pahsimeroi Chinook Salmon Facility - **IFG**
Pahsimeroi Steelhead Collection Facility - **IFG**
Rapid River Fish Hatchery - IFG
Red River Rearing/Holding Area - **IFG**

Oregon

Big Creek Fish Hatchery - OFW
Bonneville Fish Hatchery - OFW
Cascade Fish Hatchery - OFW
Clatsop Co. Economic Development Project - County
Eagle Creek National Fish Hatchery - USFWS

Appendix 3

Gnat Creek Fish Hatchery - OFW
Klaskanine Fish Hatchery - OFW
Leabury Fish Hatchery - OFW
McKenzie Fish Hatchery - OFW
Oakridge Fish Hatchery - OFW
Oregon Aqua Foods (Springfield, Oregon) - Private
Oxbow Fish Hatchery - OFW

Washington

Aberdeen Trout Hatchery - WDG
Abernathy Salmon Cultural Development Center - USFWS
Allison Springs Salmon Rearing Area - **WDF**
Beaver Creek Steelhead Hatchery - WDG
Bumping River Paddle Wheel Screen - Irrigation District
Chelan Trout Hatchery - WDG
Cowlitz Trout Hatchery - WDG
Elokomin Salmon Hatchery - WDF
Elsen Creek Hatchery - Squaxin Tribe
Enetai Creek Hatchery - Skokomish Tribe
Garrison Springs Salmon Hatchery - WDF
George Adams Salmon Hatchery - WDF
Goldendale Trout Hatchery - WDG
Hoodspport Salmon Hatchery - WDF
Humptulips Salmon Hatchery - WDF
Kennedy **Creek** Egg Box Program - WDF
Klickitat Salmon Hatchery - WDF
Little White Salmon National Fish Hatchery - USFWS
Mariculture Northwest - Private
McKernan Salmon Hatchery - WDF
Moore-Clarke Company (Food Processing)- Private
Naches Fish Hatchery - WDG
Naselle Salmon Hatchery - WDF
Nelson Springs (Coop.) - WDG
Pacific Power and Light Co. Intake, Naches - PP & L
Priest Rapids Salmon Hatchery - WDF
Puyallup Salmon Hatchery - WDF
Quilcene National Fish Hatchery - USFWS
Quineault National Fish Hatchery - USFWS
Quinault Tribal Fish Hatchery - Quinault Tribe
Ringold Springs Rearing Pond - WDF
Ringold Springs Steelhead Pond - WDG
Rocky Reach Hatchery - WDF
Samish River Adult Holding Facility - WDF
Satsop Springs Rearing Area - WDF
Sequalechew Lake - WDF
Shelton Trout Hatchery - WDG
Skumania Steelhead Hatchery - **W** DGI

South Tacoma Steelhead Hatchery - WDG
Spring Creek National Fish Hatchery - USFWS
Swecker's Salmon Hatchery - Private
Tulalip Tribal Salmon Hatchery - Tulalip Tribe
Vancouver Fish Hatchery - WDG
Washougal Salmon Hatchery - WDF
Wells Salmon and Trout Hatchery - WDG/WDF
Yakima City Water Diversion - City of Yakima
Yakima Trout Hatchery - WDG

APPENDIX4

HATCHERY EQUIPMENT LIST BY FUNCTION

A. TRANSPORTATION, FISH AND PERSONNEL

1. Pickup Truck, 1/2 Ton
2. Pickup Truck, 3/4 Ton
3. Feed and Fish Tank Flat-Bed, 2-1/2 Ton
4. Fingerling and/or Adult Fish Transport Tanks With Accessories
5. CB Mobile Units
6. Boat Suitable for Need
7. Tractor/Hoe, Broom, Loader and Mower
8. Forklift
9. Mini-Motor Powered Carts
10. Fish Pump With Tower
11. CB Base Station
12. CB Antenna

B. MAINTENANCE OF GROUNDS-FACILITIES

1. Sludge Pump
2. Ladders, Step and Extension
3. Push Brooms

MAINTENANCE OF GROUNDS-EQUIPMENT

1. Hydraulic Jack, 12 Ton
2. Battery Charger, 8 Amp, 6 and 12 volts
3. Booster Cables, 12 Volt x 20 ft. long
4. Grease Gun
5. Auto Creeper
6. Oil and Gasoline Containers
7. Funnels (Various Sizes)

MAINTENANCE OF GROUNDS - GENERAL

1. Woodworking Hand Tools
2. Metalworking Hand Tools
3. Welding Equipment and Clothing
4. Portable Emergency Generator
5. Portable Emergency Lighting
6. Gas Welder

MAINTENANCE OF GROUNDS - GENERAL (cont'd.)

7. Arc Welder
8. Wood Vise
9. Drill Press and Vise
10. Band Saw
11. Wood Lathe
12. Metal Vise with Cinch
13. Table Saw
14. Flammable Storage Cabinet
15. Guns and Gun Safe
16. Small Hand and Power Tool Cabinets/Lock
17. Sawdust Vacuum
18. Electric Air Compressor
19. Portable Electric Circle Saw
20. Radial Arm Saw
21. Mitre Box/Back Saw
22. Hand Truck, 300 lb. Capacity
23. Bench Grinder, 3/4 HP
24. Electric Drill and Bits
25. Solder Gun Kit
26. Heavy Duty Staple Gun Set
27. Pop Rivet Gun Set
28. Hand Saws
29. Hack Saw
30. Come-A-Long
31. Hand Truck
32. Pipe Cutter
33. Wrecking Prybar (Small and Large)
34. Cloth end Metal Measuring Tapes
35. Wire and Paint Brushes
36. Tap and Die Set
37. Power Sanders
38. Pipe Threader
39. Rubber Mallet
40. Hemmers, Sledges and Axes
41. Pickaroon
42. Bolt Cutter
43. Extension Cord with Trouble Lite
44. Garbage Cans
45. Face Shield

MAINTENANCE OF GROUNDS - GHOUNDS

1. Shovels, Snow and Gardening
2. Weed Eater - Gas
3. Lawn Mower - Gas

Appendix 4

MAINTENANCE OF GROUNDS - GROUNDS (cont'd.)

4. Wheelbarrow - Industrial
5. Garden and Leaf Rake and Hoe
6. Stainless Steel Weed Sprayer
7. Brush and Limb Trimmers
8. Garden Hose, Spray Nozzles (Pistol Grip), and Sprinklers

C. HATCHERY BUILDING - OFFICE

1. Typewriter
2. Calculator with Tape
3. Desks
4. Chairs
5. Filing Cabinets
6. Waste Baskets
7. Table
8. Book Case and Credenzas
9. Clock
10. Plain Paper Copy machine

HATCHERY BUILDING - LAB

1. Laboratory Fume Hood
2. Laboratory Refrigerator
3. Laboratory Stools
4. Laboratory Table Top with Cabinets
5. Glassware
6. Chemicals
7. Microscopes
8. Dissecting Microscope Lite
9. Balance Scales
10. Spectrophotometer
11. PH Meter
12. DO Meter
13. Maximum - Minimum Thermometers
14. Calibrating Thermometers
15. Dissecting Tools
16. Propane Torch with Holder
17. Bench Top Autoclave
18. Stir Hotplates

HATCHERY BUILDING - CREW ROOM

1. Microwave Oven
2. Brooms, Mops and Dust Pans

HATCHERY BUILDING - CREW ROOM (cont'd.)

3. Lunch Table
4. Chairs
5. Refrigerator
6. Stove or Hot Plate
7. cot
8. Lockers
9. Large Bulletin Board

D. SPAWNING - HOLDING POND

1. Bleeding Racks
2. Egg Pails and Stands
3. Work Table
4. Carcass Boxes
5. Portable 12 cubic feet Temporary Holding Tank
6. Adult Dip Nets
7. Adult Fish Crowder or Seine
8. Spawning Knives
9. Spawning Club
10. Cooler Insulated Chests
11. House Trailer for Security during Adult Holding and Spawning
12. Spawning Clothing, Gloves and Boots
13. Boom Hoist

E. INCUBATION

1. Egg Weighing Scoop
2. Egg Tongs
3. Burlap Bags
4. Egg-Picking Machine
5. Egg-Picking Table
6. Low-Water Alarm

F. REARING - INTAKE

1. Screen and Pond Brushes
2. Pike Poles
3. Rack and Screen Rakes

REARING - POND

1. Screen end Pond Brushes
2. Fish Weighing Scale/Holder

Appendix 4

REARING - POND (cont'd.)

3. Prams for Pond Feeding
4. Hand Cart
5. Dip Nets - Small Fish
6. Seine - Small Fish
7. Rack and Screen Rakes
8. Pond Cleaning Vacuum Pump/Accessories
9. Pump/Standpipe for Filling Fish Hauling Tanks
10. Coded Wire Tagging Machine
11. Trailer Mounted Blower Feeder
12. Pond Crowder
13. Fish Feeders (**Demand** and or Automatic)
14. Hatcheryman's **Raingear**
15. Low-Water Alarms

REARING - FEED ROOM

1. Feed Weighing Scales
2. Hand Cart
3. Feed Buckets (5 gal.)
4. Feed Room Scoops

REARING - GENERAL

1. Wash Down Pump/Suction and Discharge Hose
2. Portable High Pressure Washer Pump with **Accessories**

G. SAFETY-FIRST AID - GENERAL

1. First Aid **Kits** (Shop & Trucks)
2. Stretcher/Wool Blanket
3. Safety Goggles
4. Respirator **Mask/Filters**
5. Air Splint Set
6. Hard Hats
7. Hazard Signs (Keep Out, No Trespassing, Danger, Detour, etc.)
8. Fire Pump/Hose and Nozzle
9. Fire Extinguishers (Buildings & Trucks)
10. Life Vests
11. Ear Cover - Noise Suppression
12. Bulletin Board

APPENDIX 5

HATCHERY PERSONNEL JOB DESCRIPTIONS

The following job descriptions were furnished courtesy of the Idaho Department of Fish and Game and are reproduced without change except for an addition to the Fish Hatchery Superintendent 2 minimum qualifications (in brackets).

Class code: 00784

FISH HATCHERY SUPERINTENDENT 2

CLASS PURPOSE

To direct the operation of a fish hatchery for the production of fish to be planted in Idaho waters; and perform related duties.

PRINCIPAL ACCOUNTABILITIES

1. Hatchery management. Typical responsibilities: directs the operation of a fish hatchery; supervises and trains staff; develops and monitors budget; maintains records and prepares reports on hatchery operation; is responsible for inventory and maintenance of equipment and capital improvements; coordinates the hatchery operation with other department functions.
2. Aquaculture. Typical responsibilities: spawns fish and monitors the development of eggs and fry; develops and implements feeding schedules required for specific growth rates; cleans hatching tanks and raceways; observes fish behavior for signs of stress or disease; develops and implements water and feed treatments and prophylactic measures; grades and sorts fish by size and species; distributes, transports, and plants fish.
3. Public relationships. Typical responsibilities; conducts hatchery tours and answers questions; speaks to interested groups.

GENERAL INFORMATION

Incumbents in this classification direct the operation of a grade 2 fish hatchery.

MINIMUM QUALIFICATIONS

[FMC recommends one full year of experience at a comparable station. See text.]

Any combination of education, training, and experience that demonstrates competence in each of the following:

Appendix 5

Considerable knowledge of: department rules and regulations related to fish hatcheries; identifying characteristics, nutritional requirements, and behaviors of various fish species; spawning techniques; fish development; water quality relating to hatchery operation and fish planting; fish planting techniques.

Good knowledge of other department programs that relate to fish hatcheries.

Ability to: supervise a technical staff; provide training in hatchery operations; recognize abnormal behavior and disease symptoms of various fish species; develop and implement prophylactic and control measures; calculate feeding rates; develop and monitor a budget; interpret rules and regulations; establish policies and procedures; write narrative reports; give oral presentations; establish and maintain effective working relationships.

PROBATIONARY PERIOD:

Entrance: 2080 hours (12 months)

Promotion: 1040 hours (6 months)

Adopted: 7/70; revised: 4-73; 7/78; 2/83

JOB CONTENT EVALUATION: D12 175/D3(29)50/D1P 87/B3II:14 = 326

Overtime code: S

Class code: 00786

FISH HATCHERY SUPERINTENDENT 1

CLASS PURPOSE

To direct the operation of a hatchery for the production of fish to be planted in Idaho waters; and perform related duties.

PRINCIPAL ACCOUNTABILITIES

1. Aquaculture. Typical responsibilities: spawns fish and monitors the development of eggs and fry; develops and implements feeding schedules required for specific growth rates; cleans hatching tanks and raceways; observes fish behavior for signs of stress or disease; develops and implements water and feed treatments and prophylactic measures; grades and sorts fish by size and species; distributes, transports, and plants fish.
2. Hatchery management. Typical responsibilities: directs the operation of a fish hatchery; supervises and trains staff; develops and monitors budget; maintains records and prepares reports on hatchery operation; is responsible for inventory and maintenance of equipment and capital improvements; coordinates the hatchery operation with other department functions.

GENERAL INFORMATION

3. Public relations. Typical responsibilities; conducts hatchery tours and answers questions; speaks to interested groups.

Incumbents in this classification either direct a Grade 1 hatchery or serve on the staff of a Grade 2 or 3 hatchery.

MINIMUM QUALIFICATIONS

Any combination of education, training, and experience that demonstrates competence in each of the following:

Considerable knowledge of: identifying characteristics, nutritional requirements, and behaviors of various fish species; spawning techniques; fish development; water and feed treatments and prophylactic measures.

Good knowledge of: department rules and regulations related to fish hatcheries; water quality relating to hatchery operation and fish planting; fish planting techniques.

Ability to: recognize abnormal behavior and disease symptoms of various fish species; write narrative reports; give oral presentations; establish and maintain effective working relationships.

PROBATIONARY PERIOD:

En trance: 2080 hours (12 months)

Promotion: 1040 hours (6 months)

Adopted: 7/70; revised: 4-73; 2/83

JOB CONTENT EVALUATION: D12 152/C3(25)38/C1P 57/B3II:14 = 261

Overtime code: S

Class code: 00810

FISH CULTURIST

CLASS PURPOSE

To perform technical duties at spawning stations or fish hatcheries for the production of fish to be planted in Idaho waters; and perform related duties.

Appendix 5

PRINCIPAL ACCOUNTABILITY

Aquaculture. Typical responsibilities: spawns fish and monitors the development of eggs and fry; calculates growth gains; implementing feeding schedules required for specific growth rates; cleans hatching tanks and raceways; observes fish behavior for signs of stress or disease; implements water and feed treatments and prophylactic measures; grades and sorts fish by size and species; records amounts and types of feed given to fish, numbers of fish of various sizes and species, and daily fish mortality; transports and plants fish; writes narrative reports on feeding experiments and fish diseases and plantings; conducts tours of hatchery and explains hatchery operation; assists in maintenance of hatchery buildings and grounds.

MINIMUM QUALIFICATIONS

Any combination of education, training, and experience that **demonstrates** competence in each of the following:

Good knowledge of: identifying characteristics, nutritional requirements, **and** behaviors of various fish species; spawning techniques; egg development; common fish diseases and prophylactic measures.

Some knowledge of: water quality relating to hatchery operation and fish planting, first aid; basic carpentry and **hand** tools.

Ability to: **Calculate** percentage, proportion, and volume; read **and** apply technical terminology related to fish medications; **write** narrative reports concerning feeding experiments **and** fish diseases; give oral presentations; drive a one-ton truck; diagnose and repair minor mechanical problems.

Physical ability to: lift **50-pound** bags.

PROBATIONARY PERIOD:

Entrance: 1040 hours (6 months)

Promotion: **520** hours (3 months)

Adopted: **2/83**

JOB CONTENT EVALUATION: CII 115/C 2(22)25/CXR 29/B3II:14 = 183

Overtime code: Y

APPENDIX 6

METHODS USED TO DETERMINE FISH COMPLEMENT AND REARING SPACE FOR PROTOTYPE STATIONS

PART I. METHODS OF ESTIMATING THE NUMBERS OF ADULTS, EGGS, OR ALEVINS REQUIRED TO ACHIEVE PRODUCTION GOALS

In order to achieve the program production goals set out for the hatchery, the required number of adult fish, eggs, or alevins to be handled must be determined. The example which follows illustrates the procedures we used in this report.

Goal: Produce 200,000 **coho** smolts at 20 fish per pound and 200,000 **coho** fingerlings at 200 **fish** per pound.

Procedure: Using Table 2 in Chapter 9 we find that **coho** smolts survived from fertilized eggs to release at the rate of 75 %. Thus, to calculate the number of eggs required, we used a direct proportion:

$$\frac{75\%}{200,000 \text{ (Smolts)}} = \frac{100\%}{x} \quad \text{or } x = 266,667 \text{ (or } 267,000)$$

Thus 267,000 fertilized eggs are required to produce 200,000 **smolts**.

To determine the fertilized egg requirement for the fingerling release at 200 coho/pound, we again use Table 2 which shows that 90 percent survive from fertilization to feeding, and 93 percent of the fish survive the first 100 days of feeding. Thus to find the survival level from fertilization to the end of 100 days of feeding, we multiply 90 (percent survival from fertilization to first feeding) x 93 (percent survival for first 100 days of feeding), or 83.7 percent. Again using direct proportion:

$$\frac{83.7\%}{200,000 \text{ (fingerlings)}} = \frac{100\%}{x} \quad \text{or } x = 238,949 \text{ (or } 240,000)$$

Thus 240,000 eggs are required to produce 200,000 fingerlings.

When we add the two egg requirements together, the result is a total requirement of 507,000 eggs. Since there are an estimated 2,400 eggs per **coho** female (Table 2), we need 211 females for spawning. Either Table 2 or Table 3 in Chapter 9 can be used to make percentage calculations using the number of eggs or number of females as a base.

We used Table 3 and determined that the number of **coho** adults needed to be held at one time is 137 for 267,000 eggs. Thus, for 507,000 eggs (our total egg requirement), we need to hold 260 adults. **Again** using the **direct** ratio:

$$\frac{137 \text{ (adults)}}{267,000 \text{ (eggs)}} = \frac{x \text{ (adults)}}{507,000 \text{ (eggs)}} \quad x = 260 \text{ (male and females)}$$

Appendix 6

Another method, using proportion, would have been to observe from Table 3 in a program that requires 111 females for spawning. For this, 137 are projected to be held at one time. Thus:

$$\frac{111}{137} = \frac{211}{X} \quad \text{or } x = 260$$

Thus 260 adult fish must be projected for holding at one time for spawning purposes.

PART II. METHODS USED TO DETERMINE REARING SPACE REQUIRED IN LARGE PONDS TO MEET PRODUCTION GOALS

The maximum rearing densities for salmonids in ponds less than 4,000 ft^3 capacity can be read directly from Table 2, Chapter 5. For ponds exceeding 4,000 ft^3 capacity, we reduced the density factor (**pounds/ ft^3**) shown in the table by 1% for each 1,000 ft^3 above 4,000, up to a 50% reduction.

To determine the rearing space requirement, given the maximum rearing density allowed from Table 2, and the pounds to be reared, we used the following steps, where:

X	=	pond space in 000's of ft^3
P	=	pounds of fish in 000's
d	=	maximum rearing density allowed (Table 2, Chapter 5) by size and species (e.g. 2 lbs/ft^3 , 1 lb/ft^3)
P'	=	a value beyond which pond space x increases linearly with desired poundage P.

1) Solve for

$$p' = \frac{(1.04)^2 d}{.04}$$

2) If $P > P'$, Solve for X using this formula:

$$X = \frac{P}{d/2} \quad \text{or} \quad \frac{2P}{d}$$

3) If $P < P'$, solve for X using this formula:

$$X = \frac{1.04d - \sqrt{(1.04d)^2 - (4)(.01d)(P)}}{.02d}$$

Example: Using steps 1 and 2.

x	=	pond space in 000's of ft^3
d	=	1.0 lbs/ft^3 (Table 2, Chapter 5)
P	=	38,500 pounds of fall chinook @ 100/lb

Step 1: Solve for P'

$$P' = \frac{(1.04)^2 d}{.04}$$

$$= \frac{(1.04)^2 (1.0)}{.04}$$

$$= 27.04 \text{ lbs}$$

Step 2: Since $P > P'$

$$38.5 > 27.04$$

$$X = \frac{2P}{d} = \frac{(2) (38.5)}{1} = 77, \text{ or}$$

$x = 77,000 \text{ ft}^3$ (pond space required for a **38,500-lb** fall chinook population @ **100/lb**)

Example: Using steps 1 and 3.

X = pond space in 000% of ft^3
 d = 1.7 **lbs/ft³** (Table 2, Chapter 5)
 P = 20,300 pounds of **coho @ 20/lb**

Step 1: Solve for P'

$$P' = \frac{(1.04)^2 d}{.04} = \frac{(1.04)^2 (1.7)}{.04} = 45.96 \text{ lbs}$$

Step 3: Since $P < P'$
 $20.30 < 45.969$

$$X = \frac{(1.04) (1.7) - \sqrt{(1.04 \times 1.7)^2 - (4) (.01) (1.7) (20.3)}}{(.02) (1.7)}$$

$$= \frac{1.768 - \sqrt{3.1258 - 1.3804}}{.034}$$

$$= \frac{1.768 - 1.321}{.034} = 13.14, \text{ or}$$

$x = 13,140 \text{ ft}^3$ (space required) for a **20,000-lb coho** population @ **20/lb**.

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